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A Q Model Investment System in Material and Immaterial Assets*

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Abstract:

The aim of this paper is to study the determinants of investment on material and immaterial assets of Spanish firms considering they are heterogeneous assets. With this objective, we propose an investment model based on both prospective models and Tobin's q. The developed model is then applied to analyse the investment determinants of material and immaterial assets over a panel of 87 non-financial Spanish firms that have been quoting on the Stock Market during 12 years. Results show that material investment decisions are isolated from immaterial assets, whereas immaterial investment is affected by tangible investment and stock.

Keywords: *Investment models, Assets Heterogeneity, Tobin's q, Spanish Firms.*

JEL Classification: D21, M21, M10

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1. Introduction

The aim of this paper is to analyze which variables determine investment decisions on material and immaterial assets under a technology specification that considers the existence of multiple capital goods (Chirinko, 1993 b; Epstein, 1983; Wildasin, 1984; Hayashi and Inoue, 1991; Bond and Cummins, 2000; Cummins and Dey, 1998). On an international scale, different studies based on this type of model have been conducted, generally distinguishing between the existence of tangible and intangible assets or between structures and equipment, with most of the literature referring to the latter. Few papers, however, have applied this line of research to the Spanish economy, where there is a vacuum in the study of the relationship between investment in tangible assets and the existence of intangible assets, although some studies have analysed the decisions of Spanish firms to invest in intangible assets, considering the existence of tangible assets as a significant variable (Galende and Suárez 1999).

The contribution of this paper is three-fold: (1) it distinguishes between tangible (material and liquidable) and intangible (immaterial) assets, considering that they are heterogeneous in the creation of value for the firm, (2) it analyses the existence of crossover effects when making investment decisions and, (3) it proposes the use of the marginal q of each of the types of asset presented in the investment model, which are introduced through a link between the assumptions of prospective investment models and those of investment models based on Tobin's q.

The paper contains four more sections. The second presents the theoretical model and the model to be estimated. The third describes the sample and the variables used. The fourth explains the methodology used and the results obtained and, finally, the fifth presents the most significant conclusions.

2. The Investment Model

2.1. The theoretical model

To construct the investment model we assume the neoclassical objective of firm's value maximization through optimal use of its resources. In each period, the firm faces a Cobb-Douglas production function which considers different productive factors cumulative as capital goods. It is assumed that the profit function is linearly homogeneous in the capital stock accumulated in each of the capital goods and their investment, and that capital goods are semi-fixed factors. Furthermore, to simplify the notation, it omits the explicit dependence between the profit function and the price of the inputs. Other assumptions are that there are no taxes, that the firm does not pay debts and that both prices and technological shock (ε_s) are determined for each period before having to decide on its investment.

In each period, the firm chooses its investment in each type of capital asset $\mathbf{I}_t = (I_{1t},..., I_{Nt})$, where N is the number of different capital assets and t is the period of time. This is equivalent to defining a given sequence of capital stocks $\mathbf{K}_t =$

(K_{1t},..., K_{Nt}) $\mathbf{K}_{t-1,}$ which maximises the market value of the firm at time t (V_t). The firm's market value is then defined as:

$$V_t = E\left\{\sum_{s=t}^{\infty} \beta_s^t \Pi\left(K_{j_s}, I_{j_s}, \varepsilon_s\right)\right\} \quad (1)$$

where β is the discount factor, Π the profit function, $\mathbf{K}_{js}$ is the vector representing the capital stock for each asset j at the start of the period s, $\mathbf{I}_{js}$ is the vector representing the investment made in each asset j in the period s, and ε_s represents the technological shock of period s, which follows a Markov process and is observed by the firm at time s.

Equation (1) must be maximised subject to a series of constraints, determined by the expression:

$$K_{j,t+s} = (1-\delta_j)K_{j,t+s-1} + I_{j,t+s} \quad (2)$$

where δ_j is the depreciation rate of asset j and $s \geq 0$,

Let $\lambda_{j,t}$ be the Lagrange coefficient vector to maximise equation (1) subject to the constraints imposed in equation (2). In the optimal case, the following must be true:

$$\lambda_{j,t} = -\left(\frac{d\Pi_t}{dI_{j,t}}\right) \quad (3)$$

and

$$\lambda_{j,t} = \frac{d\Pi_t}{dK_t} + E_t\left[\sum_{s=t}^{\infty} \beta_{s+1}^t \left(1-\delta_j\right)^{s+1} \frac{d\Pi_{s+1}}{dK_{j,s+1}}\right] \quad (4)$$

These maximum conditions express that, for each asset, the shadow price of the last capital unit invested on it must be the same as the value it is capable of generating for the firm in the long run[4].

Three types of assets are distinguished: material, immaterial and liquidable assets. Combining equations (3) and (4) and taking N=3, firm's market value is redefined as:

$$V_t = \sum_{j=1}^{3} \lambda_{j,t}(1-\delta_j)K_{j,t-1} \quad (5)$$

[4] This equation can also be expressed as:

$$\lambda_{j,t} = E_t\left[\sum_{s=0}^{\infty} \beta_s^t \left(1-\delta_j\right)^s \frac{d\Pi}{dK_j}\right] \text{ or } \lambda_{jt} = \left(\frac{d\Pi_t}{dK_{jt}}\right) + \left(1-\delta_j\right)\beta_{t+1}^t E_t\left[\lambda_{j,t+1}\right]$$

See Abel and Blanchard (1986) and Bond and Cummins (2000) for a more detailed development.

where the subindex j=1 refers to material assets, subindex j=2 to immaterial assets and subindex j=3 to liquidable assets. It is considered that each group of assets presents homogeneous internal behaviour in the sense of Wildasin (1984)[5].

Developing the summation, considering that the shadow price of the liquidable assets is equal to one ($\lambda_{3,t}=1$) and replacing $\lambda_{1,t}$ by its optimal value ($q^*_{1,t}p_{1,t}$) and replacing $\lambda_{2,t}$ by the optimal condition shown in equation (3), we obtain the following expresion for the marginal $q^*_{1,t}$ for the material assets:

$$q^*_{1,t} = \frac{V_t - K_{3,t-1}}{p_{1,t}(1-\delta_1)K_{1,t-1}} - \frac{1}{p_{1,t}}\left(\frac{1-\delta_2}{1-\delta_1}\right)\left(\frac{K_{2,t-1}}{K_{1,t-1}}\right)\left(\frac{d\Pi_t}{dI_{2,t-1}}\right) \quad (7)$$

Similarly, for immaterial assets we obtain that the marginal q^*_2 of this type of asset is represented by the expression:

$$q^*_{2,t} = \frac{V_t - K_{3,t-1}}{p_{2,t}(1-\delta_2)K_{2,t-1}} - \frac{1}{p_{2,t}}\left(\frac{1-\delta_1}{1-\delta_2}\right)\left(\frac{K_{1,t-1}}{K_{2,t-1}}\right)\left(\frac{d\Pi_t}{dI_1}\right) \quad (8)$$

The adjustment cost function is quadratic and separable in the different assets investments and stocks. The implication of this assumption is that the costs of installing material assets have no effect on the adjustment costs of immaterial assets, and vice versa. Furthermore, the costs of installing material (immaterial) assets are not altered by the capital stock previously accumulated in other capital goods.

The adjustment cost function[6] would therefore have the following form:

$$G_t = \frac{b_1}{2}\left[\frac{I_{1,t}}{K_{1,t}} - a_1\right]^2 K_{1,t} + \frac{b_2}{2}\left[\frac{I_{2,t}}{K_{2,t}} - a_2\right]^2 K_{2,t} \quad (9)$$

such that a_j and b_j, are the parameters of the adjustment cost functions.

So:

$$\frac{d\Pi_t}{dI_{1,t}} = -g_t b_1\left[\frac{I_{1,t}}{K_{1,t-1}} - a_1\right] - p_{1,t} = -q^*_{1,t}p_{1,t} \quad (10)$$

and

$$\frac{d\Pi_t}{dI_{2,t}} = -g_t b_2\left[\frac{I_{2,t}}{K_{2,t-1}} - a_2\right] - p_{2,t} = -q^*_{2,t}p_{2,t} \quad (11)$$

[5] In the case of loss of output, the prices of all capital assets must remain fixed and the adjustment cost function must be additive and separable by investment and capital pairs for each type of asset, following a quadratic form (Wildasin, 1984).

[6] The work assumed adjustment costs with loss of output, similar to when the adjustment cost function is established in terms of loss of productive capacity. The functional form of the model, and therefore the results obtained, are the same in both cases.

From (9), we obtain the following investment equation:

$$\frac{I_{1,t}}{K_{1,t-1}} = a_1 + \frac{1}{b_1}\frac{p_{1,t}}{g_t}\left(q^*_{1,t} - 1\right) + \varepsilon_t \qquad (12)$$

To simplify the model, we assume that the relative price index of the material and immaterial assets relative to the output remains constant over time. Replacing (11) in (7), and introducing the expression obtained in the investment equation, we obtain the following investment model for material and immaterial assets:

$$\frac{I_{1,t}}{K_{1,t-1}} = \alpha_1 + \alpha_2(q_{1,t} - 1) + \alpha_3\left(\frac{I_{2,t}}{K_{1,t-1}}\right) + \alpha_4\left(\frac{K_{2,t-1}}{K_{1,t-1}}\right) + \varepsilon_t$$

$$(13)$$

$$\frac{I_{2,t}}{K_{2,t-1}} = \alpha'_1 + \alpha'_2(q_{2,t} - 1) + \alpha'_3\left(\frac{I_{1,t}}{K_{2,t-1}}\right) + \alpha'_4\left(\frac{K_{1,t-1}}{K_{2,t-1}}\right) + \varepsilon'_t$$

Where[7]:

1.- $\alpha_1 = a_1$ 2.- $\alpha_2 = \frac{1}{b_1}\frac{p_1}{g}$

3.- $\alpha_3 = -\frac{b_2}{b_1}\left(\frac{1-\delta_2}{1-\delta_1}\right)$ 4.- $\alpha_4 = \frac{1}{b_1}\left(\frac{1-\delta_2}{1-\delta_1}\right)\left[a_2 b_2 - \frac{p_2}{g}\right]$

5.- $\alpha'_1 = a_2$ 6.- $\alpha'_2 = \frac{1}{b_2}\frac{p_2}{g}$

7.- $\alpha'_3 = -\frac{b_1}{b_2}\left(\frac{1-\delta_1}{1-\delta_2}\right)$ 8.- $\alpha'_4 = \frac{1}{b_2}\left(\frac{1-\delta_1}{1-\delta_2}\right)\left[a_1 b_1 - \frac{p_1}{g}\right]$

The model shows that the investment in material assets is a function of the firm's evaluation ratio relative to the replacement value of the material assets, of the rate of investment in immaterial assets and of the initial distribution of the capital stock between the two types of asset. More specifically, the effect of the investment in immaterial assets on the investment in material assets is negative,

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[7] The notation has been simplified by denoting $q_{j,t} = \frac{V_t - K_{3,t-1}}{p_{j,t}\left(1-\delta_j\right)K_{ji,t-1}}$ for j = 1, 2 and (1+2).

This notation has been taken solely for convenience, without identifying this value with Tobin's q ratio, as the term used is really only part of the marginal q of each of the goods, which is completed by the rest of the terms appearing in the model. The use of the marginal q instead of its approximation through the mean q not only enables us to distinguish between the value generated by each of the firm's capital goods, but also the possible returns obtained by firms capable of generating a sustainable competitive advantage. The use of this notion enables us to make a simple comparison between the proposed and traditional models and can only be zero when the immaterial assets depreciate in one period or when the adjustment costs of this asset are constantly zero.

Symmetrically, the investment in immaterial assets is a function of the firm's evaluation ratio relative to the replacement value of the immaterial assets, of the rate of investment in material assets and of the initial distribution of the capital stock between the two types of asset. Once again, we see that, symmetrically to the previous equation, the effect of the investment in material assets on the investment in immaterial assets is negative, and can only be zero when the material assets depreciate in one period or the adjustment costs of that asset are zero.

The impact of the initial distribution of capital in the firm is not determined by the theoretical model, but it shows a relationship between the sign of α_3 and α_4 (and α'_3 and α'_4). If the depreciation of the immaterial (material) assets takes place in a single period, the initial distribution of capital in the firm is not an explanatory variable of the investment in material (immaterial) assets, so we would obtain the traditional investment model. When all the investment is depreciated in the period in question this is a current expenditure and not an investment proper, so if one of the two assets behaves in this way it is not classified as a capital good. In this case, the investment model would consider a single productive capital asset.

Furthermore, given the ratio between the input and output prices, α_4 indicates that the investment in material (immaterial) assets will be greater, the greater the adjustment costs associated to the immaterial (material) assets.

2.2. The model to be estimated

The theoretical model presented is not applicable in practice, as it is underspecified and therefore offers an infinite number of possible solutions. Different alternatives have been suggested in the literature to solve this problem.

Hayashi and Inoue (1991) relate the growth ratio of a scaled index of different capital inputs with Tobin's q. This solution is based on assuming the weak separability of different capital assets in the firm's profit function, enabling them to divide the maximisation problem into two stages. In the first, they decide how to separate capital aggregation over time. In the second, they solve the static problem of dividing the aggregate capital into individual capital stocks which minimise the cost of capital. However, the consideration of weak separability between capital inputs implies implicitly assuming that they are substitutive (Cummins, 2004)

Following the theoretical proposal presented by Wildasin (1984), Chirinko (1993) estimates an equation in which the capital investment of each asset relative to the total capital stock depends on Tobin's q and the capital stock ratios of the rest of the assets relative to the aggregate capital stock. To avoid under-specification, the author assumes that capital goods present a common structure in their adjustment costs. He thus first calculates the total investment to be made by the firm and then decided how to divide that total investment between the different capital assets. On this solution, homogeneity is implicitly considered in the adjustment costs.

Bond and Cummins (2000) assume that the ratio between tangible and intangible capital stock remains constant over time. However, looking at the data presented by Nakamura (2000) for the North American economy, we see that the first of these assumptions is not true. Furthermore, when performing the estimation, they only analyse decisions to invest in tangible assets, considering that the firm's intangible investments is known. According to Eberly (2000), this could bias the study's conclusions. In our model, taking intangible asset investment as a known data and not as a variable to be estimated, would imply that intangible investment is decided before and independently from investment in tangible assets.

Finally, Bontempi et al (2004) adapt the calculation of the fundamental q proposed by Abel and Blanchard (1986) and Gilchrist and Himmelberg (1995) to calculate the shadow price of heterogeneous assets in a panel data of Italian firms. They consider that the shadow price of capital can be calculated by estimating a set of autoregressive equations which forecasts the marginal profit of capital.

Based on the different solutions proposed in the literature and their results, we decided to use instruments to solve under-specification problems. We specifically sought instruments to approximate the value of the shadow price of the investment.

Following the proposal presented by Bontempi et al (2004) and prospective model theory, we assume that non-observable expectations present a stochastic process. We have, however, introduced some different considerations. (1) The difference with prospective models is that they specify the stochastic process, for operational reasons, through a first order univariate regression. In this paper, however, the order of integration of the variable is not predetermined, but established through the estimation of the model. (2) The difference with the work by Bontempi et al (2004) is that these authors use a sequential prospective model calculating fundamental q value for each type of capital asset and introducing those values into the model. Our proposed solution is considering a simultaneous prospective model that enables us to continue using the firm's market value as a relevant variable on firm's investment decisions.

The functional form of the empirical model is then obtained from an autoregressive specification for the shadow price of λ_i,

$$\lambda_{i,t} = \mu_i \lambda_{i,t-s} + \varepsilon_t$$

from which instruments can be taken so that[8]

[8] To simplify the notation, we eliminate the coefficients determining that this equation is independent for each firm

$$\hat{\lambda}_{i,t} = \mu_i \left[g_t b_i \left(\frac{I_{i,t-s}}{K_{i,t-s-1}} - a_i \right) - p_{i,t-s} \right]$$

Replacing the value of $\hat{\lambda}_{i,t}$ in $q^*_{j,\,t}$ and repeating the steps taken to develop the theoretical model, we obtain the following system of investment equations for material and immaterial assets:

$$\frac{I_{1,t}}{K_{1,t-1}} = \beta_1 + \beta_2 (q_{1,t} - 1) + \beta_3 \left(\frac{I_{2,t-s}}{K_{1,t-1}} \right) \left(\frac{K_{2,t-1}}{K_{2,t-s-1}} \right) + \beta_4 \left(\frac{K_{2,t-1}}{K_{1,t-1}} \right) + \varepsilon_t$$

$$\frac{I_{2,t}}{K_{2,t-1}} = \beta'_1 + \beta'_2 (q_{2,t} - 1) + \beta'_3 \left(\frac{I_{1,t-s}}{K_{2,t-1}} \right) \left(\frac{K_{1,t-1}}{K_{1,t-s-1}} \right) + \beta'_4 \left(\frac{K_{1,t-1}}{K_{2,t-1}} \right) + \varepsilon'_t \qquad (14)$$

where the new coefficients are:

1.- $\beta_1 = a_1$ 2.- $\beta_2 = \dfrac{1}{b_1} \dfrac{p_1}{g}$

3.- $\beta_3 = -\dfrac{\mu_2 b_2}{b_1} \left(\dfrac{1-\delta_2}{1-\delta_1} \right)$ 4.- $\beta_4 = \dfrac{\mu_2}{b_1} \left(\dfrac{1-\delta_2}{1-\delta_1} \right) \left[a_2 b_2 - \dfrac{p_2}{g} \right]$

5.- $\beta'_1 = a_2$ 6.- $\beta'_2 = \dfrac{1}{b_2} \dfrac{p_2}{g}$

7.- $\beta'_3 = -\dfrac{\mu_1 b_1}{b_2} \left(\dfrac{1-\delta_1}{1-\delta_2} \right)$ 8.- $\beta'_4 = \dfrac{\mu_1}{b_2} \left(\dfrac{1-\delta_1}{1-\delta_2} \right) \left[a_1 b_1 - \dfrac{p_1}{g} \right]$

From equation (14) we can group all the possible estimations around three main situations: related investments in material and immaterial assets, semi-related investments or unrelated investments. The different possibilities and their combinations are shown on Table 1.

The first case, related investment, implies that the investment in each of the firm's capital assets responds to the theoretical model considered, depending on the shadow price of the other asset. On this situation, it is necessary to use the instrumented model.

The second case, semi-related investment, shows that only the investment model of one of the assets considers the full effect of the other on its marginal q. This situation could be more or less restrictive. The most restrictive would be to consider that the firm makes its investment decisions related to one of its capital assets as if the other did not exist. The least restrictive situation would occur when the firm makes its investment decisions on one asset as if investment on the other would be null that period.

Finally, unrelated investment occurs when neither of the two capital assets considers the full effect of the other on its marginal q. Once again, this situation could arise in the most restrictive situation, in which the existence of the other asset is not considered, or in the least restrictive situation in which the investment in the other capital asset in the same period is considered null.

Table 1: Different considerations of independence in investment decisions between material and immaterial assets

Type of investment	Assumption	Functional form of the model
Related investment	–	$I_1 = f(q_1, \hat{\lambda}_{2,t})$
		$I_2 = f(q_2, \hat{\lambda}_{1,t})$
Semi-related investment	$\hat{\lambda}_{2,t} = 0$	$I_1 = f(q_1)$
		$I_2 = f(q_2, \hat{\lambda}_{1,t})$
	$I_2 = 0$	$I_1 = f(q_1, K_{2,t-1}/K_{1,t-1})$
		$I_2 = f(q_2, \hat{\lambda}_{1,t})$
	$\hat{\lambda}_{1,t} = 0$	$I_1 = f(q_1, \hat{\lambda}_{2,t})$
		$I_2 = f(q_2)$
	$I_1 = 0$	$I_1 = f(q_1, \hat{\lambda}_{2,t})$
		$I_2 = f(q_2, K_{1,t-1}/K_{2,t-1})$
Unrelated investment	$\hat{\lambda}_{1,t} = \hat{\lambda}_{2,t} = 0$	$I_1 = f(q_1)$
		$I_2 = f(q_2)$
	$I_1 = I_2 = 0$	$I_1 = f(q_1, K_{2,t-1}/K_{1,t-1})$
		$I_2 = f(q_2, K_{1,t-1}/K_{2,t-1})$

3. Description of the Sample and the Variables Used

3.1. Description of the sample

The analysis of this model requires the firms in the sample to trade on the Spanish stock market. We use a sample of 87 non-financial firms which traded continuously on the Spanish stock market in 1991-2002[9]. This involves working with a balanced panel of 1044 observation, although in some cases the use of lagged variables involves using certain years as a reference for the calculation of

[9] The sample is a time enlargement of the sample developed by Ramírez (1997) and Delgado (2005), eliminating the firms which did not trade until the end of the period.

said variables, reducing the total number of years with which the regressions are made[10].

The firm data was obtained from reports presented to the National Stock Market Commission. We decided to use this source because of its reliability and accuracy. The annual reports provide the accounting data required to measure the variables.

The trading values of the firms were obtained from data published by the specialised press. The data required to construct the price indices were obtained from reports published by the National Statistics Institute and National Accounts. Finally, technical progress was calculated based on 192 firms comprising a non-balanced panel from 1961 to 2002[11].

3.2. Presentation of the variables

Material assets are those resources used in the firm's permanent productive activity that are easily observed, measured and quantified. Material values needed are calculated or proxy from material asset and related accounts.

Immaterial assets are those assets used in the firm's permanent productive activity but they are not easily observed, measured and/or quantified. Immaterial values needed are calculated or proxy from immaterial asset and related accounts.

Liquidable assets are those resources that are not used in the firm's permanent productive activity and are easily converted into cash. Liquidable values needed are calculated or proxy the accounts related to financial fixed assets, net monetary assets and stocks accounts, with net monetary assets defined as the value of the "debtors and disposable" and "short-term financial assets" items less "short-term debt at no cost".

Investment in material assets is a function of the material q, investment in immaterial assets in relation to the stock of material assets at replacement prices and the stock of immaterial assets at replacement prices in relation to the stock of immaterial assets at replacement prices. Together, these variables represent the value of the marginal q of the material assets. The material q is calculated as the quotient between market value less liquidable assets at replacement prices in the numerator and the stock of material assets at replacement prices in the denominator.

Investment in immaterial assets is a function of the immaterial q, investment in material assets in relation to the stock of immaterial assets at replacement prices and the stock of material assets at replacement prices in relation to the stock of material assets at replacement prices. Together, these variables represent the value of the marginal q of the immaterial assets. The immaterial q is calculated as the quotient between market value less liquidable

[10] Specifically, the final number of years to be used depends on the number of years required to calculate the autoregression which is best adapted to the shadow price of the assets.
[11] This sample is based on the set of firms used by Espitia (1985), subsequently enlarged by Giner (1993), Ramírez (1997) and Delgado (2005)

assets at replacement prices in the numerator and the stock of immaterial assets at replacement prices in the denominator.

To calculate the investment in material assets, we use the variation in the balance sheet item entitled "gross fixed material assets" between t and t-1, whereas we calculate the investment in immaterial assets from the balance sheet item entitled "gross immaterial assets" between t and t-1. Each of them is corrected for (i) positive variations in the regularisation reserve and (ii) the elimination of old assets, which is calculated from the accumulated and book depreciation values for the period. In this case, the revaluation reserves are assigned to material assets when the law expressly establishes that only material assets can be revaluated. If both material and immaterial assets could be revaluated, the revaluation reserves would be distributed among the groups of assets considered in proportion to their relative importance on the firm's balance sheet.

The value of the material assets at replacement prices is obtained from the replacement value of the assets in the material fixed assets item. To calculate the replacement price of the assets, we follow the methodology proposed by Espitia (1985), based on Lindemberg and Ross (1981). This methodology involves accepting three assumptions. (i) In the first place, it is assumed that economic depreciation is well approximated by the book depreciation rate. (ii) Secondly, it is assumed that firms evaluate their stocks based on the mean cost criterion. (iii) Thirdly, it is assumed that the price of the assets remains constant relative to the output price over time. The annual price increase is calculated from the capital good price index, obtained from the implicit gross fixed capital formation deflator provided in the national accounts.

We thus calculate:

$$\mathrm{K}_{\mathrm{Tg,t}} = \mathrm{K}_{\mathrm{Tg,\,t\text{-}1}} \frac{(1+\phi)}{(1+\delta)(1+\theta)} + I_{Tg,t}$$

where $K_{Tg,t}$ represents the stock of material assets at replacement prices in period t, Φ is the price index of the material assets, δ is the rate of depreciation of the material assets and θ is technical progress.

The value of the immaterial assets at replacement prices is the value of immaterial fixed assets at replacement prices. We thus calculate:

$$\mathrm{K}_{\mathrm{Intg,t}} = \mathrm{K}_{\mathrm{Intg,\,t\text{-}1}} \frac{(1+\phi)}{(1+\delta)(1+\theta)} + I_{Intg,t}$$

where $K_{Tg,t}$ represents the stock of immaterial assets at replacement prices in period t, Φ is the price index of the immaterial assets, δ is the rate of depreciation of the immaterial assets and θ is technical progress.

For these estimations, we use sector and time-specific dummy variables as control variables. There are 11 grouping dummies, one for each sector considered. Each variable has a value of 1 for firms in the sector associated to the dummy and zero for the rest. The time-specific dummy variables are 12, each of which is associated to one of the years studied in the sample. These variables have a value of 1 in the data produced in the year associated to the dummy and zero in the rest.

4.Methodology And Results

The panel data structure holds during the estimations. This type of data structure can be estimated considering the existence of fixed or random effects, being the structure or variances or covariances also relevant in order to choose the estimation method. We therefore test the existence of fixed or random effects, spatial correlation and auto-correlation in order to select the most appropriate estimation method given the particularities of our sample.

The existence of particular effects pertaining to a firm (both fixed and random) and serial correlation are analysed through the tests proposed by Bera, Sosa-Escudero and Yoon (2001). These tests are considered more appropriate than those traditionally proposed by Breusch and Pagan (1980) to analyse the existence of random effects and by Baltagi-Li (1995) to analyse the existence of auto-correlation, because they are robust in the presence of heteroskedasticity[12].

When the existence of effects is detected, we use the Hausman test to determine whether they are fixed or random effects. When the asymptotic conditions required to perform the analysis are not met, the estimation is made treating the errors as if they were random[13].

To analyse the independence of the error terms of the cross sections of the sample (no sample correlation) we use the test proposed by Pesaran (2004). This methodology is selected because it is a non-parametric test, acceptable when the time series is small in comparison with the cross section series. In these cases, the Breusch-Pagan (1980) test is not valid. If the asymptotic properties are not met, the estimation is made treating the errors as non-correlated, as in almost all the cases in which the test was performed, we observed that said independence was met.

As the analyses performed show the existence of random effects and auto-correlation in most of the covariance structures of the models to be estimated, the

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[12] The tests available for analysing the existence of heteroskedasticity do not suitably adapt to the data of the sample. The Lagrange test, the likelihood quotient and Wald's test are sensitive to the assumption of normality in the errors. The modified Wald statistic, proposed by Greene (2000), is another option, but its power is reduced in the context of panel data with few time-related data compared with the number of firms. Although the tests performed show the existence of heteroskedasticity, these results should be initially analysed with caution. However, making the estimations assuming the existence of heteroskedasticity does not worsen the conditions of the model or alter the results when said heteroskedasticity does not exist.

[13] This decision was made because in all the cases in which the Hausman test was performed, it showed that the effects observed in the test proposed by Bera et al (2001) were of a random nature.

selected method of estimation was FGLS (Feasible Generalized Least Squares)[14]. This method enables us to estimate considering the panel structure of the sample data and also considering the existence of heteroskedasticity, heteroskedasticity and sample correlation and either of these two options together with auto-correlation (which in turn could present a common coefficient for all the firms in the sample or an individual coefficient for each one) without the need for prior assumptions related to the structure of the variance of the errors.

Using the FGLS method of estimation maintains the efficiency of the t-test to measure the significance of the variables individually, and Wald's test to measure their joint significance. The likelihood logarithm and derived criteria (BIC and Akaike) are appropriate for making comparisons between nested models, with the same variable to be explained, and applied to the same sample. When said conditions are not met (as in the case of the comparison between the three types of model estimated according to the considerations about the heterogeneity of the different capital assets) we considered using the predictive goodness of the models as the selection criterion. This goodness was evaluated through the coefficient of inequality and Theil (CDT), expressed as:

$$CDT = \frac{\sqrt{\dfrac{\sum_{t=1}^{n}(\hat{Y}_t - Y_t)^2}{n}}}{\sqrt{\dfrac{\sum_{t=1}^{n}\hat{Y}_t^2}{n}} + \sqrt{\dfrac{\sum_{t=1}^{n}Y_t^2}{n}}}$$

This coefficient is dimensional, contains a quadratic loss function in order to penalise large forecasting errors and its value varies from zero to one. The closer to zero the better forecasting capacity found in the model.

The program used for the econometric analysis was STATA, release 9.0. This program also provides the tests required to determine the covariance structure. These tests update those included in the program, providing robust versions.

The procedure and presentation of results is as follows: (1) For each model, we perform the tests determining whether or not there are firm effects, auto-correlation and sample correlation. The results of these tests are shown in the second part of the results tables. (2) The estimation is made considering the q of the period. However, following some proposals found in the literature, the firm may not immediately respond to the investment signals issued by the market, so we also estimate the different models considering that the variable explaining

[14] Except for one, all the estimations performed showed the presence of heteroskedasticity and auto-correlation in the covariance matrix. The presence of random effects and serial correlation was not a constant, although they are random in all the cases in which the existence of effects is observed.

investment is the variable q delayed one period. We thus perform four estimations for each model (M1, M2, M3 and M4). The first two (M1 and M2) correspond to the q of the period (Q_t) and the second two (M3 and M4) with the lagged q (Q_{t-1}). In each of these cases, we present the estimation considering the possibility that the auto-correlation coefficient (Rho_i) is the same for all the firms in the sample (M1 and M3) and the possibility that the auto-correlation coefficient is individual for each of them (M2 and M4). If the auto-correlation coefficient is the same, the table header shows its estimated value. (3) Each table summarises which variables are significant under different scenarios and shows their level of significance and their effect. We also provide the BIC and CDT criteria and Wald's test to allow for a comparison between the different estimations and the different models.

As explained on the presentation of the model to be estimated, when investment decisions on material and immaterial assets are supposed to be related, the autoregressive process order for shadow prices is determined through the estimation goodness. Table 2 is an enlarged version of table 1, including a new column with the assumptions related to the behaviour of shadow prices providing more goodness of fit. In turn, each of these situations can be estimated in four ways, considering the use of the q of the period vs the lagged q and an autoregression coefficient common to all the firms in the sample vs an individual coefficient for each firm. Tables 3 and 4, respectively, show the estimations for the tangible and immaterial assets in all the different possible scenarios[15].

Table 2: Estimation selected according to the independence of investment decisions between material and immaterial assets

Type of investment	**Assumption**	**Functional form of the model**	**Best possible estimation**
Related investment	–	$I_1 = f\,(q_1,\ \hat{\lambda}_{2,t})$	$\hat{\lambda}_{2,t} = \lambda_{2,t}$
		$I_2 = f\,(q_2,\ \hat{\lambda}_{1,t})$	$\hat{\lambda}_{1,t} = \mu\lambda_{1,t-2} + \varepsilon_t$
Semi-related investment	$\hat{\lambda}_{2,t} = 0$	$I_1 = f\,(q_1)$	–
		$I_2 = f\,(q_2,\ \hat{\lambda}_{1,t})$	$\hat{\lambda}_{1,t} = \mu\lambda_{1,t-2} + \varepsilon_t$
	$I_2 = 0$	$I_1 = f\,(q_1, K_{2,\,t-1} / K_{1,\,t-1})$	–
		$I_2 = f\,(q_2,\ \hat{\lambda}_{1,t})$	$\hat{\lambda}_{1,t} = \mu\lambda_{1,t-2} + \varepsilon_t$

[15] To avoid too much information, the results shown in the tables are limited to the estimations in which we obtained the best results according to the CDT criterion. Considering all the possible estimations, we see that, in this case, the greatest goodness of fit is obtained when material investment considers the shadow price considered for immaterial assets in the period, whereas the immaterial investment model shows better goodness of fit when the shadow price of the tangible assets is considered an autoregressive of the 2nd order (see tables 3 and 4).

	$\hat{\lambda}_{1,t} = 0$	$I_1 = f(q_1, \hat{\lambda}_{2,t})$	$\hat{\lambda}_{2,t} = \lambda_{2,t}$
		$I_2 = f(q_2)$	_
	$I_1 = 0$	$I_1 = f(q_1, \hat{\lambda}_{2,t})$	$\hat{\lambda}_{2,t} = \lambda_{2,t}$
		$I_2 = f(q_2, K_{1,t-1}/K_{2,t-1})$	_
Unrelated investment	$\hat{\lambda}_{1,t} = \hat{\lambda}_{2,t} = 0$	$I_1 = f(q_1)$	_
		$I_2 = f(q_2)$	_
	$I_1 = I_2 = 0$	$I_1 = f(q_1, K_{2,t-1}/K_{1,t-1})$	_
		$I_2 = f(q_2, K_{1,t-1}/K_{2,t-1})$	_

The results of the estimation of the investment model for material assets are showed in table 3. We can see that investment in material assets is independent from the firm's immaterial assets. Indeed, the best estimation for material assets ignores the shadow price of the immaterial assets.

In any of the analyses performed to include the effect of the immaterial assets on material investment decisions ($I_1 = f(q_1, \hat{\lambda}_{2,t})$), we see that in no case is the variable representing the firm's capital ratio significant. In the theoretical model, however, this is only possible if the immaterial assets are not subject to adjustment costs, or if they are classified as expenses and not investment, with an annual deprecation of one. Therefore, the results appear to show that firms invest in material assets as if immaterial assets did not exist. This is the same as considering that immaterial assets are literally an expense, with a zero shadow price.

This idea is confirmed by the results of the model estimated under this assumption. As we mentioned earlier, two different assumptions are possible when considering that tangible investment does not depend on immaterial investment. The first is that tangible investment is made without considering the possibility of immaterial investment ($I_2 = 0$; $I_1 = f(q_1, K_{2,t-1}/K_{1,t-1})$). In this case, however, tangible investment continues to depend on the firm's capital ratio. The results obtained for this estimation are shown in table 3. We can see that the goodness of fit of the model, as shown by the CDT, is greater than when considering immaterial investment (CDT=0.0279 when not considered vs CDT=0.0301 when considered). We observe, however, that the variable considering the firm's capital ratio continues to be insignificant.

The second possibility is to assume that immaterial assets do not influence material asset investment decisions ($\hat{\lambda}_{2,t} = 0$; $I_1 = f(q_1)$). Analytically, this assumption is the same as considering that firms ignore the possibility of creating value through investment in immaterial assets when contemplating material investment decisions. This assumption involved better goodness of fit (CDT =

0.024). In this case, the most appropriate estimation considers the material q of the period and an individual auto-correlation coefficient for each firm. When we look at this further, we see that the mean q of a firm with no financial assets has a very high correlation (0.98*** when considering the q of the period and 0.99*** when considering the lagged q) with the q of the material assets, whereas this correlation is much smaller in the case of immaterial assets (0.057 when considering the q of the period and 0.062 when considering the lagged q). This, possibly due to the high proportion of material assets relative to immaterial, could be the reason why the variables related to immaterial assets are not relevant when it comes to deciding on investments in material assets, in which case the mean q of productive assets can be identified with the marginal q of material assets.

The results of the selected estimation ($\hat{\lambda}_{2,t} = 0$; $I_1 = f(q_1)$) show that the firm's investment in material assets positively and significantly depends on the material q of the period. When making the estimation with the q of the period, the coefficient accompanying the material q variable is 4 times greater than when the lagged q is used, involving very significant variations in adjustment costs. One possible explanation would be due to the fact that investments involving a great expense for the firm take longer, possibly because a delay in the investment could represent a source of information in which any related uncertainty is eliminated. This would be particularly important in cases involving property options. This theory suggests that, in some cases, the investment should not be seen as a decision to be made now but at the appropriate time (Amram and Kulatilaka, 2000). If there is an important source of uncertainty related to the investment, the value of the option is higher than that of the decision, leading firms to delay the project. This methodology studies investment decisions when, besides uncertainty, the investment involves a high degree of irreversibility (Dixit and Pindyck, 1994). Thus, investments responding to the lagged q may be precisely those which involve more uncertainty and higher adjustment costs, as the latter form part of irreversible "investment".

Table 3: Material assets model

$\hat{\lambda}_{2,t} = \lambda_{2,t}$				
Variable	**M1** **Q_t** **Rho_i =0.3188**	**M2** **Q_t** **Rho_i**	**M3** **Q_{t-1}** **Rho_i =0.3123**	**M4** **Q_{t-1}** **Rho_i**
Constant	0.0707***	0.0753***	0.0699***	0.0706***
Material q	0.0027***	0.0027***	0.0005	0.0007**
K_2 / K_1	0.0070	0.0061	0.0127	0.0104
I_2 / K_1	0.0355***	0.3742***	0.0409**	0.0432***
Sectorial variables			S3	S3
Time variables	96, 99, 00, 01	96, 98 99, 00, 01	96, 99, 00, 01	96, 99, 00, 01
ALM (N) (Var(u)=0)	22.00***	22.00***	26.06***	26.06***
ALM (rho=0)	22.16***	22.16***	17.72***	17.72***

Pesaran (no sample corr.)	1.488	1.488	1.727*	1.727*
BIC	-1421.79	-1584.54	-1414.48	-1580.41
CDT	0.0337	0.0301	0.0416	0.0350
Wald	51.59***	80.56***	45.32***	76.89***
$\lambda_{2,t}$ **= 0**				
Constant	0.0728***	**0.0776*****	0.0725***	0.0771***
Material q	0.0026***	**0.0028*****	0.0005**	0.0007**
Sectorial variables			S3	S3
Time variables	96, 99, 00, 01	**96, 98 99, 00, 01**	96, 99, 00, 01	96, 98, 99, 00, 01
ALM (N) (Var(u)=0)	23.20***	23.20***	28.12***	28.12***
ALM (rho=0)	21.72***	21.72***	17.27***	17.27***
Pesaran (no sample corr.)	1.482	1.482	1.713*	1.713*
BIC	-1430.03	-1591.24	-1422.75	-1587.31
CDT	0.0270	0.0244	0.0336	0.00264
Wald	41.76***	70.63***	37.81***	58.18***
$I_2 = 0$				
Constant	0.0729***	0.0781***	0.0747***	0.077***
Material q	0.0026***	0.0028***	0.0005	0.0007**
$\mathbf{K_2 / K_1}$	0.0004	-0.0054	0.0068	-0.0017
Time variables	96, 99, 00, 01	96, 98 99, 00, 01	96, 99, 00, 01	96, 98, 99, 00, 01
ALM (N) (Var(u)=0)	23.12***	23.12***	27.70***	27.70***
ALM (rho=0)	21.26***	21.26***	17.05***	17.05***
Pesaran (no sample corr.)	1.432	1.432	1.689*	1.689*
BIC	-1422.00	-1584.48	-1419.26	-1580.42
CDT	0.0324	0.0279	0.0353	0.0312
Wald	41.80***	70.97***	32.51***	57.92***

We also see that, when independently considering investment in material assets, the fixed time effects from 1996 to 2001 (except for 1997) are significant and positive. This is significant if we consider that the period of analysis considered in the data panel corresponds to the end of one (1991 to 1994) and the beginning of another economic cycle (from 1994 on), which, in 2001, had already shown signs of the deceleration which became evident in 2002. The fixed time effects show that firms reacted to the upwards cycle by increasing their investment in material assets.

The fact that investment in material assets is independent from immaterial investment shows that firms can first calculate their desired investment in material assets and then include this information to calculate their investment in immaterial assets. The results of this possibility are included in table 4 under the *"known I_1"* heading.

Table 4 shows that the independence of material from immaterial assets during investment decisions is not mutual, as immaterial investment does consider the existence of material assets in the firm. Specifically, the estimation with the lower BIC and best goodness considers the shadow price which determined material investment two years earlier[16]. This appears to confirm the idea than immaterial assets respond to the existence of material assets in a slow accumulation process, which is consistent with the results obtained by Chiao (2002) and Jong (2007).

Table 4 : Immaterial assets model

$\hat{\lambda}_{1,t} = \mu\lambda_{1,t-2} + \varepsilon_t$				
Variable	**M1** **Q_t** **Rho_i =0.385**	**M2** **Q_t** **Rho_i**	**M3** **Q_{t-1}** **Rho_i =0.401**	**M4** **Q_{t-1}** **Rho_i**
Constant	0.696***	1.2080***	0.6818***	**1.3922*****
Immaterial q	0.0026***	0.0031***	0.0075***	**0.0077*****
K_1 / K_2	0.0106***	0.0098***	0.0059***	**0.0044*****
I_1 / K_2	0.1228***	0.0172***	0.0021	**0.0044*****
ALM (N) (Var(u)=0)	0.39	0.39	0.06	**0.06**
ALM (rho=0)	11.71***	11.71***	16.23***	**16.23*****
Pesaran (no sample corr.)	0.1	0.1	0.5	**0.5**
BIC	2990.51	2884.11	2517.19	2394.62
CDT	0.0273	0.0209	0.0158	**0.0154**
Wald	341.23***	687.56***	4537.76***	2606.14***
$\lambda_{1,t} = 0$				
Constant	1.6141***		1.5765	3.6247***
Immaterial q	0.0072***		0.0099***	0.0107***
Sectorial variables			S15	
Time variables			1998	1999,2000,2001
ALM (N) (Var(u)=0	0.62		1.25	1.25
ALM (rho=0)	1.95		17.63***	17.63***
Pesaran (no sample corr.)	0.1		16.65***	16.65***
BIC	3462.15			
CDT	0.0237		0.0402	0.0203
Wald	123.03***		839.87***	742.92***
$I_1 = 0$				
Constant	0.7338***	1.3771***	0.8141***	1.4788***
Immaterial q	0.0025***	0.0028***	0.0048***	0.0059***
K_1 / K_2	0.0114***	0.0113***	0.0075***	0.0062***
ALM (N) (Var(u)=0	2.26***	2.26***	2.47***	2.47***
ALM (rho=0)	24.39***	24.39***	19.61***	19.61***
Pesaran (no sample corr.)	0.195	0.195	0.292	0.292
BIC	3026.86	2934.38	3046.97	2949.09
CDT	0.0257	0.0212	0.0242	0.0233
Wald	2778.36***	494.38***	335.26***	375.74***
Known I_1				
Constant	0.6324***	1.1612***	0.6493***	1.279***
Immaterial q	0.0023***	0.0022***	0.0038***	0.0036***
K_1 / K_2	0.0958***	0.0928***	0.0749***	0.0065***

[16] Within this scenario, the best estimation corresponds to lagged q and the consideration of an individual autocorrelation coefficient for each firm.

I_1 / K_2	0.0404***	0.0549***	0.0354***	0.0444***
ALM (N) (Var(u)=0)	1.9**	1.9**	1.18	1.18
ALM (rho=0)	7.95***	7.95***	10.99***	10.99***
Pesaran (no sample corr.)	0.014***	0.014***		
BIC	2782.78	2708.34	2784.59	2695.79
CDT	0.0301	0.0231	0.0299	0.0238
Wald	277.09***	475.81***	290.30***	389.57***

The results show that the value of the constant is more than one, whereas the coefficient accompanying the lagged q^G-immaterial is small. This appears to show that, in spite of the high adjustment costs involved, the fixed annual growth rate of these assets is very high, corresponding with the global investment behaviour of firms during the years studied, in which several studies show that firms made investments which considerably increased their immaterial assets.

With regards to the variables representing the material assets, we see that they have a positive and significant effect on immaterial investment. When we analysed the theoretical model, however, we expected material investment to have a negative effect on investment in material assets. The explanation could be found in Cummins and Dey (1998), who contemplate an investment function analysing the effect of joint investment in two different types of capital assets on adjustment costs. These authors observe that the crossover effects of the joint investment are positive, showing that there is a decrease in the adjustment costs of joint vs independent investment.

But comparing the coefficients of the variables, we see that in immaterial asset investment decisions, the effect of investment in material assets and the capital ratio is the same. This appears to show that firms are not evaluating material investment in itself, but in relation to the increase it causes in the firm's tangibility. This result deters the idea of scope economies on investment put forward by Cummins and Dey (1998) in favour of theories that there is an interrelationship between a firm's investment in immaterial assets and its material stock (Dunne, 1994; Chauvin and Hirschey, 1994; Galende and Suárez, 1998; Webster, 2002).

5. Conclusions

With the primary objective of determining the elements on which business investment in productive (material and immaterial) assets depends, we performed an empirical analysis considering that firms' assets comprise three groups: material, immaterial and liquidable assets which are heterogeneous in relation to creation of value. This analysis was motivated by Wildasin (1984), who shows that when there are multiple heterogeneous capital assets, the conditions established by Hayashi (1982) for perfect substitution between the mean q observed on the market and the marginal q of each asset are not met.

The study is based on one investment mode for material and another for immaterial assets, based on a joint maximisation model based on the neoclassic theories according to which a firm's objective is to maximise its market value. Assuming that liquidable assets have a shadow price of one, we obtain investment models in which decisions to invest in material (immaterial) assets depend on investment decisions related to immaterial (material) assets, together with the firm's degree of intangibility (tangibility).

The results obtained, however, show that whereas investment in immaterial assets does depend on variables related to the firm's material assets, investment decisions concerning material assets are not significantly affected by variable related to immaterial assets.

We see that investment decisions concerning material assets depend significantly and positively on the material q, in which liquidable assets reduce the numerator while not increasing the denominator, as would be the case when considering the firm's total assets. As a result of this, the adjustment costs of the material assets fall relative to those observed in prior papers, as occurs in Cummins and Dey (1998) when they separate a firm's investment decisions into structures and equipment. None of the variables related to immaterial assets is significant.

With regards to the variables which determine investment in immaterial assets, we see a positive and significant effect of the immaterial q variables, investment in material assets and accumulated capital stock in material assets (these last two variables weighted by the firm's immaterial capital stock). These results would justify the adaptation of the ad hoc models used in the literature, in which investment in immaterial assets depends on material asset investment variables, on the firm's degree of tangibility or intangibility or on its size. However, the estimation with better goodness of fit considers a two-year adaptation period, so the relevant variable is not the material investment made in the period, but two years earlier. This is consistent with the results obtained in models studying Granger's causality between these two variables. The effect of investment in material assets on investment in immaterial assets, however, is of the opposite sign as shown by the theoretical model, as material asset investment was expected to discourage investment in immaterial assets. The results appear to show that one possible explanation is related to the fact that investment in material assets is seen as a way to increase a firm's degree of tangibility.

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