Complementary Assets and Investment Decisions[1]

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ABSTRACT: This paper analyzes which simultaneous crossover effects among tangible, intangible and current assets affect investment and disinvestment decisions on tangible and intangible assets. Controlling for non-convexity and irreversibility effects, we analyze investment and disinvestment over 1,044 firm year observations of Spanish firms. The results show interrelations among tangible and intangible assets affecting their investment and disinvestment decisions, a different effect of current assets on investment and disinvestment, and the existence of lumping investment. The main contribution is the control for miss-specification biases since all the effects are considered together.

KEYWORDS: Investment models, complementarities, Tobin's q, tangible intangible and current

Introduction

Penrose (1959) argues that resources are seldom valuable in isolation, so it may be more fruitful to consider combinations of resources. By combining resources, firms may be able to add value if those resources are: complementary (Harrison et al, 1991), related (Dierickx and Cool, 1989) or co-specialized (Lippmand and Rumelt, 2003) in nature. The concepts of complementarities, relatedness and co-specialization all address the issue of how resources combinations can create value (Lockett, Thompson and Morgenstern, 2009). Within this framework, Dierickx and Cool (1989) highlight the importance of asset interconnectedness for the resource accumulation process. Using their terminology, asset interconnectedness implies that the cost of adding an increase of resource A to the firm's stock may be related to its existing stock of resource B

The economical perspective of complementary assets is introduced by Milgrom and Roberts (1990, 1995), so it is economics that groups most of the theoretical and empirical research on complementarities among firm activities, assets and actions. But complementarities are also an important branch of business literature. The idea of interrelated tangible and intangible assets affects fields as varied as information and communication technologies investment (Brynjolfsson et al 2002; Milgrom and Roberts, 1990), internationalization decisions (Delgado et al, 2004), the use of innovations (Teece, 1987; Stieglitz and Heine, 2007), and R&D investment decisions (Chauvin and Hirschey, 1994; Lev, 1999). None of these studies, however, determine the impact of such interrelations on investment models. Indeed, this fact is not considered on the traditional investment model, that does not even recognize the heterogeneity among the assets of the firm. Usually researches have studied the effect of complementary assets on investment through ad-hoc models or Granger causality analysis (Schumpeter, 1942; Bernstein and Nadiri, 1984; Chiao, 2002; de Jong, 2007).

Although complementarities are usually considered as something positive, they might have two opposing implications on investment. On the one hand, they might reduce a firm's investment costs (Dierickx and Cool, 1989). On the other hand, they might lead to limited factor mobility (Teece, 1987). Yet, recent studies (Jacobides et al, 2006) show that complementarities do not necessarily limit mobility. In fact, extensive literature shows that complementarities enhance innovation because they enable innovative firms to capture innovation rents (Rothaermel and Hill, 2005). Moreover, the opportunities for synergy between a firm's tangible and intangible assets seem to increase with the size and scope of its intangible assets (Ushijima, 2009). This might imply a positive effect of interconnectedness.

The reasons for which current assets affect investment is neither clear in literature. If companies are subject to financial constraints, availability of current assets would favor investment, but also disinvestment, since in both cases it would provide the firm with the necessary resources at a lower price than the market would. Such argument is the same when it is considered that companies are paying certain cost due to the existence of hidden information. However, Jensen (1986, 1989) proposes the possibility that managers undertake over-investment or, due to the same reasons, are not willing to disinvest. Vogt (1994, 1997) and Vogt and Vu (2000) studios emphasize similar conclusions and support the existence of over-investment behavior in companies.

We propose current assets to have a positive effect on the investment decisions of both tangible and intangible assets. Such approach is supported on previous works in which it can be observed that investment in productive assets, both tangible and intangible ones, depends on the firm's available cash flow (Schiantarelli ,1996; Hubbard, 1998; Bloom et al ,2007). We consider that this effect represents an interconnection between current assets and tangible and intangible ones[2].

Interconnectedness among assets implies that the part of the investment value due to complementarities can not be recovered. Studies of costly reversible investments address this circumstance. For instance, Cooper et al (1999) and Cooper and Haltiwanger (2006) among others argue that non-convexity and irreversibility play a central role in the investment process. Abel and Eberly (1996, 2002) and Asano (2002) also show that when an investment is totally or partially irreversible, investment and disinvestment policies do not follow a continuous functional pattern. Following Abel and Eberly (1994, 1996) we consider that investment function divides into three possible stages: investment, inactive, and disinvestment.

That way, the interest of the present paper is two-fold: (1) without the need of a-priory assumptions that might bias the results, we analyse which simultaneous crossover effects among tangible, intangible and current assets affect investment and disinvestment decisions on tangible and intangible assets and (2) we control for non-convexity and irreversibility effects on investment.

The paper is structured as follows. In the second section we present the model to be estimated. In the third section we describe our sample data, variable constructs and methodology. We present the results of our test in the fourth section. Fifth section closes with a discussion of our findings.

Model Presentation

In order to study interconnectedness among tangible, intangible and current assets, we use Pastor's et al (2010) investment model. They propose the following investment model for a firm with n heterogeneous and complementary assets:

$$\frac{I_{1,t}}{K_{1,t-1}} = \beta_0 + \beta_1 (q_{1,t} - 1) + \sum_i (\alpha_{1i} + \alpha_{2i}) \frac{K_{i,t-1}}{K_{1,t-1}} + \sum_i \alpha_{3i} \frac{I_i}{K_{1,t-1}} + \sum_i \alpha_{4i} \sum_j c_{ij} \frac{K_{j,t-1}}{K_{1,t-1}} \qquad (2)$$

with i from 2 to n and i≠j, $q_{j,t} = \frac{V_t}{p_{j,t}(1-\delta_j)K_{j,t-1}}$, where V_t is the market value of the firm, $K_{j,t-1}$ represents the capital stock of the asset j in the moment t-1, $I_{i,t}$ represents the investment to be made in the asset j in the moment t and c_{ij} stands for the relationship between asset i and asset j in such a way that it represents the savings (or the extra costs if the effect is a hold up one) in the adjustment costs function of asset i derived from the existence of j asset stock. Coefficients are specified as:

1. $\beta_0 = a_1$

2. $\beta_1 = \frac{1}{b_1}\frac{p_1}{g}$

3. $\alpha_{1i} = \frac{1}{b_1} c_{i,1}$

4. $\alpha_{2i} = \frac{1}{b_1}\left(\frac{1-\delta_i}{1-\delta_1}\right)\left[a_i b_i - \frac{p_i}{g}\right]$

5. $\alpha_{3i} = -\frac{b_i}{b_1}\left(\frac{1-\delta_i}{1-\delta_1}\right)$

6. $\alpha_{4i} = \frac{1}{b_1}\left(\frac{1-\delta_i}{1-\delta_1}\right)$

where b_j and a_j represent the parameters of the traditional adjustment costs function, p_i is the input price, g the output price and, δ_i the depreciation rate.

We select this model considering the way in which Pastor et al (2010) introduce the effect of complementarities on the investment cost function. These authors propose that the adjustment-cost for investment on j (Γ_j) takes the following form:

$$\Gamma_j = \frac{b_j}{2}\left(\frac{I_j}{K_j} - a_j\right)^2 K_j - \sum_i c_{ij} I_j \frac{K_i}{K_j} \qquad \text{for all j and } i \neq j \qquad (2)$$

The first term of the equation, is the common one on investment literature. The second term of the equation gathers the increase or decrease in the adjustment costs derived from the relationship (c_{ij}) and the proportion (K_i / K_j) existing among asset j and the others. When c_{ij} is positive, the effect of interrelations is positive, and the adjustment-cost function shows that adjustment costs from investment on asset j will diminish proportionally to the accumulated capital stock of asset i. When c_{ij} is negative, the effect of interrelations is negative, and it points out that adjustment costs of asset j will increase with the stock of asset i. That is, on the model proposed by Pastor et al (2010) c_{ij} represents asset interconnectedness as defined by Dierickx and Cool (1989).

We make three assumptions to adapt the model for n assets to our needs. We consider that while tangible and intangible assets are capital goods, we consider that current assets are not productive and not subject to adjustment costs. Regarding tangible and intangible assets and taking into account their different productivity rates, taxes application, depreciation rates, technical progress rates, risk sensibility and the flexibility on their use, we consider that tangible and intangible assets are heterogeneous. So, we assume (a) that the firm's assets cluster on three main groups: tangible, intangible and current assets, (b) that the shadow price of current assets is one, so there are no adjustment costs for them and (c) that investment or disinvestment is only possible on tangible and intangible assets.

Introducing assumptions (a) and (c) on equation (1), investment on tangible assets is:

$$\frac{I_{1,t}}{K_{1,t-1}} = \beta_0 + \beta_1(q_{1,t} - 1) + (\alpha_{12} + \alpha_{22} + \alpha_{43} * c_{32})\frac{K_{2,t-1}}{K_{1,t-1}} + (\alpha_{13} + \alpha_{23} + \alpha_{42} * c_{23})\frac{K_{3,t-1}}{K_{1,t-1}} + \alpha_{32}\frac{I_{2,t}}{K_{1,t-1}} \qquad (3)$$

where sub-indices 1, 2, and 3 denote, respectively, tangible, intangible, and current assets. From equation (3), taking into account that any c_{i3} represents a saving or extra cost for investing on current assets and so it is null (assumption b), and recognizing the possibility of lumpy investment, we obtain the following investment function for tangible assets:

$$\frac{I_{1,t}}{K_{1,t-1}} = \begin{cases} \beta_0 + \beta_1(q_{1,t}-1) + \beta_2 \frac{K_{2,t-1}}{K_{1,t-1}} + \beta_3 \frac{I_{2,t}}{K_{1,t-1}} + \beta_4 \frac{K_{3,t-1}}{K_{1,t-1}} & q_{1,t} > q^1_{sup} \\ 0 & q^1_{inf} < q_{1,t} < q^1_{sup} \\ \beta'_0 + \beta'_1(q_{1,t}-1) + \beta'_2 \frac{K_{2,t-1}}{K_{1,t-1}} + \beta'_3 \frac{I_{2,t}}{K_{1,t-1}} + \beta'_4 \frac{K_{3,t-1}}{K_{1,t-1}} & q_{1,t} < q^1_{inf} \end{cases} \quad (3)$$

Where $q_{1,t} = \frac{V_t}{p_{1,t}(1-\delta_1)K_{1,t-1}}$. The stretches of the function of investment in tangible assets are determined by the existing relation between $q_{1,t}$ and the limits of each of the regions; q^1_{sup} denotes the minimum value at which firms invest on tangible assets while q^1_{inf} denotes the maximum value at which firms disinvest on tangible assets. When q_1 is between both reference values, firms will not invest nor disinvest on tangible assets. Coefficients are[3]:

$$\beta_0 = a_1 \qquad \beta_1 = \frac{1}{b_1}\frac{p_1}{g} \qquad \beta_2 = \frac{1}{b_1}c_{21} + \frac{1}{b_1}\left(\frac{1-\delta_2}{1-\delta_1}\right)\left[a_2 b_2 - \frac{p_2}{g}\right] + \frac{1}{b_1}\left(\frac{1}{1-\delta_1}\right)c_{32}$$

$$\beta_3 = -\frac{b_2}{b_1}\left(\frac{1-\delta_2}{1-\delta_1}\right) \qquad \beta_4 = \frac{1}{b_1}c_{31} - \frac{1}{b_1(1-\delta_1)}$$

The effects of interconnectedness on the model are: (1) Investment on tangible assets will increase with c_{21} [β_2] and c_{31} [β_4] (decrease if they are negative). These items represents the extra saving on adjustment costs of tangible assets when they are interconnected with intangible and current assets (respectively). The effect will be proportional to the ratio of intangible and current assets (respectively) over tangible assets. (2) Investment on tangible assets will increase with c_{32} [β_2] (decrease if negative). This item represent the extra saving on adjustment cost of intangible assets when they are interconnected with current assets. This item multiplies the proportion of intangible assets over tangible assets.

Following the same steps, the investment function for intangible assets is:

$$\frac{I_{2,t}}{K_{2,t-1}} = \begin{cases} \gamma_0 + \gamma_1(q_{2,t}-1) + \gamma_2 \frac{K_{1,t-1}}{K_{2,t-1}} + \gamma_3 \frac{I_{1,t}}{K_{2,t-1}} + \gamma_4 \frac{K_{3,t-1}}{K_{2,t-1}} & q_{2,t} > q^2_{sup} \\ 0 & q^2_{inf} < q_{2,t} < q^2_{sup} \\ \gamma'_0 + \gamma'_1(q_{2,t}-1) + \gamma'_2 \frac{K_{1,t-1}}{K_{2,t-1}} + \gamma'_3 \frac{I_{1,t}}{K_{2,t-1}} + \gamma'_4 \frac{K_{3,t-1}}{K_{2,t-1}} & q_{2,t} < q^2_{inf} \end{cases} \quad (2)$$

Where $q_2 = \frac{V_t}{p_{2,t}(1-\delta_2)K_{2,t-1}}$. The stretches of the function of investment in intangible assets are determined by the existing relation between $q_{2,t}$ and the limits of each of the regions; q^2_{sup} denotes the minimum value at which firm invest on intangible assets while q^2_{inf} denotes the maximum value at which firm disinvest on intangible assets. When q_2 is between both reference values, the firm will not invest nor disinvest on intangible assets. Coefficients are:

$$\gamma_0 = a_2 \qquad \gamma_1 = \frac{1}{b_2}\frac{p_2}{g} \qquad \gamma_2 = \frac{1}{b_2}c_{12} + \frac{1}{b_2}\left(\frac{1-\delta_1}{1-\delta_2}\right)\left[a_1 b_1 - \frac{p_1}{g}\right] + \frac{1}{b_2}\left(\frac{1}{1-\delta_2}\right)c_{31}$$

$$\gamma_3 = -\frac{b_1}{b_2}\left(\frac{1-\delta_1}{1-\delta_2}\right) \qquad \gamma_4 = \frac{1}{b_2}c_{32} - \frac{1}{b_2}\left(\frac{1-\delta_1}{1-\delta_2}\right)$$

The effects of interconnectedness on the model are: (1) Investment on intangible assets will increase with c_{12} [γ_2] and c_{32} [γ_4] (decrease if they are negative). These items represents the extra saving on adjustment costs of intangible assets when they are interconnected with tangible and current assets (respectively). The effect will be proportional to the ratio of tangible and current assets (respectively) over intangible assets. (2) Investment on tangible assets will increase with c_{31} [γ_2] (decrease if negative). This item represent the extra saving on adjustment cost of tangible assets when they are interconnected with current assets. This item multiplies the proportion of tangible assets over intangible assets.

Research Methodology

Sample description and measurement of the variables

The study is undertaken on a sample of 87 non-financial companies which have been listed in the Spanish stock markets during the period 1991–2002, dealing with a balanced panel that includes 1,044 observations.

Firm accounting data have been obtained from the reports delivered to the Spanish National Securities Market Commission. Companies' quotation values have been obtained from data published by specialised press. The necessary data to compute price indexes have been obtained from the reports published by the Spanish National Statistics and Accounting Institute. Finally, we use a base of 192 companies – which shape a no-balanced panel from 1961 to 2002 – to undertake the calculus of technical progress and depreciation rates.

In our investment model the dependent variables are investment in tangible and intangible assets in the period *t* regarding capital stock in such assets in the period *t-1* ($I_{i,t}/K_{i,t-1}$). Investment in gross tangible assets (I_1) is calculated as the variation in the sum of the balance item “Tangible Fixed Assets”; investment in gross intangible assets (I_2) is calculated as the variation in the sum of the balance item “Intangible Assets”. Examples of tangible fixed assets include land and buildings, plant and machinery. Examples of intangible assets include goodwill, patents, R&D, IT equipment and trademarks.

The value of tangible assets and intangible assetes (K_i) is calculated at replacement prices following Lindemberg and Ross (1981): $K_{i,t} = K_{i,t-1}\frac{(1+\phi_i)}{(1+\delta_i)(1+\theta_i)} + I_{i,t}$ where $K_{i,t}$ stands for i assets' stock at replacement prices in the period *t*, Φ_i stands for the price index of asset i, δ_i stands for the depreciation rate of asset i and θ_i stands for technical progress of asset i. We make two assumptions: 1) The accounting depreciation rate is an appropriate approximation to economic depreciation; 2) Firms value their stocks according to the average-cost criterion.

To value “Current Assets” we use accounts regarding “financial fixed assets”, “net monetary assets”[4] and “stocks”[5].

Pastor et al (2010) developed the following expression for q_i: $q_i = \frac{V_t}{p_{i,t}(1-\delta_i)K_{i,t-1}}$ where the V_t is the market value of the firm, using the end of the year market stock price.

The study uses dummy sectorial and time variables as control variables to perform the estimations. [6]

Table 1 shows the main statistics on these variables for our sample.

TABLE 1 ABOUT HERE

To distinguish between the effect of the variables when the firm invests and when it disinvests, each explanatory variable vector is divided into two variable vectors: *var-inv*, in which each element equals the initial variable when the firm invests and 0 when the firm divests, and *var-des*, in which each element equals the initial variable when the firm divests and 0 when the firm invests.

Model Testing

On estimations we use Feasible Generalized Least Squares (FGLS), Bera et al (2001) tests, Hausman test and Pesaran (2004) test.

Coefficient of correlation might vary among firms or be unique. We use both options. We also use lagged and temporal q. So we perform four estimations (M1, M2, M3, and M4) for each asset, depending on the assumptions on autocorrelation coefficient and q. M1 and M3 correspond to a common autocorrelation coefficient, and M2 and M4 correspond to a different autocorrelation coefficient for each firm. At the same time, M1 and M2 correspond to the period's q, and M3 and M4 correspond to the lagged q.

After obtaining the coefficients for the variables under the assumption of discontinuous investment, a χ^2 test determines equality constraints. The study then re-estimates the model, considering the equality constraints observed in the test.

BIC criterion compares estimations for models with nested; whenever this is not possible, selection founds on the Theil Inequality Coefficient (TIC) which measures the predictive power.

Results

Tangible-asset investment decisions

To avoid any misspecification problem we use instruments that let us approximate the shadow prices of tangible and intangible assets through an unknown autoregressive structure.

The autoregressive structure analyzes investments in tangible assets over a five-year period by taking into account investments in intangible assets up to five years prior. Each year corresponds to an autoregressive structure of the shadow prices and therefore has a different estimation. The results of the estimation to determine the shadow prices of intangible assets show that the goodness of fit of the tangible-asset investment model is greatest when the shadow price of intangible assets is 0; in fact, the goodness of fit decreases with time. Our results indicate then that a firm's investment in tangible assets is independent from its investments in intangible assets. These results agree with Mairesse and Siu (1984) and with De Jong (2007). Accordingly with these results, we exclude $K_{2, t-1}$ and $I_{2, t}$ variables from the tangibles investment model.

We first estimate the tangible-asset model accepting that the coefficients of the variables determining tangible-asset investment and disinvestment decisions might be different, and we test this assumption using a χ^2 coefficient equality analysis. Table 2 presents the results of the χ^2 test. The results show that the test rejects the hypothesis of equal independent terms. However, the test does not reject the hypothesis of equality of the investment and disinvestment coefficients of q_1 and K_3 variables, with significance values ranging from 1% to 10% depending on the model's characteristics. These results imply that the investment function for tangible assets is not continuous and presents a gap between investment and disinvestment decisions

TABLE 2 ABOUT HERE

These results lead to a new model estimation that introduces the restrictions of equality between investment and disinvestment coefficients of q_1 variable and investment and disinvestment coefficients of K_3 variable. Table 3 shows the new results. The smallest Theil Inequality Coefficient (TIC) corresponds to estimation M2. This implies that the estimation with the greatest goodness of fit is the one that considers the period's $q_{1,t}$ and a different autocorrelation coefficient for each firm.

TABLE 3 ABOUT HERE

Results show that investment function is discontinuous in the constant, indicating the presence of fixed costs for both investment and disinvestment. In absolute terms the value of the constant is greater for investment decisions than for disinvestment decisions.

The coefficient of the variable $q_{1,t}$ is significant and positive. The mean value of $K_{1,t-1} / I_{1,t}$ is 42, so the elasticity of firms' investment in tangible assets relative to $q_{1,t}$ is 0.2. This implies that Spanish firms use 20% of their gains in market value to invest in tangible assets. Although the proportion may seem quite small, movements in *q* usually reflect changes in future rents that are unrelated to current investments (Abel and Eberly, 2005; Lorenzoni and Walentin, 2007). Moreover, in situations in which growth options are important, regressions of investments on Tobin's Q and cash flow generate small positive coefficients for Q.

The coefficient of the variable $K_{3,t-1}/K_{1,t-1}$ is also significant and positive. Since the current assets of firms are always positive -we do not consider bankruptcy firms- the value of this variable is always positive, meaning that current assets foster investment on tangible assets. In the case of disinvestment, the positive value indicates that current assets restrict disinvestment on tangible assets. The mean value of $K_{3,t-1} / I_1$ is 57, so the elasticity of the investment in tangible assets relative to $K_{3,t-1}/K_{1,t-1}$ is 0.2. This suggests that firms invest 20% of their current assets in tangible assets, and that they reduce their disinvestments in tangible assets in 20% of their financial ones.

The results found for current assets are consistent with the management of real options in tangible investment projects. This way, Graham and Harvey (2001) show that firms use part of their financial flexibility (i.e., they preserve debt capacity) to make future expansions and acquisitions. Indeed, financial flexibility is an option in itself. Moreover, real-options theory incorporates the value of the option to wait to make investment decisions (McDonald and Siegel, 1986). This way, when a firm invests, it not only increases its capital stock, it also loses the possibility of waiting for new information that could affect its investment decisions. Thus, real options theory says that it is important to consider the option value of waiting when an investment is irreversible. In turn, the importance of current assets might be related to growth options, which are quite difficult to transmit to the market. According to that, disinvestment decisions might be delayed in situations characterized by uncertainty and costly reversibility if the firm disposes of enough financial resources to keep the waiting-to-disinvest option open.

Intangible-asset investment decisions

As in the tangible assets case we solve misspecification problems using instruments to approximate the shadow prices of tangible and intangible assets. The estimation generating the greatest goodness of fit for intangible assets corresponds with a shadow price for tangible assets represented through a second-order autoregressive process. So, the investment in tangibles variable used to estimate the intangibles model is $I_{1,\, t\text{-}2}$, which is the investment made on tangible assets two years before.

We first estimate the intangible asset model accepting that the coefficients of the variables determining intangible investment and disinvestment decisions might be different, and we test whether this assumption can be refused or not using a χ^2 coefficient equality analysis. Table 4 presents the results of the χ^2 test.

TABLE 4 ABOUT HERE

Results for most estimations show that the function for intangible-asset investment and disinvestment is one and continuous. However, when considering the period's $q_{2,t}$ and an independent autoregressive structure for each firm in the sample (M2), the assumed equality of the effect of tangible assets is rejected. So, we perform the new analysis considering those circumstances.

Table 5 provides the new results. The lowest Theil Inequality Coefficient value – and thus, the greatest goodness of fit estimation- corresponds with lagged $q_{2,t-1}$ and an individual auto-regression coefficient for each firm.

Results confirm that the constant term coefficient is significant, equal and positive for investment and disinvestment decisions on intangible assets. That result implies that although firms can partially invest in intangible assets at no adjustment cost, their disinvestment will always involve a fixed cost. Although the constant value is greater than 1, the mean value of the independent variable is 5.7. So the value of the constant is plausible, thought it implies a really high effort of investing on intangible assets.

TABLE 5 ABOUT HERE

The coefficient of the variable $q_{2,t-1}$ is significant and positive. The mean elasticity of the independent variable $I_{2,\, t}$ /$K_{2,\, t-1}$ relative to $q_{2,\, t-1}$ is 4.09. The value of the constant and the low elasticity of investment in intangible assets relative to the $q_{2,\, t}$ variable seems evidence the efforts of Spanish firms' during the 1990s to increase their investments in intangible assets regardless the Stock Market Valuation. The elasticity of the investment in intangible assets relative to tangible assets reinforces this idea. This elasticity takes a value of 1.1, showing the firms' effort to reduce the gap between their tangible and intangible stocks by proportionally making greater investments in intangible assets, confirming the idea of an attempt to balance the two groups of assets.

The coefficient of the variable $K_{3, t-1}/ K_{1, t-1}$ is also significant and positive. Since the current assets of firms are always positive this implies that possessing such assets fosters investment in, and discourages disinvestment of, intangible assets. The elasticity of investment in intangible assets relative to current assets is 1.9. Again, these results suggest that firms spend most of their investment funds on intangible assets.

Aside from the specific interpretations of the data, these results have global implications. We find that a single investment function determines intangible-asset investment and disinvestment decisions, but some factors alter the effects of the response. In particular, the quantity of firm's tangible assets encourages investment in intangible assets if the market shows an investment movement, but discourages their disinvestment. Likewise, current assets favor greater investments in intangible assets but hinder their disinvestment. Finally, disinvestment in intangible assets is always subject to a fixed cost, implying a cumbersome irreversibility that firms have to deal with.

Discussion and Concluding Remarks

Our aim in this paper is to analyze the effect of existing tangible (intangible) assets over investment and disinvestment decisions on intangible (tangible) assets controlling for the effect of current assets and lumpy investment. Our results are coherent with previous literature.

For tangible assets they show that tangible assets investment or disinvestment decisions do not depend on intangible assets. Tangible assets investment function is discontinuous in the constant, indicating the presence of the fixed costs for both investment and disinvestment. Moreover, current assets foster investment in tangible assets and discourage their disinvestment. This increases the range of inaction, where the investment is null as the firm prefers to "wait and see".

For intangible assets, they show that tangible assets affect investment and disinvestment decisions on intangible assets within a two years lag. There is a single investment function that determines intangible asset investment and disinvestment decisions, but both tangible and current assets favor greater investments on intangible assets while hinder their disinvestment. In addition, disinvestment in intangible assets is always subject to fixed costs, implying a cumbersome irreversibility that firms have to deal with.

Our results also show that current assets foster investment on tangible and intangible assets and discourage their disinvestment. These results are consistent with studies that suggest a degree of irreversibility existing in productive-asset investments (Bertola, 1988), mainly because although acquisition and divestiture are both ways of recombining assets across firms, their implications are different in several respects. Their impact on a firm's assets, which is positive for acquisition and negative for divestiture, is the most obvious. Their impact on cash flow is the second major difference. Although firms acquiring external assets bear upfront costs to obtain future synergy gains, firms selling off assets receive part of the gains in advance and in cash (Stewart and Glassman, 1988). This difference suggests that divestiture is an attractive option, particularly to firms with a strong need to boost short-term cash flows. For this reason, divestment literature traditionally focuses on financially distressed firms (Kruse, 2002). However, divestiture is not always a response to financial health problems. Matsusaka's (2001) theoretical model suggests that financially sound firms divest assets, and often combinations of assets, to maximize synergy gains from innate technological capabilities.

These results are also consistent with the real options theory via the option of waiting to disinvest—an option easily retained if the firm does not need the money from the sale of assets because it has other sources of liquidity (Brennan and Schwartz, 1985; Trigeorgis, 1993). Indeed, the execution of the option to invest or disinvest may imply an extra cost. The existence of real options thus increases the separation between the marginal product of capital that justifies investment and the marginal product of capital that justifies disinvestment. This increases the range of inaction, where investment is 0 as the firm prefers to "wait and see."

On balance, our study finds that complementarities between existing and new assets generate lower adjustment costs, which increase investments. The loss of such complementarities implies greater disinvestment adjustment costs, which leads firms to fail to respond to the market's disinvestment signals. This conclusion combines two perspectives. On the one hand, the different accumulated assets enable firms to develop a series of organizational, technological, or knowledge-based idiosyncratic capabilities that help generate sustainable competitive advantages (Dosi et al, 1990; Teece et al, 1997). On the other hand, the results are consistent with studies claiming that certain assets or routines develop capabilities difficult to replicate so that a firm's historical evolution limits its strategic choices (Collins, 1991). Looking at the attempt to recognize interconnectedness on investment models, our results show (1) that the existing interconnectedness among tangible, intangible and current assets can be analyzed using a Tobin's q based investment model and (2) that interconnectedness is not a symmetrical effect, as previously reported on several papers based on Granger causality. Summing up, this study makes a contribution to the understanding of the relationship among tangible, intangible and current assets in place and the investment in new tangible and intangible ones.

Notes

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[2] Considering that firms might invest on current assets in order to modify future investment on tangible or intangible assets exceeds the aim of this paper.

[3] Note that the expression for the coefficients is the same on investment and disinvestment decisions, although we expect that their values differ.

[4] Understanding net monetary assets as the value of the items "debtors and available" and "short-term financial assets" minored by "short-term debt without explicit cost"

[5] In turn, stocks are valued at replacement prices and calculated as: $EXR_{i,t} = EXC_{i,t} \frac{2P_{s,t}}{(P_{s,t} + P_{s,t-1})}$ where $EXR_{i,t}$ stands for stock at replacement prices for the firm *i* in the period *t*, $EXC_{i,t}$ stands for accounting stocks of the firm *i* in period *t*, and $P_{s,t}$ indicates the price index of the output of the sector *s* to which the firm *i* belongs.

[6] Companies have been classified into 11 sectors following the Organization for Economic Cooperation and Development (OECD) classification. These sectors are mining industries; food products; textile and wood industry; oil, chemicals, rubber and plastics; metal and mechanical products; office machines, computers, radio, television, and communications equipment; electricity, gas and water; construction; trade and repair; transport and communication; Property and business activities (excluding holdings). Time dummy variables comprises 12 years, from 1991 to 2002

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TABLE 1. SAMPLE STATISTICS

VARIABLE	MEAN	STD. DEV
Investment tangibles	138.34	1029
Investment intangibles	57.97	483
Tangible assets	1.38	5434
Intangible assets	69.50	683
Current assets	331.40	1148

TABLE 2. ANALYSIS OF EQUALITY OF COEFFICIENTS OF THE INVESTMENT FUNCTION OF TANGIBLE ASSETS WITH INTERRELATIONS

Estimation / Hypothesis	M1	M2	M3	M4
$\beta_{0,\ investment} = \beta_{0,\ disinvestment}$	353.89	553.18	340.88	575.66
$\beta_{1,\ investment} = \beta_{1,\ disinvestment}$	1.74***	0.14***	0.48***	0.98***
$\beta_{4,\ investment} = \beta_{4,\ disinvestment}$	3.43**	1.35***	5.57**	0.99***
***, ** and * indicates 1,5 and 10% significance level, respectively				

TABLE 3. TANGIBLE ASSETS INTERRELATED WITH FINANCIAL ASSETS ACCORDING TO COEFFICIENT EQUALITY

$I_{1,t}$ / $K_{1,t-1}$	M1 Q t	M2 Q t	M3 Q t-1	M4 Q t-1
Constant $_{investment}$	0.1037***	0.1115***	0.1053***	0.1120***
Constant $_{disinvestmen}$	-0.0766***	-0.0896***	-0.0749***	-0.0909***
q_1	0.0038***	0.0036***	0.0031***	0.0035***
$K_{3, t-1}$	0.0037***	0.0035***	0.0032***	0.0031***
ALM(N) (H_0:Var (u)=0)	3.67***	3.67***	3.62***	3.62***
ALM (H_0: rho =0)	23.04***	23.04***	20.59***	20.59***
Pesaran (H_0: no sample corr.)	1.39	1.39	1.68*	1.68*
BIC	-1696.10	-1855.88	-1691.59	-1852.83
TIC	0.0241	0.0208	0.0256	0.0222
Wald	1156.74	1405.59	1137.46	1408.85
***, ** and * indicates 1,5 and 10% significance level, respectively				

TABLE 4. ANALYSIS OF EQUALITY OF THE COEFFICIENTS OF THE INVESTMENT FUNCTION OF INTERRELATED INTANGIBLE ASSETS

Hypothesis \ Estimation	M1	M2	M3	M4
$\gamma_{0,\ investment} = \gamma_{0,\ disinvestment}$	0.87***	0.93***	1.20***	1.38***
$\gamma_{1,\ investment} = \gamma_{1,\ disinvestment}$	0.36***	0.52***	0.02***	0.06***
$\gamma_{2,\ investment} = \gamma_{2,\ disinvestment}$	3.18***	10.97*	2.08***	3.90***
$\gamma_{3,\ investment} = \gamma_{3,\ disinvestment}$	0.51***	2.71***	0.76***	1.13***
$\gamma_{4,\ investment} = \gamma_{4,\ disinvestment}$	0.65***	1.18***	0.59***	1.84***
$\gamma_{2,\ investment} = \gamma_{2,\ disinvestment}$ under I1 inv	-	1.71***	-	-
$\gamma_{2,\ investment} = \gamma_{2,\ disinvestment}$ under I1 dis	-	0.03***	-	-
$\gamma_{2,\ investment} = \gamma_{2,\ disinvestment}$ under I2 inv	-	9.33	-	-
$\gamma_{2,\ investment} = \gamma_{2,\ disinvestment}$ under I2 dis	-	0.04***	-	-
***, ** and * indicates 1,5 and 10% significance level, respectively				

TABLE 5. INTANGIBLE-ASSET INVESTMENT AND DISINVESTMENT DECISIONS, COEFFICIENTS ACCORDING TO EQUALITY ANALYSIS

$I_{2,t}$ / $K_{2,t-1}$	M1 Q t	M2 Q t	M3 Q t-1	M4 Q t-1
Constant	0.3024*	0.6814*	0.4671*	1.1349*
q_2	0.0020*	0.0025*	0.0059*	0.0053*
$K_{1,t}$ under I_2 inv and I_1 inv	0.0092*	0.0085*	0.0059*	0.0051*
$K_{1,t}$ under I_2 inv and I_1 dis		0.0050*		
$K_{1,t}$ under I_2 dis and I_1 inv		-0.0178**		
$K_{1,t}$ under I_2 dis and I_1 dis		-0.0269		
I1	0.0079*	0.0082*	0.0025	0.0031***
K3	0.0184*	0.0207*	0.0058*	0.0095*
ALM(N) (H_0:Var (u)=0)	1.77**	1.8**	0.37	0.37
ALM (H_0: rho =0)	11.04*	11.3*	13.13*	13.13*
Pesaran (H_0: no sample corr.)	-	0.14	-	-
BIC	2386.34	2314.63	2364.27	2296.28
TIC	0.0252	0.0261	0.0230	0.0220
Wald	1950.02	2945.54	1760.01	1745.68
***, ** and * indicates 1,5 and 10% significance level, respectively				