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Pitfalls in Investment Euler Equations*

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Abstract

This paper investigates three pitfalls concerning the test of the Euler equation facing quadratic adjustment costs and perfect capital markets on a large balanced panel data of 4025 french firms. First, the quadratic parameterization of adjustment costs is too restrictive, and power series approximations of adjustment costs are tested. Second, we isolate firms whose optimal Euler condition is not altered even in the presence of fixed adjustment costs. Third, we identify instruments which contribute to model failure via standard GMM tests. These methods point that financial instruments contribute to reject strongly the standard model, which shows that it is misspecified.

JEL classification: C23; D21; D92

Keywords: Investment; Adjustment costs; Financial constraints; Generalized method of moments

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Résumé

Cet article considére trois problèmes associées à l'estimation de l'équation d'Euler du modèle d'investissement soumis à des coûts d'ajustement et lorsque les marchés financiers sont parfaits. Nous utilisons un panel cylindré de 4025 entreprises industrielles françaises. En premier lieu, la forme quadratique des coûts d'ajustement est trop restrictive et nous testons une approximation polynomiale des coûts ajustements. En second lieu, nous isolons les entreprises dont l'équation d'Euler n'est pas modifiée par les difficultés de revente du capital excédentaire. En troisième lieu, nous identifions les variables instrumentales qui peuvent contribuer au rejet de l'estimation par les tests d'exogénéité associés à la méthode des moments généralisés. Les variables instrumentales financières contribuent à rejetter fortement l'équation d'Euler, ce qui met en avant un problème de spécification.

Classification JEL: C23; D21; D92

Mots-clés: Investissement; Coûts d'ajustement; Contraintes financières; Méthode des moments généralisés

1. Introduction

The tests of the neo-classical model of investment facing quadratic adjustment cost has been hardly successful. In the 1980s, the test of the first order condition with respect to investment, linking investment and Tobin's marginal q, produced poor regressions. Furthermore, the proxy of Tobin's marginal q was not able to summarize the effect of all factors relevant to the investment decision: for example, cash-flows remained an additional regressor which typically had a statistically significant coefficient (Chirinko [1993]). These failures, as well as the difficulties to measure properly Tobin's marginal q, led empirical researchers to estimate the first order condition with respect to capital of the neoclassical model (the so called Euler equation) using the generalized method of moments (GMM) (Whited [1992], Bond and Meghir [1994] and other papers surveyed in Schiantarelli [1996] and Hubbard [1998]). Yet the econometric results were not successful.

From a theoretical point of view, at least three pitfalls affect the standard model: (1) the symmetric quadratic adjustment cost function is too restrictive, (2) fixed cost of adjustment adjustment costs may explain the decision of zero investment or very low level of investment (Dixit and Pindyck [1994]) (3) capital markets are not perfect and financial variables may matter when explaining investment behaviour[1].

In this paper, we follow the recent approach proposed by Whited [1998] tackling these three problems on panel data. First, we approximate the marginal adjustment cost function by a power series. Second, to deal with the issue of investment facing fixed costs of adjustment, we divide our sample into two groups of firms: near zero investment firms and others. Third, to explore the issue of financial constraints, we examine whether financial instruments are responsible for the rejection of the overidentifying restrictions. If it is the case, it suggests that financial instruments are missing variables included into the error term of the Euler equation estimated with the GMM method.

Section 2 presents the neoclassical model and the Euler equation. Section 3 presents the data and the estimation method. Section 4 presents the GMM results. Section 5 concludes.

2. A Simple Investment Model

2.1. The model

Analyzing investment begins with an expression for the value of the firm, which in turn stems from the arbitrage condition governing the valuation of shares. The after-

[1] Other assumptions of the neo-classical model, such as rational expectations or a non-accelerated scrapping rate, are also questionable.

tax return to the owners of the firm at time t reflects capital appreciation and current dividends. In equilibrium, if the owners are to be content holding their shares, this return must equal $(1 - m_t)r_t^0$ the after tax nominal return on riskless (government) bonds between period t and period $t + 1$ (r_t^0 represents the nominal return before income tax and m_t is the personal income tax on dividends and interest income in period t).[2]

$$\frac{(1 - c_t)\left(E_t[V_{i,t+1}] - V_{it}\right) + (1 - m_t)\theta_t E_t[d_{i,t+1}]}{V_{it}} = (1 - m_t)r_t^0 \tag{2.1}$$

where V_{it} is the value of the firm i at time t, c_t is the accrual-equivalent capital gains tax rate, θ_t is the dividend received by the shareholder when the firm distributes one unit of post-corporate tax earnings[3]. Therefore, the tax rate on dividends is $(1 - m_t)\theta_t$. E_t is the expectation operator conditional on information known at time t. The after-tax capital gain of the current shareholders thus depends on the change in the market value of the firm. The dividends of the firm at time $t + 1$ are $d_{i,t+1}$. In the absence of bubbles, solving the capital market arbitrage condition yields the following expression for the firm's market value at time zero:

$$V_{i,0} = E_{i,0} \sum_{t=0}^{t=+\infty} \left(\prod_{s=0}^{s=t-1} \beta_{is} \right) (\gamma_t d_{it}) \tag{2.2}$$

where the firm's one period nominal discount factor is:

$$\beta_{it} = \frac{1}{1 + \left(\frac{1-m_t}{1-c_t}\right) r_t^0}. \tag{2.3}$$

γ_t is the tax discrimination parameter that determines the relative tax advantage of dividend income against capital gains:

$$\gamma_t = \frac{(1 - m_t)\theta_t}{1 - c_t} \tag{2.4}$$

The owners of firm i choose dividends, investment, labour and the price of output in maximizing the present value of dividends d_{it} on date t in a infinite horizon, subject to several constraints.

The first constraint is the capital stock accumulation identity:

$$K_{it} = I_{it} + (1 - \delta)K_{i,t-1} \tag{2.5}$$

where K_{it} is its capital stock at time t, I_{it} its investment at time t, and δ the constant rate of economic depreciation.

[2] This derivation follows Poterba and Summers [1985].

[3] Under an imputation relationship between corporate and personal taxes, the parameter $\theta_t = 1/(1 - s_t)$ where s_t is the rate of imputation. Under a classical relationship, θ_t is simply unity.

The second "flow of funds" constraint defines the dividends of the firms. Cash inflows include sales and net borrowing, while cash outflows consist of dividends, factor and interest payments, and investment expenditures:

$$\begin{aligned} d_{it} &= (1-\tau_t)\left(p_{it}F(K_{i,t-1},N_{it}) - p_{it}\Psi(K_{i,t-1},I_{it}) - w_t N_{it} - i_{i,t-1}B_{i,t-1}\right) \\ &\quad + B_{it} - B_{i,t-1} - p^I_{st} I_{it}, \end{aligned} \quad (2.6)$$

where:
N_{it} = a vector of variable factors of production for firm i at time t,
$F(K_{i,t-1}, N_{it})$ = the firm's revenue function ($F_K > 0$,$F_{KK} < 0$),
$\Psi(K_{i,t-1}, I_{it})$ = the cost of adjusting the capital stock[4],
w_t = a vector of nominal factor prices at time t,
i_{it} = the nominal interest rate on debt at time t,
B_{it} = the value of net debt outstanding for firm i at time t,
p_{it} = the price of final goods at time t,
p^I_{st} = the sectorial price of capital goods at time t (incorporating tax considerations),
τ_t = the corporate income tax rate, against which interest payments are assumed to be deductible.

The third constraint is a downward sloping demand function for its product. Demand is assumed to depend upon the price charged by the firm relative to the average price of competitors of the same industry sector, p_{it}/P_{st}. The average price level is taken as given by each individual firm. Demand is equal to output net of adjustment costs. The inverse of the demand function of the firm can therefore be written as:

$$p_{it}/P_{st} = \varphi^{-1}\left(F(K_{i,t-1}, N_{it}) - \Psi(K_{i,t-1}, I_{it})\right) \quad (2.7)$$

We define the elasticity of demand by $e = \varphi'\left(p_{it}/P_{st}\right) p_{it}/\varphi\left(p_{it}/P_{st}\right)$.

The fourth constraint is related to irreversibility or to the failure of the second hand market for capital, *i.e.* we assume that investment cannot be negative (Arrow [1968]):

$$I_{it} \geq 0. \quad (2.8)$$

The fifth constraint follows Whited [1992] in assuming that the firms face a debt ceiling B^*_{it}:

$$B_{it} \leq B^*_{it}. \quad (2.9)$$

We also assume that dividends have to be non-negative:

[4]In our presentation, adjustment costs are valued at value added price (they are considered as a part of the production function), but an alternative where they are valued at investment price is also possible (adjustment costs are then considered as a part of the cost of investing).

$$d_{it} \geq 0. \tag{2.10}$$

The last constraint rules out Ponzi finance. It prevents the firm from borrowing an infinite amount to pay dividends.

$$\lim_{T\to+\infty} \left(\prod_{s=0}^{s=T-1} \beta_{is} \right) B_{iT} = 0, \forall t. \tag{2.11}$$

The optimal path of the firm is given by the first order conditions for labour N_{it}, for capital K_{it} (Euler equation) and for debt B_{it}:

$$F_N(K_{i,t-1}, N_{it}) = \frac{w_t}{\mu p_{it}}, \tag{2.12}$$

$$\begin{aligned} & E_t\beta_{it}[\frac{\gamma_{t+1+}\lambda^d_{i,t+1}}{\gamma_t + \lambda^d_{it}}[\mu p_{i,t+1} F_K(K_{it}, N_{it+1}) - \mu p_{i,t+1}\Psi_K(K_{it}, I_{i,t+1}) + \\ & \mu p_{i,t+1}(1-\delta)\Psi_I(I_{i,t+1}, K_{i,t}) + \frac{(1-\delta)p^I_{i,t+1}}{1-\tau_{t+1}}]] \\ & +E_t\beta_{it}[-(1-\delta)\lambda^I_{i,t+1}] + \lambda^I_{it} \\ = \; & p_{it}\mu\Psi_I(I_{i,t}, K_{i,t-1}) + \frac{p^I_{it}}{1-\tau_t}, \end{aligned} \tag{2.13}$$

$$\gamma_t + \lambda^d_{it} - E_t\left[\beta_{it}\left(\gamma_{t+1} + \lambda^d_{i,t+1}\right)(1 + [1-\tau_{t+1}]i_{it})\right] - \lambda^B_{it} = 0. \tag{2.14}$$

The parameter μ denotes the inverse of the markup: $\mu = \left(1 - \frac{1}{e}\right)$. λ^I_{it} is the Lagrange multiplier related to the constraint of non-negative investment.

The Euler equation and the following transversality condition lead to sufficient conditions for the optimal plan of the firm (Stokey *et al.* [1989]):

$$\lim_{T\to+\infty} \left(\prod_{i=0}^{j=T-1} \beta_{ij} \right) \frac{\partial d_{iT}}{\partial K_{iT}} K_{iT} = \lim_{T\to+\infty} \left(\prod_{i=0}^{j=T-1} \beta_{ij} \right) \frac{\partial d_{iT}}{\partial B_{iT}} B_{iT} = 0. \tag{2.15}$$

2.2. From Theory to Testing

In order to derive the Euler equation explicitly, it is necessary to specify the adjustment cost function. The usual parameterization of the function Ψ is *quadratic* and linearly homogeneous in investment and capital $\frac{\alpha}{2}\left(\frac{I_{it}}{K_{i,t-1}} - v\right)^2 K_{i,t-1}$, where v can be interpreted as the "normal" rate of investment when adjustment costs are zero (it could be equal to the scrapping rate δ). As argued by Whited [1998], this specification is too restrictive. We follow the approach of Newey [1994] of using power series to represent Ψ. We specify an adjustment-cost function which is still linearly homogeneous in investment and capital (Whited [1998]):

$$\Psi(K_{i,t-1}, I_{it}) = \left[\alpha_0 + \sum_{m=2}^{M} \frac{1}{m}\alpha_m \left(\frac{I_{it}}{K_{i,t-1}}\right)^m\right] K_{i,t-1} \tag{2.16}$$

Furthermore, it is necessary to compute the marginal productivity of capital. Under the assumption of linear homogeneity of the production function, the following equality holds:

$$F\left(K_{it}, N_{i,t+1}\right) = F_K\left(K_{it}, N_{i,t+1}\right) K_{it} + F_N\left(K_{it}, N_{i,t+1}\right) N_{i,t+1} \tag{2.17}$$

In this expression, F_N and F_K are the marginal productivity of capital at period t and of labour at period $t+1$, respectively. Using the first order condition for labour (equation 2.12), the preceding equation can be rewritten as:

$$F_K\left(K_{it}, N_{i,t+1}\right) = \frac{F\left(K_{it}, N_{i,t+1}\right) - \frac{1}{\mu}\frac{w_{t+1}}{p_{i,t+1}} N_{i,t+1}}{K_{it}} \tag{2.18}$$

We substitute F_K, Ψ_I, Ψ_K into the Euler equation for capital. We assume that managers' expectations are rational and introduce an expectational error $\varepsilon_{i,t+1}$, where $E_{it}\left(\varepsilon_{i,t+1}\right) = 0$, $E_{it}\left(\varepsilon^2_{i,t+1}\right) = \sigma^2_{i,t+1}$ and $\varepsilon_{i,t+1}$ uncorrelated with any period t information. The neo-classical model is such that the positivity constraint on investment does not bind ($\lambda^I_{it} = \lambda^I_{i,t+1} = 0$) as well as the one on dividends ($\lambda^d_{it} = \lambda^d_{i,t+1} = 0$) and the debt ceiling constraint ($\lambda^B_{it} = \lambda^B_{i,t+1} = 0$). We rewrite the Euler equation of the neo-classical model (2.13) as follows for its estimation:

$$\begin{aligned}
& \beta_{it}\frac{p_{i,t+1}}{p_{it}}\left[\frac{F\left(K_{it}, N_{i,t+1}\right) - \frac{w_{t+1}}{p_{i,t+1}} N_{i,t+1}}{K_{it}} - (1-\mu)\frac{F\left(K_{it}, N_{i,t+1}\right)}{K_{it}}\right] \\
& +\beta_{it}\frac{p_{i,t+1}}{p_{it}}\left[\frac{(1-\delta)}{E_t\left[1-\tau_{t+1}\right]}\frac{p^I_{i,t+1}}{p_{i,t+1}}\right] - \frac{1}{1-\tau_t}\frac{p^I_{it}}{p_{it}} \\
- \quad & \alpha_0\mu\beta_{it}\frac{p_{i,t+1}}{p_{it}} \\
& + \sum_{m=2}^{M}\alpha_m\mu\left(\beta_{it}\frac{p_{i,t+1}}{p_{it}}\left[\frac{m-1}{m}\left(\frac{I_{i,t+1}}{K_{it}}\right)^m + (1-\delta)\left(\frac{I_{i,t+1}}{K_{it}}\right)^{m-1}\right] - \left(\frac{I_{it}}{K_{i,t-1}}\right)^{m-1}\right) \\
= \quad & \varepsilon_{i,t+1} - f_i - YEAR_{t+1}
\end{aligned} \tag{2.19}$$

Additionally, we have allowed for the possibility of fixed firm-specific and time-specific effects, denoted f_i and $YEAR_t$ respectively. The time effect can be interpreted as capturing aggregate business cycle. The fixed effect can be interpreted as accounting for firms characteristics, which are the time invariant components of firms differences in, for example, product demand, capital intensity, and growth opportunities. A standard manner to deal with a fixed effect is to estimate the Euler equation in first differences.

The parameter α_0 multiplies a variable related to the cost of capital (the discount rate which we assume to be equal to the government ten years bond rate, modified by the sectorial value added price inflation $\left(\beta_t \frac{p_{i,t+1}}{p_{it}}\right)$). This sectorial variable is not eliminated by taking first differences and therefore we estimate the parameter α_0. Whited [1998], by contrast, does not estimate it.

Let us precise what are the marginal costs of adjustment. Investment appears in the Euler equation because the Euler equation emphasizes the trade-off between the adjustment costs of investing this year $\sum_{m=2}^{M} \alpha_m \mu \left(\frac{I_{it}}{K_{i,t-1}}\right)^{m-1}$ with respect to the discounted marginal adjustment costs of investing next year:

$$\beta_{it} \frac{p_{i,t+1}}{p_{it}} \left[-\alpha_0 \mu + \sum_{m=2}^{M} \alpha_m \mu \left(\left[\frac{m-1}{m} \left(\frac{I_{i,t+1}}{K_{it}} \right)^m + (1-\delta) \left(\frac{I_{i,t+1}}{K_{it}} \right)^{m-1} \right] \right) \right]. \quad (2.20)$$

If all coefficients α_m (for $m \geq 2$) are not significantly different from zero, then adjustment costs are zero and investment does not show up in the Euler equation. In this case, the Euler equation boils down to the estimation of the mark up of the marginal product of capital over its marginal cost, without any insight on investment behaviour.

For the quadratic case, it can be easily seen that there is no fundamental difference between the estimation of the usual quadratic adjustment cost function $\frac{\alpha}{2} \left(\frac{I_{it}}{K_{i,t-1}} - v \right)^2 K_{i,t-1}$ and our parameterization when $M = 2$. On the one hand, the marginal costs of adjustment on date $t+1$ imply the following relation between the level of the investment ratio such as adjustments costs are zero in the usual specification (v) and the ratio $\frac{\alpha_0}{\alpha_2}$: $\frac{\alpha_0}{\alpha_2} = v \left(1 - \delta + \frac{v}{2}\right)$. On the other hand, the marginal costs of adjustment on date t are $\alpha \frac{I_{it}}{K_{i,t-1}} - \alpha v$ in the usual case, whereas they are only $\alpha_2 \frac{I_{it}}{K_{i,t-1}}$ in our case. As explained later on, the Euler equation is estimated in first differences so that the constant term αv is eliminated in the traditional specification. Finally, both estimations are identical.

2.3. Explicit Investment Facing Credit Rationing

When the debt ceiling constraint is binding ($B_{it} = B_{it}^*$), Chatelain [1998] shows that the flow of funds equation has to be written with a binding constraint on the dividend floor ($d_{it} = 0$). We divide the flow of funds equation by the capital stock $p_{i,t-1}^I K_{i,t-1}$:

$$\begin{aligned} \frac{p_{st}^I I_{it}}{p_{s,t-1}^I K_{i,t-1}} + \frac{(1-\tau_t) p_{it} \Psi(K_{i,t-1}, I_{it})}{p_{s,t-1}^I K_{i,t-1}} &= (1-\tau_t) \frac{(p_{it} F(K_{i,t-1}, N_{it}) - w_t N_{it} - i_{i,t-1} B_{i,t-1})}{p_{i,t-1}^I K_{i,t-1}} \\ &\quad + \frac{B_{it}^*}{p_{i,t-1}^I K_{i,t-1}} - \frac{B_{i,t-1}}{p_{i,t-1}^I K_{i,t-1}}. \end{aligned} \quad (2.21)$$

Substituting the adjustment cost function by a power series approximation, we derive a polynomial equation for the ratio of the investment rate $I_{it}/K_{i,t-1}$ depending on the ceiling of the debt/capital ratio and of cash flows from operating activities defined as cash-flows less the debt service. In the particular case when the adjustment cost parameters are close to zero, it follows that a firm facing credit rationing on date t has an investment behaviour which depends on cash-flows (denoted $CF_{it} = p_{it}F(K_{i,t-1}, N_{it}) - w_t N_{it}$), on the debt service ($i_{i,t-1}B_{i,t-1}$), on the debt ceiling B^*_{it} and the previous level of debt.

Therefore, one can test either the neo-classical Euler equation or the non-nested model of explicit investment facing credit rationing, which depends on financial variables: cash-flows, interest payments and debt[5].

3. Sample Information and Estimation Method

3.1. Data

The data set we used comprises annual companies accounts data extracted from the "Centrale des Bilans" database at the Banque de France. They consist of accounting tax forms and additional information taken from surveys collected by the Banque de France. Due to our estimation program, we chose to select a balanced sample of $N = 4025$ firms in the manufacturing sector over the period 1988-1996 (nine years). This sample was obtained after deleting outliers for several variables (see the data appendix for the sample selection). Although the selection of a balanced panel creates a potential bias, our sample contains much more smaller companies than other studies in the field (the median size of companies is of 60 employees).

3.2. Estimation method

Our econometric model takes into account the standard fixed firm effects for regression models with panel data and year effects. We estimate the year effects by including time dummies in our model. The estimation of the econometric model presents three potential groups of problems. First, there may be a correlation between explanatory variables and the fixed effect f_i. Second, explanatory variables can be endogenous. Third, there is heteroscedasticity of disturbances. The usual method used to taken into account these problems is the generalized method of moments (GMM), (Hansen [1982]).

More formally, the GMM estimation proceeds in two steps. A first step is an instrumental variable estimation which provides estimated residuals. It does not take into account the heteroscedasticity and the autocorrelation of the disturbances. For the second step, let us denote by η the vector of stacked disturbances associated

[5] Another possibility is to test the Euler equation taking into account the explicit Lagrange multipliers related to the dividend constraints (Chatelain [1999] and [2000]). See also alternatives for testing other particular non-nested hypotheses in Hall [1999].

with the Euler equation. Estimating this equation by GMM amounts to minimize the following objective function with respect to the parameters appearing in this equation:

$$\underset{\Theta}{Min}\left[Z'\eta\left(\Theta\right)\right]'\left(Z'\Omega Z\right)^{-1}Z'\eta\left(\Theta\right) \tag{3.1}$$

where Θ is the vector containing the unknown parameters, Z is the matrix of instruments of dimensions $(T\cdot N, T\cdot k)$, where T is the number of years. It is a diagonal matrix with blocks of identical dimensions (N,k), if the same set of instruments is used for each year. Z is defined as:

$$Z = diag\left(Z_{93}, Z_{94,}Z_{95}, Z_{96}\right) \tag{3.2}$$

Ω is the variance covariance matrix of the univariate disturbance $\eta_{it} = \varepsilon_{it} + f_i + YEAR_t$. Due to the panel structure of our data set, we can use the generalization of White's [1980] results and estimate $Z'\Omega Z$ (as $N \to +\infty$) by:

$$\widehat{Z'\Omega Z} = \frac{1}{N}\sum_{i=1}^{N}\left[Z_i'\eta_i\left(\widehat{\Theta}\right)\right]\left[Z_i'\eta_i\left(\widehat{\Theta}\right)\right]' \tag{3.3}$$

where $\eta_i\left(\widehat{\Theta}\right)$ is the vector of the *estimated residuals* of the *first step* of estimation of the model with instrumental variables. This means that we allow for any kind of possible heteroscedasticity[6].

We then perform a test of all overidentifying restrictions (Hall [1999]). The null hypothesis is that the restrictions on the moments or orthogonality conditions are verified for the vector of estimated parameters $\widehat{\Theta}$ (as it should be in the "true" model), i.e. $E\left[Z_{it}'\eta_{it}\left(\widehat{\Theta}\right)\right] = 0$. Under this null hypothesis, the product of the minimized value of the objective function and the number of observations (the J or $Sargan$ statistic), has a χ^2 distribution with $T\cdot k - p$ degrees of freedom, where k is the number of instruments for a given year and p is the number of parameters to be estimated. The overidentifying restrictions are rejected if this χ^2 exceeds a prespecified value, corresponding usually to the start of the 5% right hand tail of the χ^2 distribution.

3.3. The Choice of Instruments

An important practical issue when estimating the Euler equation is the choice of instruments. A nice feature of rational expectations models is that it is easy to include instrumental variables. Forecasting errors are due to information that was not available on the current date. Thus any variable in the present period must be orthogonal to future residuals. Therefore, the expectation of the error term multiplied by the instrumental variable is unchanged and usually zero (instrumental variables should

[6] We use the program done on the statistical software SAS-IML by Blanchard, Bresson, Sevestre and Teurlai. This program allows for GMM estimation which is *non-linear* with respect to parameters on dynamic *balanced* panel data (whereas the Arellano and Bond [1991] DPD program allows for linear GMM estimation on dynamic unbalanced panel data).

be correlated with endogenous explanatory variables, but uncorrelated with the error term).

Variables at least one period lagged are theoretically valid instruments (as first difference are taken, instruments two periods lagged are valid). Arellano and Bond [1991] suggest to use all explanatory variables, with all possible lags to get consistent estimates for linear models. But one has to remain parsimonious when selecting instrumental variables for GMM estimations: having too many instruments leads the chi-squared test to over-reject the overidentifying restrictions of the model (Kocherlakota [1990]).

Testing the validity of a group of instruments amounts to testing a subset of orthogonality conditions (or overidentifying restrictions) related to these instruments. The formal proof of this Sargan difference test is presented in Hansen, Eichenbaum and Singleton [1988] and Hall [1999]. The null hypothesis is that the restrictions on some moments (or orthogonality conditions) are verified for a subset of instruments, so that these instruments are valid. The difference of the Sargan statistics between the model estimated with all the instruments (hence with more degrees of freedom) and the model estimated with fewer instruments has a χ^2 distribution with degrees of freedom determined by the difference of degrees of freedom of the two models. The subset of overidentifying restrictions are rejected if this χ^2 exceeds a prespecified value.

4. Results

4.1. Tests on the adjustment cost parameterization

A first issue is the choice of the truncation parameter M in the power series approximation of the adjustment cost function. We follow Whited's [1998] strategy to determine this choice, by using the Sargan difference test developed by Newey and West [1987]. First we choose a "high" starting value for M (in our case $M_{\max} = 5$) and estimate the model. Then, using the same optimal weighting matrix, we estimate a sequence of restricted models for progressively lower values of M. Intuitively, if excluding these parameters produces a significant increase in the Sargan statistic, then this exclusion restriction is rejected. More formally, the null hypothesis is $\alpha_{M_{\max}-j} = 0$ for $j = 0..., k$. The difference of the Sargan statistics between the model estimated with fewer parameters α_m (hence, with more degrees of freedom) and the model estimated with the maximum of parameters α_m has a χ^2 distribution with degrees of freedom determined by the difference of degrees of freedom of the two models. The null hypothesis is rejected if this χ^2 exceeds a prespecified value[7]. The appropriate maximum value for M will then be the highest one for which the exclusion restrictions on the parameters $\alpha_{M_{\max}-j}$ are accepted against all models with a lower M.

Results are reported in table 1, for the full sample (column $M = 5$ to $M = 2$):

[7] In the case of the test of only one parameter, the Student test provides a similar outcome as the Sargan difference test.

Insert table 1

Ten instruments deflated by the lagged capital stock have been used for the full sample: year dummies from 1993 to 1996, three real variables Y_{t-2}/K_{t-3}, I_{t-3}/K_{t-4},$(I_{t-2}/K_{t-3})^2$ and their lags[8]. The overidentifying restrictions of the real instruments are accepted at least at the 8% level for all models. Therefore, the set of instruments is accepted.

The null hypothesis $\alpha_5 = 0$ is accepted at the 38% level so that the model $M = 5$ is rejected against the model $M = 4$. The test of exclusion restrictions on parameters leads to retain the model for $M = 4$ against the models $M = 3$ (the null hypothesis $\alpha_4 = 0$ is rejected at the 5% threshold, as the p-value is 1.5%) and $M = 2$ (the null hypothesis $\alpha_4 = \alpha_3 = 0$ is rejected at the 5% threshold)[9].

For the best model $M = 4$, the inverse of the markup parameter μ is strongly significant. It corresponds to a rather high markup (45%). The coefficient of the nominal interest rate less the sectorial inflation rate (α_0) is significant and negative. All the coefficients of the adjustment cost function are significant at the 10% threshold but not at the 5% threshold. Moreover, for $M = 4$, the lagged marginal adjustment cost evaluated at the median of investment amounts to two third of the median of investment. For the usual quadratic case ($M = 2$), the adjustment cost parameter α_2 is not significantly different from zero, as found by Whited [1998] on a sample of U.S. firms and Barran and Peeters [1998] on a sample of Belgium firms. This confirms the failure of the neoclassical model of investment with *quadratic* adjustment costs to explain investment behaviour.

Estimating the power series approximation of a more general smooth adjustment cost function improved the regression with respect to the usual case $M = 2$. In order to confirm these results, we tackle the issue of irreversibility and of financial constraints in the following sections.

4.2. The Irreversibility of Investment

A more general adjustment cost function can also take into account fixed adjustment costs or irreversibility. There is at least two reasons for which firms do not invest: first, they face fixed adjustment costs, so that they only do discrete jumps of investment, once the marginal product of these new investment exceeds a threshold (Abel and Eberly [1994]), and second, they face a second hand market for capital goods which is not working properly, so that they are not able to decrease as much as they would like

[8]Testing the instruments (I_{t-2}/K_{t-3}) and (I_{t-3}/K_{t-4}), the overidentifying restrictions are accepted at the 12% level for $M = 4$ on the full sample. Therefore (I_{t-2}/K_{t-3}) can be accepted as an instrument as well as its squared term. With the instrument (I_{t-3}/K_{t-4}) and (I_{t-4}/K_{t-5}), the overidentifying restrictions are accepted at the 22% level (see table 1, full sample, column $M = 4$). Therefore, we retained the instruments (I_{t-3}/K_{t-4}) and (I_{t-4}/K_{t-5}).

[9]On the model $M = 4$, we checked that the orthogonality conditions related to lagged real instruments Y_{t-3}/K_{t-4}, I_{t-4}/K_{t-5},$(I_{t-3}/K_{t-4})^2$ are accepted. Therefore, we retain the largest set of instruments, including these lags.

their capital during adjustment periods (Arrow [1968]). In the second case, constraints of non-negative investment binding on the current period and/or the next one lead to the addition of $E_t\beta_{it}[-(1-\delta)\lambda^I_{i,t+1}]+\lambda^I_{it}$ in the error term of the Euler equation (the Lagrange multiplier λ^I_{it} is related to the unobservable notional demand for negative investment). Therefore, the Euler equation is altered for these firms. Conversely, if we observe a firm with only strictly positive investment, we know that it has attained an interior solution to its maximisation problem, and we can infer that its Euler equation ought to hold.

Following Whited [1998], we divide our sample of firms into two groups. The first group consists of firms who only undertake positive investment over the five years 1992-1996 (3378 firms, i.e.83.9% of our sample). The second group consists of the remaining firms (647 firms). We label it mixed investment group. We defined "zero" investment when the investment ratio $I_{it}/K_{i,t-1}$ is below the first decile of this ratio from years 1993 to 1996 (1.14%) in order to have a "mixed" investment group sufficiently large for GMM estimations. Before estimating Euler equations, it is useful to compare descriptive statistics of the variables of the full sample and on the two subsamples of positive investment firms and mixed investment firms. This is presented in table 2:

Insert table 2

In the full sample, the median size of firms is of 60 employees, with a mean of 245 employees. The split of the sample between positive investment firms and others shows that size is a major difference between the two subsamples. The mixed investment firms subsample present a median of 27 employees with an average of 64, whereas the positive investment firm subsample presents a median of 72 employees and an average of 280 employees. This is easily explained by the fact that large firms contains a higher number of production units, so that their aggregate presents more often a positive investment, even if each production unit faces fixed costs, whereas smaller firms are closer to a single production unit facing fixed costs[10]. The subsamples differ also with respect to cash-flows, which are much lower for the mixed investment group. Other financial variables (the debt/capital ratio, reported interest expenses/capital and the apparent interest rate), however, are similar within the two groups.

We report the econometric results with the optimal truncation parameter of the power series development of the adjustment cost function in table 1, column $I > 0$ ($M = 4$) and column $I \approx 0$ ($M = 2$)[11]. The results for positive investment firms lead to identical comments as for the full sample. The only difference is that the Sargan statistic is lower and the p-value is higher than for the full sample case for the overidentifying restrictions tests. This confirms that this subsample is closer to interior solution of the standard model than the full sample.

[10]Plant level data are not available in our dataset.

[11]We performed similar tests for the choices of the optimal M than for the full sample case. They are not reported here but are available upon request.

For the subsample of mixed investment firms, the optimal truncation parameter lead to choose a model where the adjustment costs parameter multiplying investment (α_2) is nearly zero. The Euler equation boils down to the estimation of the markup, altering the relation between the condition of marginal product of capital and the cost of capital. This is not surprising since investment is a variable close to zero in this subsample.

4.3. Tests on the Exogeneity of the Financial Variables

Another problem with the standard neoclassical model of investment is its possible misspecification due to the omission of financial variables. In particular, we have seen that investment facing credit rationing depends on financial variables such as *cash-flows, interest payments and debt.* In order to test the misspecification of the neo-classical Euler equation, we add three instruments: cash-flows CF_{t-2}/K_{t-3}, the debt ratio B_{t-2}/K_{t-2}, and reported interest expenses $\left[iB\right]_{t-2}/K_{t-3}$ and their lags, *i.e.* the explanatory variables of the non-nested model of the equation of investment facing credit rationing[12].

Indeed, if the econometrician estimates a standard version of the neoclassical model, any of these financial variable will fall into the error term. Including these financial variables in the set of instruments ought to force a rejection of the overidentifying restrictions. In contrast, if the "true" model is the neoclassical model, only real variables determine the firm's investment decisions. Then, it is much less likely that using these financial instruments will affect the tests of the overidentifying restrictions. Therefore, the test of the exogeneity of financial instruments, which is the test of the subsample of the overidentifying restrictions related to these instruments, can be interpreted as follows: if it is rejected, the hypothesis of credit rationing is not rejected.

The test has been done on the "best" regressions with respect to the adjustment cost function ($M = 4$ for the full sample and for positive investment firms and $M = 2$ for mixed investment firms). Results are presented in table 3:

Insert table 3

The overidentifying restrictions are strongly rejected at the 5% level on the full sample (column 1) and on the positive investment sample (column 2). According to the Sargan statistic criterium, there is a global endogeneity problem which we consider to be caused by a specification problem. This point is corroborated by the test of the omission of the three financial instruments, which claims that these instruments may

[12] As we observed that financial variables are serially correlated, lagged financial variables should also be correlated with the error term, if these financial variables are explaining investment facing credit rationing. As cash-flows appears differently in the neoclassical model and in the financially constrained one, we classify them within the "financial" instruments subset.

be correlated with the error term[13].

For the mixed investment group, the real and financial instruments estimation leads to accept the overidentification restrictions at the 5% threshold. But the orthogonality of financial instruments with the error term is rejected at the 3% level. The rejection of the neo-classical model is much less strong than on the positive investment subsample.

5. Conclusion

This paper has shown that changes of the adjustment costs parameterisation of the standard model (power series approximation and excluding zero investment firms in order to take into account fixed costs) led to better estimations, when real instruments are used. But it has also shown that these improvements in the specification were not able to improve the fit when financial instruments where used. Standard GMM test led to conclude that the standard Euler equation is misspecified and that financial variables are omitted. Further research will consider these less restrictive parameterizations of adjustment costs with explicit financial constraints.

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Data Appendix.

A1. Sample Selection:

The data source consists of compulsory accounting tax forms (collected by the Banque de France in the database FIBEN) and of additional information (in particular on leasing) taken from surveys collected by the Banque de France (the database "Centrale des Bilans"). These data are collected only from firms who are willing to provide them, a procedure which creates a bias (small firms of less than 20 employees are under-represented). No statistical sampling procedure has been used to correct this bias.

A first elimination of outliers has been done on a larger unbalanced sample on industrial firms without holdings. The exclusion of outliers was done on ratios built on common information to the two databases. A first step consisted of deleting firms with missing or inconsistent data: we selected firms with no more than one fiscal account on the same year and for which the length of accounting period is 12 months. We deleted firms for which the number of employees, sales, value added, assets, investment, debt are negative (the number of observations (or firms accounts) is then 294 096. In a second step, we excluded firms who present an investment ratio I_{it}/K_{it} higher than one, firms who present a debt ratio B_{it}/K_{it} which is over the last percentile of the empirical distribution, and finally we excluded outliers which exceeded five times the interval between quartiles for the 6 following variables: $\ln(K_{it}/L_{it}), \ln(Y_{it}/L_{it}), \ln(Y_{it}/K_{it}), (p_{it}Y_{it}-w_{it}L_{it})/p_{it}Y_{it}, (Y_{it}-\frac{w_{it}}{p_{it}}L_{it})/K_{it}, [iB]_{it}/B_{it}$.

We computed the capital stock and debt *including leasing.* Therefore, we restricted our sample to the data originated from the Centrale des Bilans database (120 814 initial observations). There remained 103 692 observations after cleaning outliers (a loss of $14,6\%$ of observations). The balanced sample amounts to 39 168 observations over 9 years (a loss of 62% of the remaining observations), *i.e.* 4352 firms. Nonetheless, as there remained outliers for the ratio of $I_{it}/K_{i,t-1}$, where both investment and the capital stock include leasing, we excluded the last percentile of these observations over the balanced sample. This last restrictions led to our sample of 36225 observations over 9 years (a loss of 7.5% of the remaining observations), *i.e.* 4025 firms.

A2. Construction of the Variables:

The individual variables:

The first source is the compulsory accounting forms of the French General Tax Code provided by firms and numbered by the tax administration (D.G.I.) from 2050 to 2058. We provide the code of each data omitting the two first number of each leaflet. For example, we denote "[50].FN" the box FN of the tax form 2050. The second source is the Banque de France survey of the "Centrale des bilans". The form 2065 provides information on mergers and acquisitions. The form 2066 provides information on leasing. For example, we denote "[cdb66].112" the box 112 of the survey form 2066.

- Gross value added at market price is the value of production minus the value of the intermediate inputs. The value of production includes total net sales [52].FL, change in inventories of own production of goods and services [52].FM, own production of goods and services capitalized [52].FN. The value of intermediate inputs is the sum of purchases of bought-in goods (including customs duties) [52].FS, of the change in inventories of bought-in goods [52].FT, of the purchases of raw materials and other supplies (including customs duties) [52].FU, of the change in inventories of raw materials and supplies [52].FV, of other purchases and external charges [52].FW, of rents for leasing in current assets [cdb66].111 and of rents for leasing in fixed assets [cdb66].112.

- Cash flow is the sum of gross value added and of operating subsidies [52].FO minus the sum of duties and taxes other than income tax [52].FX, of wages and salaries [52].FY and of employee welfare contributions and similar charges [52].FZ.

- Productive gross investment including leasing is the sum of total increases by acquisition of tangible assets [54].LP and of investment financed by new leasing contracts in current assets [cdb66].02.1 and in fixed assets [cdb66].02.2 minus the sum of the decreases by transfers of tangible assets under construction [54].MY, of the decreases by transfers of deposits and prepayments [54].NC and of the increases of assets by mergers and acquisitions [cdb65].03.1

- Interest and similar charges are [52].GR.

- Gross debt includes quasi equity [51].DO (proceeds from issues of participating securities plus subordinated loans), convertible bonds [51].DS, other bonds [51].DT to which the bond redemption premium [50].CM is subtracted, bank borrowings [51].DU, other borrowings [51].DV, other liabilities [51].EA and discount [58].YS.

- The capital stock is the sum of the capital stock financed by leasing and of the capital stock without leasing. The capital stock without leasing is the value in replacement terms of the capital stock book value of property, plant and equipment. To convert the book value of the gross capital stock into its replacement value, we used the following iterative perpetual inventory formula:

$$K_{it} = \frac{[p^I_{it} I_{it}]}{p^I_{st}} + (1-\delta) K_{i,t-1}$$

where the investment goods deflator is denoted p^I_{st} and the depreciation rate is taken to be 8%. The capital stock book value on the first available year ($t_0 = 1988$) is deflated by assuming that the sectorial price of capital is equal to the sectorial price of investment T_{mean} years before the date when the first book value was available, where T_{mean} represents the corrected average age of capital (this method of evaluation of capital is sometimes labeled as the "stock method"). The average age of capital T_{mean} is computed by using the sectorial useful life of capital goods $T_{\max}$ and of the share of goods which has been already depreciated on the first available year in the firms accounts $\frac{DEPR_{it_0}}{p_K K_{it_0}}$ ($DEPR_{it_0}$ is the total book value of depreciation allowances in year t_0) according to the following formula[14]:

$$\begin{aligned} T_{mean} &= T_{\max}\left[\frac{DEPR_{it_0}}{p_K K_{it_0}}\right] - 4 \qquad \text{if } T_{\max}\left[\frac{DEPR_{it_0}}{p_K K_{it_0}}\right] > 8 \\ T_{mean} &= T_{\max}\left[\frac{DEPR_{it_0}}{p_K K_{it_0}}\right]\frac{1}{2} \qquad \text{if } T_{\max}\left[\frac{DEPR_{it_0}}{p_K K_{it_0}}\right] < 8 \end{aligned}$$

The sectorial useful life of capital goods is $T_{\max} = 15$ years, except for sectors C4 ($T_{\max} = 13$), sector D0 ($T_{\max} = 16$), sectors E1 and E2 ($T_{\max} = 14$), sector E3 ($T_{\max} = 12$), and finally sector F1 ($T_{\max} = 17$).

The book value of the gross capital stock of property, plant and equipment on the first available year is obtained by the sum of land [50].AN, buildings [50].AP, industrial and technical plant [50].AR, other plant and equipment [50].AT, plant property and equipment under construction [50].AV and payments in advance/on account for plant property and equipment [50].AX.

The book value of depreciation allowances is obtained by the sum of the depreciation, amortization and provisions on land [50].AO, on buildings [50].AQ, on industrial and technical plant [50].AS, on other plant and equipment [50].AU, on plant property and equipment under construction [50].AW and on payment in advance/on account for plant property and equipment [50].AY.

- The leasing capital stock is the value in replacement terms of the capital stock book value of property, plant and equipment. To convert the book value of the gross capital stock into its replacement value, we use the "stock method" described above for the initial level of capital without leasing.

[14]This formula is used by Jacques Mairesse in the Bond et al. [1997] paper. The computation of the capital stock we used has been done by J.-C. Teurlai, who adapted a SAS program kindly provided by Jacques Mairesse.

But, in this case, $T_{\max}$ represents the sectorial length of the *fiscal* useful life of equipments: $T_{\max} = 8$ years, except for sectors C1, C2, C3 ($T_{\max} = 7$) and for sectors C4, D0, E1, E2, E3 ($T_{\max} = 9$)[15].

The leasing capital stock book value on the first available year is obtained by the sum of current assets [cdb66].05.1 and of fixed assets [cdb66].05.2. The total of the book value of leasing depreciation allowances is the base of depreciation corrected by the ratio of the effectively paid rents on current assets [cdb66].08.1 and on fixed assets [cdb66].08.2 divided by scheduled rents on current assets [cdb66].07.1 and on fixed assets [cdb66].07.2.

Depreciation is the book value of current assets [cdb66].05.1 and fixed assets [cdb66].05.2 used at the end of the period minus the residual value of current assets [cdb66].06.1 and of fixed assets [cdb66].06.2. The residual value of assets is the premium paid by the leasor if he wants to buy the assets he is currently renting.

The sectorial variables:

We selected 5 sectors at NAF16 level: food products, consumption goods industries, equipment goods industries, intermediate products industries, car industry, which amounts to 15 sectors at NAF36 level.

- Investment goods deflators p^I_{st} at NAF36 sectorial classification are taken from the Annual National Accounts (base 1980).

- Gross value added deflators p_{it} are taken from the Annual National Accounts, at NAF36 classification (base 1980).

The aggregate variables:

- The "risk-free" interest rate is the French 10 years government reference bond rate.

- The depreciation rate is assumed to be 8%.

- The statutory corporate income tax rate was 34% in 1992, 33.33% in 1993 and 1994 and 36.66% in 1995 and 1996.

[15]The fiscal length of life of equipment has been evaluated by Cette and Szpiro [1988].

Table 1 : GMM ESTIMATION OF INVESTMENT FONCTION WITH REAL INSTRUMENTS

	Full sample *4025 firms*				**I>0** *N=3378*	**I≈0** *N=647*
Parameter	**M =5**	**M = 4**	**M = 3**	**M = 2**	**M = 4**	**M = 2**
μ	0.66 *(12.8)*	0.69 *(19.0)*	0.68 *(19.1)*	0.68 *(19.6*	0.71 *(17.14)*	0.65 *(15.74)*
α_0	-0.51 *(-2.49)*	-0.48 *(-2.51)*	0.38 *(-2.00)*	-0.36 *(-1.95)*	-0.27 *(-1.71)*	0.01 *(0.01)*
α_2	1.37 *(1.83)*	1.14 *(1.80)*	-0.08 *(-0.56)*	0.02 *(1.06)*	1.22 *(2.06)*	0.01 *(0.01)*
α_3	-5.30 *(-1.85)*	-4.23 *(-1.88)*	0.16 *(0.70)*	-	-4.17 *(-2.04)*	-
α_4	5.77 *(1.68)*	3.94 *(1.93)*	-	-	3.65 *(2.01)*	-
α_5	-0.99 *(-0.70)*	-	-	-	-	-
Test of overidentifying restrictions						
Sargan statistic	22.71	23.46	29.36	29.97	21.31	21.95
Degrees of freedom	18	19	20	21	19	21
P-Value	0.2019	0.2175	0.080	0.092	0.32	0.40
Test of the exclusion restrictions on parameters						
Sargan difference test (χ^2)	-	0.75	-	-	-	-
Degrees of freedom	-	1	-	-	-	-
P-Value	-	0.38	-	-	-	-
Sargan difference test (χ^2)	-	-	5.9	6.51	-	-
Degrees of freedom	-	-	1	2	-	-
P-Value	-	-	0.015	0.038	-	-
Marginal adjustment costs						
Mean	0.057	0.051	-0.004	0.001	0.060	0.000
Median	0.045	0.039	-0.003	0.001	0.047	0.000

Note : Values between brackets are the Student statistic. The estimates of the time dummies are not reported here. Degrees of freedom are defined as T.*k* - *p* where T is number of periods (4), *k*, the numbers of instrumental variables and *p* the numbers of parameters.

The set of instruments consists of four time dummies and three non-financial variables Y_{t-2}/K_{t-3} , I_{t-3}/K_{t-4} , $\left(I_{t-2}/K_{t-3}\right)^2$, to which are added their lags (therefore there are 10 instruments).

Table 2 : DESCRIPTIVE STATISTICS OVER THE YEARS 1993 TO 1996

	Full sample *4025 firms*		**Positive-investment** *3378 firms*		**Mixed-investment** *647 firms*	
	Mean	**Median**	**Mean**	**Median**	**Mean**	**Median**
Capital	87,37	10.52	100.3	12.65	19.92	4.09
Labour	245	60	280	72	65	27
Capital / Labour	0.238	0.175	0.239	0.180	0.233	0.150
Value-Added *(t)* / Capital *(t-1)*	1.033	0.797	1.036	0.810	1.018	0.745
Cash-Flow *(t)* / Capital *(t-1)*	0.206	0.158	0.222	0.170	0.126	0.100
Investment *(t)* / Capital *(t-1)*	0.091	0.087	0.100	0.069	0.050	0.017
Debt *(t) /* Pk*(t)* Capital *(t-1)*	0.562	0.376	0.554	0.376	0.608	0.372
Interest Expenses *(t)* / Pk*(t)* Capital *(t)*	0.051	0.032	0.050	0.033	0.054	0.029
Interest Expenses *(t)* / Debt *(t)*	0.101	0.089	0.101	0.089	0.099	0.089

Note: The monetary unit is the million french francs. The debt ratio (Debt *(t) /* Pk*(t)* Capital *(t-1)*) and reported interest expenses (Interest Expenses *(t)* / Pk*(t)* Capital *(t)*) are not computed with the leasing specific information.

Table 3 : **GMM ESTIMATION OF INVESTMENT FONCTION WITH REAL AND FINANCIAL INSTRUMENTS**

	Full sample *4025 firms*	**I>0** *3378*	**I≈0** *N=647*
Parameter	**M = 4**	**M = 4**	**M = 2**
μ	0.54 *(23.1)*	0.53 *(20.94)*	0.55 *(20.00)*
α_0	0.06 *(0.44)*	0.13 *(1.12)*	0.52 *(2.37)*
α_2	0.22 *(0.41)*	0.81 *(1.48)*	-0.02 *(-0.69)*
α_3	-1.40 *(-0.71)*	-3.09 *(-1.61)*	-
α_4	1.71 *(0.94)*	2.93 *(1.68)*	-
α_5	-	-	-
Test of overidentifying restrictions			
Sargan statistic	116.25	111.38	60.87
Degrees of freedom	43	43	45
P-Value	1.1×10^{-8}	5.6×10^{-8}	0.057
Test of the omission of three financial instruments			
Sargan difference test (χ^2)	92.79	90.07	38.92
Degrees of freedom	24	24	24
P-Value	5.0×10^{-10}	1.4×10^{-9}	0.0278
Marginal adjustment costs			
Mean	0.005	0.029	0.000
Median	0.005	0.023	0.000

Note : Values between brackets are the Student statistic. The estimates of the time dummies are not reported here. Degrees of freedom are defined as T.*k* - *p* where T is number of periods (4), *k*, the numbers of instrumental variables and *p* the numbers of parameters.

The set of instruments consists of four time dummies, three non-financial variables Y_{t-2}/K_{t-3} , I_{t-3}/K_{t-4} , $(I_{t-2}/K_{t-3})^2$ and their lags, to which are added three financial variables B_{t-2}/K_{t-2} , $[iB]_{t-2}/K_{t-2}$, CF_{t-2}/K_{t-3} and their lags (therefore there are 16 instruments).

Notes d'Études et de Recherche

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