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IT assets, organization capital and market power: Contributions to business value ☆

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ABSTRACT

How much IT capital contributes to the economic value of firms is a relevant but complex issue, since the contribution may come from different sources that are difficult to separate. In this paper, we model the determinants of the economic value of multi-asset firms with market power when the adjustment costs of investing in IT capital turn into organization capital, increasing the future cash flow of the firm. The resulting valuation equation, new in the literature, has four simultaneous sources of economic value: (i) purchase costs of the assets, (ii) adjustment costs, (iii) organization capital, and (iv) rents from market power. The model is tested with a unique data base from Spanish banks in a time period when these banks invested heavily in IT capital. We find that 54% of the economic value of the representative bank corresponds to the purchase cost of material and immaterial assets, including IT capital. The remaining 46% corresponds to the contributions of: adjustment costs (17%), organization capital (7%) and rents from market power (22%).

1. Introduction

The observed time-increasing gap between the market and book value of firms has been interpreted as evidence of the growing importance of intangible assets for modern firms [10,12,40].[1] The market and book values of firms reached historically high differential levels at the turn of the new century, with the growth of investment in information technology (IT) assets and the diffusion of new business models exploiting this technology [14,18,27,33]. The capitalization of expenses in IT-related assets (mainly software expenses) explained only part of the difference between market and book values, so the conclusion was that there were other, hidden intangible assets, besides IT, that were created when firms invested in computer technology, generally referred to as *organization capital* [16,17]. The study of organization capital tied to IT investments continues to be of broad interest regarding the measurement of the size and profitability of intangible assets.[2] Related to this, management research has examined for many years (with yet inconclusive results) whether IT capital can be a source of competitive advantage and economic rents or, to the contrary, whether IT capital is accessible to all firms, so each firm just earns a competitive return ([19] and [37] for a review).

The market value of a firm can be above the book value for reasons other than having excluded intangibles from the assets reported in balance sheets, as dictated by accounting conventions. One of these is that book values fall behind the replacement cost of the assets, which is the correct economic benchmark for comparison purposes. The other, and probably more important, reason is that firms earn economic rents because of market power [28,44]. Moreover, organization capital has the distinct feature, compared with other intangible assets, that it is produced internally by firms jointly with output, or

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[1] For an update of the debate around the accounting of intangibles, see the collection of papers on the topic in Abacus, 45, September 2009.

[2] The concept of organization capital can be assimilated to Marshall's "third" factor of production, together with labor and capital. Organization capital is viewed as individual (entrepreneur's ability, human capital of workers) or collective (embedded in the organization) knowledge of how to effectively combine inputs to produce output [4,53]. Organization capital would be part of what Holsapple and Joshi [32] refer to as "organizational knowledge resources". Empirical studies on organization capital sometimes look at those organization practices that have been shown to affect the economic performance of firms; Black and Lynch [10] include among such practices: giving voice to the workers, flexibility in work-organization, and investment in training workers. Other papers estimate the organization capital of firms as one component of the total factor productivity in their production function [4,41,54]; yet others obtain the capital from the economic value of the firm [17,18,22]. Finally, Corrado, Hulten and Sichel [21] refer to capital in the form of "firm-specific resources" that resemble organization capital.

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while investing in market-purchased assets[3] and little is known on how to account for this feature of the organization capital in the valuation of firms. Thus, there are reasons to believe that existing models of the determinants of the economic value of firms do not properly identify the multiple sources of value (normal returns to capital invested, growth expectations, economic rents) and their interactions with IT and organization capital. This paper proposes a model of investment for multi-asset firms, including IT and organization capital, and derives a general valuation equation of the firm. Next, the equation is empirically estimated with data from Spanish banks, to examine what have been the sources of value for the banks in the sample during the period of time studied.

The model is based on the existing theory of investment [14,16,22,29,59], where firms make investment, capital stock and output decisions to maximize their value subject to adjustment costs (for example, time and resources spent installing the new equipment, time to train workers on how to use it, interruptions of activity for the reorganization of work, …). These costs (referred to as "time compression diseconomies" in the management-resource based literature [24,51]) make it unprofitable for value-maximizing firms to move instantly from the current stationary equilibrium to the next.

The basic investment theory for the multi-asset firm is extended in this paper in two yet unexplored situations: i) the value-maximizing firm faces a price inelastic demand for the product sold, which gives the firm market power; ii) the adjustment costs incurred in the process of investing in market-purchased assets, especially IT assets, become *valuable* assets (in the sense that they contribute positively to future cash flows) that become part of the organization capital of the firm. We model the ex-ante economic value-maximization problem of a firm with these extensions, and solve for the equilibrium conditions in terms of the economic valuation equation that emerges as an implicit solution of the ex-ante maximization problem. Then, we reconcile our results with the empirical valuation equations used in the literature to model the determinants of the economic value, including papers on IT Business Value.

We find that the valuation equation resulting from the optimal solution of the firm's decision problem depends on the stock of services from the market-purchased assets, on the stock of organization capital built in the investment process and, when the firm has market power, on the revenues from sales of the product. We also find that, in the optimal solution, the marginal return of each asset is equal to its marginal cost, which in turn is equal to purchase price plus the marginal adjustment cost. Finally, the coefficient of the revenues of sales in the valuation equation is equal to the inverse of the elasticity of the demand (absolute value), which in turn is equal to the relative profit margin in the profit-maximizing firm. Therefore, the revenues term in the valuation equation measures the contribution to the firm's economic value of the economic rents resulting from market power.

Our methodology is applied to examine the determinants of the economic value of firms, with data from Spanish banks for the period 1984–2003, when banks invested most heavily in IT capital. Using bank level data, we obtain estimates of the stock of physical capital, advertising capital, IT capital, and financial assets at their replacement cost, for every bank and year. We also obtain an estimate of the stock of human capital from the annual training expenditures reported by banks. We consider that the training expenditures belong to the adjustment costs due to the investment in IT capital. In this case, the expenditures are financing the accumulation of new assets that become part of the organization capital of the bank [10]. Only a few banks in the sample are listed on the stock market, so the fundamental economic value for each bank is estimated as the present value of future forecasted cash flows.

The results support the hypothesis derived from the extensions of the investment model: all market-purchased assets, including IT capital, contribute positively to economic value, as expected. Human capital from training, our observable proxy for the accumulation of organization capital, also contributes positively to the economic value of the banks. Additionally, banks with higher human capital have a lower marginal cost (equal to the marginal return) of IT capital, consistent with our predictions. The measure of revenues from sales has a positive and significant effect on the economic value, indicating the existence of market power from a price-inelastic demand. The empirical results support the notion that advertising capital and the network of branches give banks market power, but we find no evidence of IT contributing to the generation of economic rents. Finally, we are able to decompose the economic value of the representative bank in the contributions from rents that reward the opportunity purchase cost of the market-supplied assets (up to 54%), rents that reward the adjustment cost of growth (17%), the costs of organizational capital (7%) and the rents from market power (22%).

The methodology and results of the paper contribute to the literature on IT and the performance of firms in several ways.[4] With one exception [16], research papers on IT and Business Value [2,3,7,9,16,17,23,55] do not explicitly model the derivation of the empirical valuation equation and we interpret the results in the context of a model of investment for a multi-asset firm. To our knowledge, no other paper jointly models market power and the internal accumulation of organization capital to obtain a general equilibrium valuation function of firms, as we do here. The explicit modeling approach has the advantage that the parameters of the empirical model can be interpreted in the context of the theory. In this respect, the paper provides new insights on the implications of the complementarities between IT and organization capital for their contribution to the economic value of the firm. Additionally, a model of the behavior of firms helps to identify the true endogenous and exogenous variables, and we then use the appropriate econometric technique to avoid biases in the estimation of the parameters. The paper uses a unique data set from banks that is more comprehensive in the modeling and in the empirical analysis than other papers [5,31,57] on IT capital and economic performance of banks. The empirical application provides a novel and detailed calculation of the sources of economic value for the banks in the sample.

The rest of the paper is organized as follows. Section 2 presents the valuation equation to be estimated with the new results from the two extensions. Section 3 contains the empirical analysis of the determinants of the economic value of Spanish banks, illustrating the framework proposed in the paper to separate the contribution to economic value of adjustment costs and intangibles, and the contribution of rents from market power. Section 4 presents the main conclusions and implications of the paper.

[3] Atkenson and Kehoe [4] define organization capital as "a firm-specific capital good *jointly produced* with output and embodied in the organization itself" (emphasis added). This definition is widely accepted in the literature [22,41]. Brynjolfsson and Yang [16] claim that to make computers fully productive, firms build-up complementary, value-creating resources, in the form of "organization capital" (new ways of organizing production, training, motivating and empowering workers,…). Other sources of organization capital as a spill-over from production activities include: the "human capital" from training new managers as firms increase in size and in coordination needs (Penrose [52]); learning by doing (Rosen [56]); the accumulation of knowledge on the characteristics of employees, facilitating more appropriate job placement (Prescott and Visscher [53]); the accumulation of firm specific human capital [6,35].

[4] We limit the references to papers that use the economic value of the firm, or profits, as a performance variable because this paper uses the economic value of the firm as the measure of performance; a complete analysis of the contribution of IT to firms' performance would also include a long list of papers that use output growth and productivity as the performance variable (see [9,37,43]).

2. Theory of investment and economic value of the multi-asset firm

2.1. The model of the firm

Consider a firm that decides in t how much to invest in each type of the N different market-purchased capital goods, $I_t = (I_{1t}, I_{2t}, \ldots, I_{Nt})$. The firm holds a stock of market-purchased capital services at the beginning of the period t, $K_{t-1} = (K_{1t-1}, \ldots, K_{Nt-1})$ that changes over time as the result of new investments and the depreciation of old ones,

$$K_{j,t+s} = \left(1-\delta_j\right)K_{j,t+s-1} + I_{j,t+s};\ \mathrm{j} = 1,\ldots,\ \mathrm{N} \quad s>0 \tag{1}$$

where δ_j is the depreciation rate of capital asset j.

To make the new invested assets fully productive, the firm incurs adjustment costs according to the cost function,

$$C(K_s, I_s) = \sum_j C_j\left(K_j, I_j\right) = \sum_j p_j \frac{b_j}{2}\left(\frac{I_j}{K_j} - a_j\right)^2 K_j \tag{2}$$

where b_j is a positive (cost) parameter, a_j is the stationary investment rate for which the adjustment costs are zero (in general equal to δ_j, the depreciation rate), and p_j is the purchase price of asset j.

Let M_j be the stock of intangible assets resulting from the expenditures in the form of adjustment costs associated with market-purchased asset j. The stock M_j will vary over time as the net result of depreciation and the flow of new intangibles from the current expenses in adjustment costs, C_j:

$$M_{jt} = \left(1-x_j\right)\cdot M_{j,t-1} + f\left(C_{jt}\right) j = 1,\ldots,M \tag{3}$$

where x_j is the depreciation rate of the intangible assets and $f\,(C_{jt})$ is the flow of intangibles produced with the adjustment costs incurred in period t, which in turn depend on I and K (from Eq. (2)).

Let $\Pi\ (K_s, M_s, I_s, e_s)$ be the net cash flow of the firm in period s as a function of the stock and the investment flow of the assets in the period, and of the random productivity shock e_s, once the variable production inputs (for example labor) are optimized. This function will then have three separate components: gross revenues from operations, adjustment costs, and the outlay from the current market-purchased assets[5]:

$$\Pi(K_s, M_s, I_s, e_s) = R(K_s, M_s, e_s) - C(K_s, I_s) - \sum_j p_{js} I_{js} \tag{4}$$

Gross revenue is in turn equal to the price times the quantity of product sold, $R(\cdot) = p(Q(K_s, M_s))\cdot Q(K_s, M_s)$ where the price is non-increasing with the quantity sold (i.e. firms can have market power); p_{js} is the current market purchase price of one unit of capital asset j, and $C(.)$ is given by Eq. (2).

The economic value of the firm in period t, V_t, will be equal to the present value of expected future cash flows,

$$V_t = E_t\left\{\sum_{s=t}^{\infty} \beta_s^t \cdot \Pi(K_s, M_s, I_s, e_s)\right\} \tag{5}$$

where E_t is the expectations operator, conditional on the information available at the beginning of period t, and $\beta^t{}_s$ is the discount factor.

The optimization problem of the firm is to choose I, K and M such that V_t is maximized and subject to constraints (1) to (4). The solution to this problem, under the assumption of linear homogeneous cash-flow function $\Pi(K_s, M_s, I_s, e_s)$, is presented in Appendix A. From this solution, the economic value of a firm, assuming that all market-purchased assets can contribute to organization capital, is given by (all variables at their optimal values):

$$V_t = \sum_j^M \lambda_{jt}\left(K_{jt} - I_{jt}\right) + \sum\nolimits_j z_{jt} M_{jt} + \sum_{s=t}^{\infty} \beta_s^t \frac{1}{\varepsilon} p(Q(K_s, M_s))\cdot Q(K_s, M_s). \tag{6}$$

The weight λ_{jt} is the marginal return in terms of contribution to the economic value of the firm of one additional unit of stock of market-purchased asset j. The weight z_{jt} is the marginal return of one additional unit of organization capital from asset j. In the optimal solution, the marginal return is equal to the full marginal cost of the asset determined by the model: $\lambda_{jt} = p_{jt} + C'_{Ijt} - z_{jt} f'_{C_{jt}} C'_{Ijt}$. The marginal cost includes the purchase market price of one unit of asset, p_{jt}, the marginal adjustment cost arising from the new investment, C'_{Ijt}, and the marginal contribution to the economic value from the built-in intangible assets, $z_{jt} f'_{C_{jt}} C'_{Ijt}$, this last with negative sign, since its contribution to value is to reduce the effective marginal cost. One unit of new investment requires expenditures in adjustment cost equal to C'_{Ijt}, which in turn will generate $f'_{C_{jt}}$ units of intangible asset whose shadow price is equal to z_{jt}. Finally, $(K_j - I_j) = (1\text{-}\delta_j)K_j$ is the stock of the market-purchased asset j at the beginning of the period, and M_j is the corresponding stock of intangibles built in the process of making asset j fully productive.

The parameter ε is the absolute value of the price elasticity of demand, which can be constant or vary over time, and β_s^t is the discount factor used in the present value calculation. In the period-by-period profit-maximizing solution, the firm with market power sets the relative difference of output price p and marginal cost mc equal to the inverse of the price elasticity of demand ($\frac{p-mc}{p} = \frac{1}{\varepsilon}$). Therefore, the component

$$\sum_{s=t}^{\infty} \beta_s^t \tfrac{1}{\varepsilon} p(Q(K_s, M_s))\cdot Q(K_s, M_s) = \quad = \sum_{s=t}^{\infty} \beta_s^t (p(Q(K_s, M_s)) - c_s)\cdot Q(K_s, M_s)$$

gives the present value of the excess of revenues over the full average cost c (equal to marginal cost under the assumption of the model); that is the present value of the economic profits (rents) of the firm.

2.2. Related literature

The theory of investment for the multi-asset firm has solved the value-maximization problem of the firm, assuming that adjustment costs do not generate valuable intangible assets ($z_{jt} = 0$) and that the firm does not have market power ($\varepsilon_s = \infty$). Now Eq. (6) would be $V_t = \sum_j \lambda_{jt}(K_{jt} - I_{jt}) = \sum_j \left(p_{jt} + C'_{Ijt}\right)(K_{jt} - I_{jt})$, as in [14,16,17,22].

When firms have market power, but the adjustment costs are zero ($C'_{Ij} = 0; \forall j$), Eq. (6) becomes $V_t = \sum_j p_{jt}(K_{jt} - I_{jt}) + \sum_{s=t}^{\infty} \beta_s^t \frac{1}{\varepsilon_s} p(Q(K_s, M_s))\cdot Q(K_s, M_s)$, so the economic value is now equal to the current purchase cost of the assets plus the present value of the rents from market power (see [28,44], and [36] for the particular case of banks).

With no market power ($\varepsilon_s = \infty$) and no adjustment costs ($C'_{Ij} = 0$), the economic value of the firm from the value-maximizing decisions will be equal to the market purchase cost of the assets at the beginning of the period $V_t = \sum_j p_{jt}(K_{jt} - I_{jt})$. Then, under no adjustment costs and perfectly competitive product markets, the economic value of the firm is just equal to the current purchase cost of the market-supplied assets [27].

When the marginal adjustment cost is positive (the current investment rate is different from the stationary rate) and the adjustment costs do not generate valuable intangible assets ($z_j = 0$), the economic value of the firm in a competitive market (no market power) is expected to be equal to the current purchase cost of the market-supplied assets,

[5] Martín-Oliver and Salas-Fumás [45] contain a static model of the banking firm and a complete description of the profit function and production technology of banks, compatible with the synthetic cash flow function used in this paper.

plus the expected costs incurred in installing and making these market-purchased assets productive, $V_t = \sum_j \left(p_{jt} + C'_{Ijt}\right)(K_{jt} - I_{jt})$. The economic value of the firm will be higher than the purchase cost of the market-supplied assets (the difference is equal to the present value of adjustment costs) $V_t - \sum_j p_{jt}(K_{jt} - I_{jt}) = \sum_j C'_{Ijt}(K_{jt} - I_{jt})$. This difference is sometimes used as a measure of the growth opportunities of the firm [39].

If adjustment costs provide firms with valuable intangible assets, then the valuation equation with no market power would be:

$$V_t = \sum_j \left(\left(p_{jt}\left(K_{jt} - I_{jt}\right) + C'_{Ijt}\left(K_{jt} - I_{jt}\right) + z_{jt}\left(-f'_{C_j} C'_{Ijt}\left(K_{jt} - I_{jt}\right)\right) + z_{jt} M_{jt}\right)\right) \tag{7}$$

The term $z_j M_j$ is the contribution of the organization capital to the economic value of the firm and $z_j(-f'_{C_j} C'_{Ijt}(K_{jt} - I_{jt})$is the cost of the investment, since z_j satisfies the condition of marginal value equal to marginal cost.

Brynjolfsson, Hitt and Yang [17] postulate and estimate the valuation equation model $V_t = \sum_j v_{jt}(K_{jt} - I_{jt})$ considering that the intangibles M_{jt} from IT capital are an omitted variable correlated with the observable stock of IT. According to our results, if the adjustment costs become valuable intangible assets, the relevant omitted variable is the difference between the value and the cost $(-f'_{C_j} C'_{Ijt}(K_{jt} - I_{jt}) + M_{jt})$. Under perfectly competitive markets, it is expected that the value and the cost of intangibles will be equal. Then, if the contribution of intangibles to the economic value of the firm is higher than their production cost, it is because intangible assets are contributing to the market power of the firm, under the assumptions of the model. Whether this is the case, is an empirical question that will be addressed for all the assets of the banks.[6]

3. Application to the Spanish banking industry

3.1. Database and variables

The valuation equation will be estimated with data form Spanish commercial and savings banks in the period 1984 to 2003. In Spain, banking has long been an unregulated industry and monopolistic competition among product-differentiated banks (with price and non-price competition variables) has been proven to be a realistic assumption about the market structure of Spanish retail banking [45]. The commercial and saving banks in the sample represent 89.25% of the total banking assets in Spain in 2003 (the rest are credit cooperatives and branches of foreign banks). The primary data come from the reports submitted to Banco de España by Spanish banks (balance sheets, income statements, and complementary notes) at the non-consolidated level. These data allow us to obtain estimates of the investment flow and capital stock of Physical (K^{Ph}), Information Technology (K^{IT}), Advertising (K^{Ad}), Financial (K^{FE}) and Human (K^{HK}) assets.

Physical operating capital includes buildings (mainly branches) and long-term assets, excluding those having to do with computer hardware. IT capital is set equal to the sum of the assets reported in the balance sheet under the heading of "information technology" plus the capitalization of the annual expenditures on IT reported in the income statement, using the perpetual inventory method. These expenditures include the acquisition and development of IT systems and software, the expenditures of renting IT-related assets, and the maintenance of those same assets. The stock of Advertising capital is obtained by applying the perpetual inventory method to the annual flow (investment) of advertising expenditures, as reported in the income statement of banks. Next, the stock of Human capital is calculated in a similar way, from the training expenditures reported by banks. Finally, financial assets are the counterpart, on the asset side of the balance sheet, of the bank equity that solves the equation:

$$\text{Equity} = (\text{Physical} + \text{IT} + \text{Advertising} + \text{Human} + \text{FinancialAssets})$$

where Equity is expressed in constant purchase power values. The stocks of each of the assets are valued at current estimated purchase cost in the market, calculated using the official price index of capital goods and services, and an estimate of the economic depreciation (see [47] for a more detailed description of the calculations). Replacement cost is the correct economic measure according to the model, as opposed to the historical acquisition costs that are usually reported in accounting statements. Table A1 in the appendix shows the depreciation rates and price indices used in the calculations of the replacement costs of the assets.

Data on expenditures labeled as "adjustment cost" are not explicitly reported by banks. Broadly defined, adjustment costs include all the expenditures needed to make market-purchased assets fully productive. There is wide evidence that the investment in IT capital has been accompanied by firms with costly reorganization of work flows and processes, expensive training programs for employees, and the experimentation of new human resource policies and practices [10,17,42]. All these initiatives aim to increase the productivity of IT capital and, therefore, they are part of the adjustment costs of investing in IT. Of all these proxy variables that capture the resources spent by banks to take full advantage of computers and IT-related assets, we can only observe the amount of money that each bank spends in training its workers. Black and Lynch [10] explicitly include training workers as part of the organization capital of the firm and point out that work organization, human management practices, and training tend to occur together. The empirical evidence shows that employee training has positive effects on the performance of firms [8,11,34] and that the organizational changes spurred by the intensity of use of IT capital modify the level and composition of the desired skills for employees [15,18].

We take the training expenditures as a measure of the adjustment costs of banks and we assume that this variable is highly correlated with the total adjustment costs from IT investment. We also assume that the training expenditures finance the accumulation of productive assets that become part of the organization capital.[7] This means that the human capital from training has positive spill-over effects over other activities of the firm (will increase the productive capacity of the bank, will allow banks to sell new services and enter new markets, and will facilitate the implementation of the other elements of the organization capital[8,10,50]).

Banks can have *market power* on both loan and deposit markets so, for each bank, data are collected on interest paid on deposits *ID*, and on gross profit margins in loans (interest on loans minus opportunity cost of loans at the interbank interest rate), *GLP*. We use the gross margin of loans rather than of the total revenue, in order to avoid

[6] Eq. (5) can also be related to the methodology often used to estimate the return from intangible assets inspired by the methodology of hedonic prices begun by Griliches [25]. For a firm with only two assets, tangible *A* and intangible *KI*, and no market power, Eq. (5) is written as $V = \lambda_1 A + \lambda_2 KI = \lambda_1 A(1 + \lambda_2 KI/\lambda_1 A)$. Taking logarithms: $\ln V = \ln \lambda_1 + \ln A + \ln(1 + \lambda_2 KI/\lambda_1 A)$. Finally, assuming that $\lambda_2 KI/\lambda_1 A$ is sufficiently small, thenln $V = \ln \lambda_1 + \ln A + \lambda_2 KI/\lambda_1 A$. Therefore, the estimated coefficient of KI/A will provide an estimate of the marginal return of intangibles *KI* relative to the marginal return of tangible assets *A* (that is an estimate of λ_2/λ_1). Some applications of this framework to estimate the return from intangibles are Hirschey [30] on the return of *R&D* and advertising; Montgomery and Wernerfelt [49] on returns from diversification strategies; Simon and Sullivan [58] on brand equity; Hall [26] on the return on investment in *R&D* over time; Konar and Cohen [38] on the environmental performance of firms, and most of the referenced papers on IT Business Value.

[7] Shu and Strassmann [57] claim that, in the case of banks, all the expenses other than interest costs are costs tied to information resources. However, it is unclear that all these expenditures become valuable assets that are then part of the organization capital of the bank.

double-counting, since compensation to deposits is one component of the cost of loans.

The economic value of the bank will be set equal to the present value of the predicted future earnings, discounted at the cost of capital of the bank. We follow the approach of Abel and Blanchard [1] and forecast the future earnings of each bank using an *ARIMA* econometric model. Earnings data are obtained from the accounting earnings after the adjustments to account for differences in the criteria between costs and investments with respect to the accounting conventions. Then, we compute the adjusted earnings as:

$$\begin{aligned}\text{Adjusted Earnings} = &\ \text{Accounting Earnings} + \text{Expenditures Advertising\&IT}\\ &+\text{Accounting Amortization}\\ &-\text{Estimated Ec Depreciation of Material\&Immaterial Assets.}\end{aligned}$$

The economic value of a bank *i* in year *t* is then calculated as follows,

$$\hat{V}_{it} = \hat{P}^t_{it} + \xi_{i,t}\hat{P}^t_{i,t+1} + \xi^2_{i,t}\hat{P}^t_{i,t+2} + \xi^3_{i,t}\bar{P}^t_i\,\frac{1+\bar{\rho}_{it}}{\bar{\xi}_{it}-\bar{\rho}_{it}} \tag{8}$$

where $\hat{P}^t_{i,t+s}$ are the predicted adjusted earnings of bank *i* at time $t+s$, given the information available at time *t* using an $AR(2)$ model; $\xi_{i,t}$ is the discount factor of each bank, inversely related to the opportunity cost of capital of that bank at time *t*. The opportunity cost of capital of the bank is equal to the risk-free interest rate plus a risk premium that takes into account the risk of loans plus the risk from debt leverage.

From $t+3$ onwards, the profits of banks are calculated applying a constant expected growth rate ρ_i to the average of the predictions for t, $t+1$ and $t+2$, $\bar{P}^t_i$. It is assumed that this rate of growth of profit is equal to the profit retention rate times the long-run Return Over Equity (*ROE*). The proxy value of the long-term growth rate $\bar{\rho}_{it}$ is obtained, assuming that banks retain one half of their earnings, and further assuming that the long-term *ROE* is equal to the average of the *ROE* of the last three years (with equity valued at replacement cost). The long-term discount factor $\bar{\xi}_{it}$ has been approximated to the average of the opportunity cost of capital of the bank in the previous three-year period.

The fact that only a few banks are listed on the stock market allows for a limited comparison between the estimated economic value of the bank and the market value from share prices. The comparison supports the assumption that the economic value and the market value are strongly correlated.[8] Another debatable issue is whether our estimated economic value of the banks is more or less appropriate to value the intangible assets than the value obtained from the share prices, if the latter are available. There are reasons to believe that our estimated economic value has some advantages over the stock market value, since the calculation simply follows the definition of discounted expected future cash flows used in the formal model. Market analysts and investors will have no more information on economic profits and cash flows than do we (notice that some data are not publicly reported, for example expenditures on IT and advertising, owned versus rented branches), so their projections to determine the recommended share price cannot be expected to be more accurate than ours. Moreover, share prices can be affected by bubbles that distort the measurement of intangibles [14] and may value rents to current shareholders that cannot be attributed to the intangible assets originating from adjustment costs (for example, share prices may incorporate a premium from corporate control activity).

Fig. 1 shows the evolution of some descriptive statistics of the Tobin's *q*, calculated as the ratio between the discounted adjusted cash flows, $\hat{V}_{it}$, and the sum of the bank's assets at replacement costs. The median *q* ratio of the banks in the sample is close to 3 in 1984 and falls to 0.94 in 1994. Since then, it has increased again, but it has remained in values below 2. Therefore, the greater competition during the last part of the sample period (liberalization of the banking sector and the incorporation of Spain in the EMU) squeezed economic profits. The coefficient of variation (standard deviation divided by mean) also decreases over time, indicating convergence in the estimated *q* across banks. For comparative purposes, Fig. 1 also shows the median of the *q* ratio calculated with raw accounting data (using profits and assets as valued in accounting books). Observing both measures, we can see that the median of the accounting-based *q* ratio always overestimates the median of the *q* ratio with adjusted cash flows and assets at replacement cost.

3.2. Adjustment costs vs. market power

In this section, we estimate the valuation equation for banks, considering adjustment costs and market power as the only sources of value for each productive asset, excluding human capital from training, which will be incorporated in the next section dedicated to the analysis of the contribution of organization capital. The model to be estimated is formulated as follows,

$$\begin{aligned}&\ln V_{it} = \mu_0 + \sum_{j\in J}\mu_j \ln p_{jt}\left(K^j_{it} - I^j_{it}\right) + d_1 \ln \mathrm{ID}_{it} + d_2 \ln \mathrm{GLP}_{it} + \eta_i + m_{it} + \varepsilon_{it}\\ &J = \{Ph, IT, Ad, FE\};\ \eta_i,\ m_{it},\ \eta_{it}\tilde{}\,iid(0,\sigma_k);\ k = \{\eta, m, \varepsilon\}\end{aligned} \tag{9}$$

where sub-index *i* refers to the bank and *t* to the time period. The equation is formulated and estimated in logs, so the estimated value of the elasticity μ_j will provide a direct estimate of the relative contribution of asset *j* to the economic value of the bank: $\mu_j = V'_{K_j}(K_j/V) = \lambda_j(K_j/V)$.[9] Super-indices *Ph*, *IT*, *Ad* and *FE* are the identifying labels of Physical, IT, Advertising and Financial types of capital, and *ID* and *GLP* stand for total deposit interest and total gross loan profits, respectively. The error term is made up of three components: η_i or bank-specific effects that control for unobserved heterogeneity across banks; m_{it}, that accounts for the measurement error in the calculation of the value of the capital stocks and, finally, ε_{it}, a random term that captures productivity shocks, measurement errors of the dependent variable, and other disturbances not explained by the model. The elasticity μ_j is expected to be non-negative. Time-dummy variables and firm-specific fixed effects capture time-varying factors common to all banks, and bank-specific effects constant over time.

If the model was formulated and estimated excluding interest on deposits *ID* and net interest of loans *GLP*, then any contribution of the rents from market power by asset *j* would be captured by the estimated elasticity μ_j. If the variables *ID* and *GLP* are included as explanatory of the economic value, the rents from market power will be part of the estimated coefficients d_1 and d_2, and consequently μ_j will be determined only by the purchase and the adjustment costs. The comparison of the estimated coefficients of the capital stock variable, with and without the revenue variables, will indicate the assets that contribute to the market power of banks (variables correlated with the omitted ones).

The estimation of Eq. (9) with the *OLS* would produce biased estimates of the parameters since the explanatory variables are correlated with the error term (productivity shocks in ε_{it} affect both the value

[8] In order to test for possible biases in our measure of the economic value of banks, for those banks listed on the market, we estimate the actual market value of the bank as the product of share price and number of issued shares at the end of each year (from 1987 to 2003). We then postulate and estimate a linear equation model, where the dependent variable is the actual market price, *Market*, and the explanatory variable is our estimated economic value of the bank, *Econvalue*. The results of the estimation are $\text{Market} = -79.83 + 1.09\cdot\text{Econvalue}$ (204 observations). The null hypotheses of intercept equal to zero and slope equal to one are not rejected at the 5% level of significance. Therefore, we have no evidence that our estimate of the economic value of banks is a biased estimate of what their market value would be if they were listed on the stock market.

[9] The marginal return = marginal cost condition as a function of μ_j is $MR_j = \left(1 + \frac{C'_{ij}}{p_j}\right) = \mu_j\cdot(V/K_j)$.

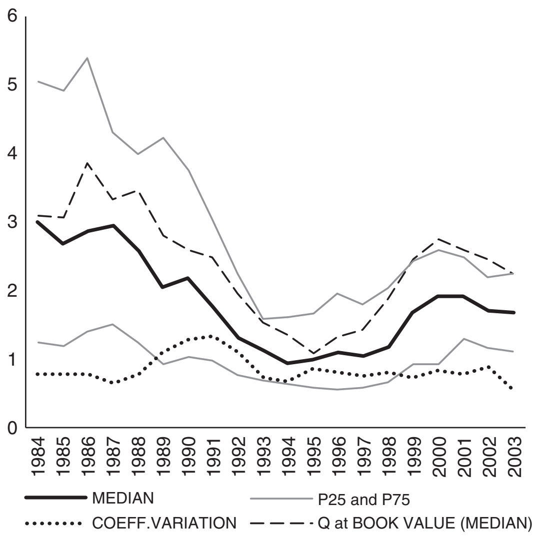

Fig. 1. Time evolution of descriptive statistics of the estimated Tobin's *Q*.

Table 1
Descriptive statistics of economic value, capital stocks and investment rates, 1984–2003.

	Average	Median	Std. dev.	P25th	P75th
Market value and Capital stocks (m€)					
V_{it}	799.6	181.6	2423	58.11	565.4
K^{Ph}	166.5	49.16	427.3	14.40	128.8
K^{IT}	7.38	3.97	8.04	1.03	10.85
K^{AD}	3.46	1.37	4.19	0.32	5.39
K^{FE}	208.5	58.15	411.1	18.18	201.2
K^{HK}	2.3	0.47	6.4	0.00	4.8
Investment rates (%)					
I^{Ph}/K^{Ph}	3.08	1.70	7.92	0.47	5.47
I^{IT}/K^{IT}	41.99	41.64	14.53	34.10	49.41
I^{AD}/K^{AD}	37.30	36.05	13.03	31.19	42.06
I^{FE}/K^{FE}	17.00	13.15	35.66	4.97	27.22
I^{HK}/K^{HK}	29.21	25.29	18.43	10.13	55.60

Notes:
K_{it} is the stock of invested assets at replacement cost of bank *i* at time *t*, V_{it} stands for its estimated economic value and I_{it} for the investment flow. Super-indices *Ph*, *IT*, *AD*, *FE*, *HK* refer to the Physical, IT, Advertising, Financial and Human capital/investment, respectively. *ID*, *GLP* are the values of the deposit interests and gross loan profits, respectively.

of the firm and its investment policy and, consequently, the value of the capital stock). In addition, measurement errors (m_{it}) are correlated by definition with the explanatory variables. Finally, another source of potential correlation arises from the existence of bank-specific effects in the error term that control for unobservable heterogeneity and can be correlated to the explanatory variables, leading to inconsistent estimates of the parameters. The standard econometric solution to these potential estimation problems is to take first differences, to eliminate unobservable firm-specific effects, and to use lagged values of the variables as instruments. However, it has been shown that, if the persistence of the variables that enter into the regression is high, then the lagged values are no longer good instruments for the first differentiated variables, leading to inconsistent estimates of the parameters. Blundell and Bond [13] propose additional moment conditions (in this case based on the orthogonal condition of the explanatory variables in differences and the fixed effects of Eq. (9)[10]), instrumented through the so-called *System-GMM estimator*, that assure consistent parameter estimates in the presence of a high degree of persistence of the variables. Model (2) is then estimated using the *GMM* system. The instrumental variables for the first-differenced orthogonal conditions are the levels of the explanatory variables in period *t*-3 and *t*-4, and for the additional orthogonal conditions are the first-differences of the explanatory variables in period *t*-2.[11]

The results of the estimation of Eq. (9) under several sets of explanatory variables are presented in Table 2. Column 1 shows the results when the only explanatory variables of the value of the bank are the stock of physical capital and the financial assets. In this specification, physical capital (mainly branches) accounts for more than 50% of the total value of the bank, whereas financial assets represent 25% of the bank value. Column 2 shows the estimated elasticity when the economic value is explained as a function of the replacement cost of *all* market-purchased assets. The estimated elasticity is statistically significant for the four market-purchased assets, with values that range from 17.5% on Advertising to 24.7% on IT capital. The hypothesis of sum of elasticity for all assets equal to 1 cannot be rejected (*p* value of 0.95).

The comparison of results from Columns 1 and 2 makes clear the over-estimation of the contribution of physical capital to the economic value of the banks when other capital inputs are excluded from the explanatory variables. When immaterial assets are excluded from the explanatory variables, their contributions to the economic value are incorporated as a part of the contribution of the physical assets. The reason is that material and immaterial assets are likely to be jointly determined from operational decisions and, thus, the stocks of all will be highly correlated. Therefore, the omission of the immaterial assets IT and Advertising from the regression will bias the estimated coefficient of the Physical capital. The estimated contribution of financial assets, on the other hand, remains practically unchanged in the two estimations, since financial assets are the result of decisions by banks to comply with the level of required regulatory capital.

Table 2
The estimated valuation equation of banks with adjustment costs and market power.

K^{Ph}	0.570***	0.231***	0.162**
	(0.059)	(0.082)	(0.081)
K^{FE}	0.241***	0.244***	0.253***
	(0.074)	(0.078)	(0.064)
K^{IT}		0.266***	0.217***
		(0.095)	(0.084)
K^{AD}		0.183**	0.073
		(0.087)	(0.084)
ID			0.217***
			(0.072)
GLP			0.019*
			(0.011)
Sargan	0.896	0.935	0.856
1st order	0.108	0.188	0.081
2nd order	0.945	0.810	0.865
N.obs	1847	1847	1842

(*) = significant at 10%, (**) = significant at 5%, (***) = significant at 1%. Standard errors in parentheses.
Notes: the dependent variable is the estimated market value of bank *i* at the end of year *t* in logarithm. K_{it}^{Ph}, K_{it}^{FE}, K_{it}^{IT}, K_{it}^{AD} stand for the stock of Physical, Financial, IT and Advertising assets held by bank *i* at the end of period *t*, all expressed in logarithms. ID_{it}, GLP_{it} are, respectively, the deposit interest and gross loan profits of bank *i* at time *t* also in logarithms. The model has been estimated with the *System GMM* as in Blundell and Bond [13]. All the estimations contain time-dummy variables. *Sargan*, *1st order* and *2nd order* present the *p*-values of the tests of Sargan and lack of first and second-order autocorrelation.

[10] The additional orthogonal conditions also require that the explanatory and dependent variables are mean-stationary. They are also accomplished if the data series have been generated for a sufficiently long time prior to the sample period, which seems like a reasonable assumption for the variables value of the bank and its capital stocks.

[11] Given the assumptions in the distributions of the error components, we could have considered a prior lag in both sets of instrumental variables (i.e., instead of using the first differences in *t*-2 as instruments of the additional orthogonal conditions, use also *t*-1). However, the set of instruments used in the estimation is robust to potential serial correlation in the error components (for instance, *MA*(1) structure in the measurement errors). See Blundell and Bond [13].

In Column 3, the empirical valuation model is modified, introducing as explanatory variables the interest from deposits *ID* and the gross profits from loans *GPL*. The respective estimated coefficients of these two variables are 0.217 and 0.019, indicating that the rents from market power (mainly from deposit markets) contribute around 23% to the economic value of the bank. Again, the inclusion of omitted variables (market power) reduces the relative contribution to the economic value of all the operating assets, with the exception of Financial assets. The operating assets are then correlated with the rents from market power, although the correlation differs across assets, an indication that their respective contributions to market power are also different. In the case of Advertising, for example, the estimated coefficient falls from 18.3% in Column 2 to 7.3% and not statistically significant in Column 3. Notice that the sum of changes in the estimated elasticity for all the operating assets, from Column 2 to Column 3, is approximately equal to the sum of the estimated coefficients for interest on loans and deposits that control for market power.

3.3. Intangible assets

We now examine how the estimations change when the human capital generated from training is included as an explanatory variable of the economic value of banks, under the assumption that the investment in training endows banks with intangible assets in the form of organization capital.

If only investment in IT assets creates organization capital, and the firm has no market power, then Eq. (6) can be written (from the first order optimality condition of marginal return equal to marginal cost, $\lambda_{jt}=p_{jt}+C'_{I_{jt}}$) as,

$$V_t = \sum_{j\neq IT}\left(\left(p_{jt}+C'_{Ijt}\right)\left(K_{jt}-I_{jt}\right)\right)+\left(p_{ITt}+C'_{IITt}\right)\left(K_{ITt}-I_{ITt}\right) + z_{ITt}\left(-f'_{C_{ITt}}C'_{ITt}\left(K_{ITt}-I_{ITt}\right)+z_{Itt}M_{ITt}.\right. \quad (10)$$

The empirical models in Table 2 ignore valuable organization capital, so they implicitly assume that z_{ITt} is equal to zero. If this was not true and organization capital was valuable but the variable organizational capital M_{ITt} is omitted as an explanatory variable, then the two last terms of the valuation equation above will cancel out, since they have opposite sign and one is the cost and the other the value of organization capital in the optimal solution. This implies that the estimated coefficient of the IT capital stock in the empirical models of Table 2 is an unbiased estimate of the marginal cost equal to marginal return of IT capital.

Now suppose that the organizational capital variable, in our case the human capital from training, is added as an explanatory variable of the economic valuation of firms as a proxy for M_{ITt}. In this case, the estimated coefficient for the IT capital variable will be $p_{IT}+C'_{IT}(1-z_{IT}f'_{C_{IT}})$, lower than the estimated coefficient when organization capital/human capital from training is excluded. Therefore, if human capital from training is part of the organization capital built when banks invest in IT, the addition of the human capital variable as explanatory of the economic value of banks in the models of Table 2 implies: i) a positive estimated coefficient of the human capital variable; ii) a lower estimated coefficient for the variable IT capital than when human capital is not included; and iii) the estimated coefficient for the IT capital variable decreases with the stock of human capital from training.

The expected results of i) and ii) are direct predictions from the theoretical model above when $z_{IT}>0$. Result iii) is an inference from ii), since the marginal cost of installing and making productive an additional unit of IT capital, equal to marginal return if the observed data come from value maximization decisions by banks, can be expected to be lower at higher levels of capital from training.

To test these predictions, Eq. (9) is estimated with the variables $\ln K^{HK}$, $\ln K^{HK}$ and $\ln K^{HK}\cdot\ln K^{IT}$ as additional explanatory variables of the economic value of banks. We expect a positive estimated coefficient for $\ln K^{HK}$ and negative for $\ln K^{HK}\cdot\ln K^{IT}$. The estimations of the extended empirical models are presented in Table 3. In the first column, we show the estimation of the basic valuation equation when the only new explanatory variable is $\ln K^{HK}$; the results must be compared with those in Column 2 of Table 2. The estimated coefficient of the new variable is positive and significant at 10%. The comparison of the estimated coefficients for the remaining explanatory variables reveals that the new coefficients tend to be lower than their counterparts in Table 2. The largest difference occurs in the coefficient of $\ln K^{IT}$ that is now 0.215, compared with 0.266 in Table 2 (20% lower); the null hypothesis that both coefficients are equal is rejected at 1%.[12] The second largest difference of coefficients between the two estimations is for Advertising capital, K^{AD}, whose estimated coefficient is reduced from 0.183 to 0.156 (15%) but the two coefficients are statistically different only at the confidence level of 10%. For Physical and Financial capital, the change in the value of the estimated coefficient is less than 5% and the difference is not statistically significant. The results are consistent with the predictions. The evidence that the inclusion of K^{HK} as explanatory variable also lowers the coefficient of Advertising capital suggests that more advertising goes together with more product innovation, and that banks also train workers to sell the new products.

In Column 2 of Table 3, we show the results of the estimation when the interest on deposits and the gross margins of loans are added as explanatory variables. The coefficient of K^{HK} is lower (30%) than in Column 1, whereas the remaining coefficients are in line with those in Column 3 of Table 2. The decline in the estimated coefficient of K^{HK} suggests that human capital also contributes to the market power of banks, but the null hypothesis that tests the equality of coefficients of K^{HK} in the two equations cannot be statistically rejected at 10%.

In Column 3 of Table 3 we show the estimated parameters of the model when the cross-product variable of stock of IT capital and stock of human capital is added as explanatory of economic value. The coefficient of the new variable is negative and statistically significant, and the estimated coefficients for the variables $\ln K^{IT}$ and $\ln K^{HK}$ increase with respect to those in Column 1. Therefore, the empirical evidence supports the hypothesis that the effective marginal adjustment costs of investing in IT (*0.330–0.037* $\ln K^{HK}$) decrease with the stock of human capital from training workers. The effect of human capital on the marginal adjustment cost of IT is economically significant: for a bank with a level of the variable $\ln K^{HK}$ one standard deviation (equal to 2.8) above the mean (equal to 4.03) the estimated value of the coefficient μ_{IT} that gives the proportion of adjustment costs from IT in the economic value of the bank (Eq. (9)), is equal to 0.07 (0.33–0.037 (4.03 + 2.8)), for the parameters shown in the last column of Table 3, i.e. 7% of the total. For a bank with human capital one standard deviation below the mean, adjustment costs from IT represent 28% of the economic value.

3.4. Calculation of adjustment costs, intangibles and rents from market power

In this section, we present our estimates of the contributions to the economic value of banks for the different components as they appear in Eq. (6). We first show how to separate the contribution from adjustment costs and the contribution from market power for asset *j*. Notice that, when the estimation incorporates the sources of market power, we have $\mu_j=V'_{K_j}(K_j/V)=\lambda_j(K_j/V)=(p_j+C'_{I_j})K_j/V$. Therefore, the proportion of adjustment costs in the economic value of the

[12] The median value of $\ln K^{HK}$ in the sample is 5.5 and the median value of $\ln K^{IT}$ is 8.5. Then, the contribution of human capital from training to the economic value of the representative firm is $0.099\cdot5.5=0.55$. The contribution of IT capital after human capital from training is introduced in the equation as explanatory variable decreases $(0.266-0.215)\cdot8.5=0.43$; therefore the contribution of the human capital variable accounts for 80% of the lower contribution resulting for the IT capital. The other 20% would be split by the other explanatory variables, especially advertising capital.

Table 3
Contribution to economic value of human capital from training employees by banks.

K^{Ph}	0.221**	0.168**	0.210**
	(0.092)	(0.087)	(0.092)
K^{FE}	0.238**	0.256**	0.261**
	(0.076)	(0.065)	(0.074)
K^{IT}	0.215**	0.196**	0.330**
	(0.094)	(0.083)	(0.113)
K^{AD}	0.156*	0.055	0.156*
	(0.089)	(0.083)	(0.089)
K^{HK}	0.0999*	0.068*	0.429**
	(0.059)	(0.041)	(0.157)
ID		0.201**	
		(0.077)	
GLP		0.018*	
		(0.011)	
$HK\ K^{IT}$			−0.037**
			(0.017)
Sargan	0.496	0.507	0.474
1st order	0.163	0.089	0.151
2nd order	0.763	0.804	0.647
N.Obs	1847	1847	1847

(*) = significant at 10%, (**) = significant at 5%, (***) = significant at 1%. Standard errors in parentheses.
Notes: The dependent variable is the estimated market value of bank i at the end of year t in logarithm. K_{it}^{Ph}, K_{it}^{FE}, K_{it}^{IT}, K_{it}^{AD}, K_{it}^{HK} stand for the stock of Physical, Financial, IT, Advertising and Human capital held by bank i at the end of period t, all expressed in logarithms. ID_{it}, GLP_{it} are, respectively, the deposit interest and gross loan profits of bank i at time t also in logarithms. The model has been estimated with the *System GMM* as in Blundell and Bond (1998). All the estimations contain time-dummy variables. *Sargan*, *1st order* and *2nd order* present the p-values of the tests of Sargan and lack of first and second-order autocorrelation.

Table 4
The relative contribution of adjustment costs, organization capital and rents from market power to the economic value of banks.

	Column 1	Column 2	Difference
Adjustment costs vs market power			
$\mu^{Ph}-K^{Ph}/V$	0.004	−0.048	0.053*
	(0.962)	(0.582)	(0.066)
$\mu^{FE}-K^{FE}/V$	−0.093	−0.074	0.018
	(0.225)	(0.250)	(0.655)
$\mu^{IT}-K^{IT}/V$	0.197**	0.178**	0.020
	(0.036)	(0.032)	(0.661)
$\mu^{Adv}-K^{Adv}/V$	0.147*	0.046	0.101**
	(0.098)	(0.579)	(0.0001)
$\mu^{HK}-K^{HK}/V$	0.098*	0.067*	0.031
	(0.099)	(0.098)	(0.474)
Market power deposit		0.201**	0.201**
		(0.009)	(0.009)
Market power loans		0.018	0.018*
		(0.098)	(0.098)

(*) = significant at 10%, (**) = significant at 5%, (***) = significant at 1%. p-values in parentheses.
Notes: μ^j is the economic value of asset j and $p_j K^j/V$ is the current market purchase cost of the asset relative to the economic value of the bank. Market power deposits/loans stand for the direct estimates of the contribution to market power of the interests on deposits and loans. The column *Difference* is the difference between the value of Column 2 minus the value of Column 1, measuring the contribution of the respective asset to market power.

bank is given by $C'_{I_j}(K_j/V) = \mu_j - p_jK_j/V$. That is, the adjustment costs from the market-purchased asset j are equal to the difference between the elasticity of the stock of asset j and the ratio of the stock of asset j over the economic value of the bank. When we perform the same calculation with the estimates obtained when the variables of market power are excluded, then the difference $\mu_j - p_jK_j/V$ will include both the adjustment costs and the contribution to the economic rents of asset j.

Column 1 of Table 4 shows the excess of elasticity over the replacement cost of the asset $\mu_j - p_jK_j/V$ when the elasticity is obtained excluding the interests on deposits and loans as explanatory variables (first column of Table 3). In Column 2, we perform the same calculation for the estimation that includes the interest variables (Column 2 of Table 3). Column 3 shows the *Difference* of the values in Column 2 minus those of Column 1, and we interpret it as the contribution of asset j to generating rents from market power.

Column 1 shows evidence of a positive and statistically significant net contribution of IT, Advertising and Human capital to the economic value of the bank. After including our market power variables (Column 2), only IT and Human capital remain positive and significant. Therefore, the positive contribution of Advertising capital in Column 1 can be attributed primarily to the contribution of advertising to the rents from market power.

We now have that the adjustment costs from the investment in IT represent 17.8% of the economic value of the representative bank in the sample,[13] and the intangible assets from training expenditures represent 6.7% of the economic value of the bank. The rents from market power represent 21.9% of the value (20.1 + 1.8), which come mainly from the contributions of advertising capital (including, possibly, product innovation) and, to a lesser extent, of physical capital (network of branches). The sum of all these components amounts to 46.6% of the economic value. The remainder corresponds to the purchase costs of the market-provided assets.

We close this section with another look at the complementarities between human capital from training and IT capital that can be inferred from the empirical analysis. The empirical results indicate that banks with greater human capital from training are also the banks with lower marginal contribution of IT capital to the value of the firm. This result is explained by the optimality condition that firms choose a level of capital stock in period t such that the marginal return is equal to the marginal cost of the asset. Banks with relatively more trained workers on how to use computers will operate under lower adjustment costs and therefore lower marginal cost of new IT capital. To satisfy the first order optimality condition, banks with lower marginal costs (greater human capital from training) will choose a level of IT capital higher than banks with higher marginal costs (lower human capital) because the marginal contribution of IT capital to economic value is positive but decreasing with the stock of capital.

To see this in our data, the sample of banks is divided into two groups, depending on whether their stock of human capital over total assets is above or below the median of the distribution of this variable. We find that the stock of IT per worker in banks with high training expenditures is, on average, 50% higher than in the banks with low expenditures, as expected. This result also implies that the marginal return of asset j, λ_j, from models (6) and (9), is not independent of the level of stock of capital; rather, the two are inversely related because marginal returns are decreasing with the stock of capital. The contribution of an asset to the economic value of the firm must be evaluated from the product of the weight times the level of stock (or the relative value of the product, as we do with elasticity μ).

3.5. Robustness tests

We have performed several tests to check the consistency and robustness of our results. We have estimated simple correlations among investment rates and capital stock per employee for the multiple assets. The results confirm a positive and significant correlation between the stock of human capital from training per worker and the investment rate in IT capital, i.e. investment in IT grows faster among banks with greater stock of human capital. Such a positive correlation is not observed with the investment rate of other assets. We have included separate cross-effect variables (with K^{HK}) for each asset (not only for IT), to test for any evidence of intangibles in other market-purchased assets. In all cases, the estimated coefficients of the cross effects were not statistically significant, except in the case of Advertising capital, with an estimated negative and significant

[13] This contribution would rise to 20% if we included the cost of training workers that is now accounted for by the variable K^{HK}

coefficient (as in the case of IT capital). We interpret this result as additional evidence in support of the hypothesis that workers are not only trained in how to use computers, but also trained in the new products that banks offer to their customers. In fact, the simple correlation of investment in advertising capital and investment in human capital is positive and statistically significant, as well as the correlation between investment in IT capital and investment in advertising. The investment rates of these immaterial assets seem to move together among the banks in the sample.

A second robustness test consisted of estimating the same model specification as the one estimated by Brynjolfsson, Hitt and Yang [17]. They estimate an empirical model where the organization capital variable only enters into the valuation equation as part of the interaction with the IT capital, i.e. the organization capital variable alone is excluded from the explanatory variables of the model. For comparison purposes, we estimate the valuation equation excluding the human capital variable K^{HK} from the explanatory variables, and keeping only the cross effect of K^{HK} with IT capital. We find that the estimated coefficient of the cross-effect variable in the new regression is positive but not significantly different from zero. Therefore, whether the organization capital variable is included or not as a separate explanatory variable (together with the cross-effect variable) has implications for the empirical estimates of the contribution of intangibles to the economic value of firms. We understand that the proper way to proceed, consistent with the theory, is to include the human capital variable together with the interaction with IT capital, the two together, as explanatory of the economic value of the banks.

Next, we have estimated the model with data generated under different but realistic assumptions of the depreciation rate of IT and advertising, above and below the values used in this paper (in the range of 30% to 50%). There is other evidence [20] showing that the assumptions about the depreciation rates of IT capital can give different results on the estimated contribution of IT to output and productivity. Our qualitative conclusions, however, remain the same.

Finally, we have tested whether the empirical results could be biased due to the existence of omitted variables explaining the differences in the initial decision of banks to spend more or less in training. In order to do this, we looked for any observable characteristics of banks that determined the level of training expenditures. More concretely, we compared the size, ownership (savings banks or commercial banks) and specialization of banks in 1983 (the first year of the sample data) between two groups of banks: those with a ratio of human capital to total assets above the median of the period, and those with a ratio below the median. We find that being a relatively high or low investor in training workers is independent of the size, the ownership, and the specialization of the bank at the beginning of our sample period.

4. Discussion and conclusion

This paper draws from the theory of investment of the multi-asset firm with adjustment costs, to study the joint accumulation of IT and organization capital by value-maximizing firms when: (i) the organization capital is an asset that directly contributes to the cash flows of the firm, (ii) the expenditures on building organization capital come from the adjustment costs of investing in IT capital, and (iii) firms do have market power (price inelastic demand for their product). The solution to the value-maximization problem shows that the path of the economic value of the firm over time is a function of the time evolution of the sum of the weighted values of the stocks of capital services from all productive assets, plus the present value of the expected rents from market power. The valuation equation derived in this paper generalizes most of the equations used in empirical research on IT Business Valuation and related literature.

The weights of the stock of capital services in the valuation equation are equal to the marginal return of the respective asset. The value-maximization condition imposes the constraint that the marginal return will be equal to the marginal cost of the asset when the firm does not have market power. On the other hand, if the firm does have market power, then the asset contributes to product differentiation and the marginal return will be higher than the marginal cost. This finding has important implications for the interpretation of the results found in research on the contribution of IT capital and business value. If IT capital is a productive asset and firms invest in it in a value-maximizing way, then the estimated coefficient of IT capital stock in empirical Business Value models is predicted to be positive. At the same time, a positive coefficient for the IT variable does not imply that IT capital is a source of competitive advantage that generates economic rents for the firm. To verify that IT is a source of competitive advantage, it is necessary to show that the estimated marginal return is higher than the (often unobservable) marginal cost. In this paper, we show a methodology to estimate the potential contribution of each capital asset, including IT capital, to the generation of economic rents.[14]

Another theoretical result from the derivation of the valuation equation, compatible with the ex-ante value-maximization problem, is the relationship between the stock of organization capital and the economic value of the firm. It has been well documented that investment in IT capital by firms coincides with substantial changes in the organization of work, high training expenditures, and a louder voice of workers in the functioning of firms [10,17]. In the context of our model, the positive spill-over effects of expenditures in adjustment costs associated with the investment in IT assets are taken into account in the modeling of the ex-ante decision problem of the firm, when such expenditures finance the accumulation of organization capital,. The implication of doing so is that the marginal gains from the spill-over effect must be subtracted from the marginal adjustment cost of the IT capital to obtain the net marginal adjustment cost. The accumulation of organization capital in parallel with the investment in IT lowers the net marginal cost of IT capital stock and, from the optimality condition, it also lowers the marginal return of the asset.

The implication of this result for Business Value research is that the stock of organization capital enters into the valuation equation as any other productive asset and, for the value of the existing stock, marginal return of organization capital will be equal to marginal cost. But when the expenditures in adjustment cost to make IT capital more productive have a positive spill-over effect, then the marginal adjustment cost of the IT investments must be net out of the marginal returns in the form of a positive spill-over. This paper formally derives this result and draws empirical implications; for example, that in empirical Business Value models, one would expect a positive effect of organization capital on the economic value of firms, and a negative effect on the estimated marginal cost of IT capital (from the positive spill-over).

The theoretical valuation equation is estimated with a panel database from Spanish banks. Data includes the stock at constant prices of the purchase cost of the stock of five different assets, including the estimated stock of human capital from training that will be our estimate of the organization capital of the banks. The results confirm the positive contribution of each asset to the economic value of the bank, as predicted by the theory, and the non-rejection of the hypothesis of market power (especially in the deposits market). Overall, the results are highly consistent with those found estimating the investing equation derived from the same theoretical model, and estimated with the same database [46].

To the best of our knowledge, the methodology used to separate the different contributions to the economic value of firms is new in the literature on IT Business Valuation, and our paper is more comprehensive on IT capital and the economic value of banks. This, as

[14] Most often, capital assets in empirical valuation models are expressed in constant Euros so the market purchase price of one unit of asset is one euro. But the purchase price of one is equal to the marginal cost of the asset when the adjustment cost, the part of the cost most difficult to observe, is equal to zero.

well as other factors, such as the panel data techniques we use, complicates the comparison of our results with those found in other papers. With these caveats, our estimated contribution of organization capital to the economic value of banks (7% of the total value) implies that banks invest 7.6 Euros in assets that are part of the organization capital for each Euro of IT capital stock,[15] a number not too far removed from the 9 Euros obtained in [17] for firms from different industries. On the qualitative side, the difference between our results and those found in the literature is the interpretation of the complementarities between organization capital and IT capital, and the implications for empirical research.

Most often, complementarities between the two variables have been understood as a positive effect of one variable on the marginal returns from the other. In the context of our paper, the complementarities between IT and organization capital appear in the form of a lower net marginal cost of the former, as the firm accumulates valuable organization capital and obtains positive spill-over effects while investing in IT. Firms with higher organization capital at a given moment of time are expected to have a higher stock of IT capital because the net marginal cost, including the positive spill-over, will be set equal to a lower marginal return resulting from higher values of the stock of the IT variable. In the literature, there is evidence of a positive estimated coefficient for the cross product of IT capital and organization capital variables in Business Value models [17,55] However, the comparison with our negative estimate is problematic, since in [17] the organization capital variable by itself is not included as an explanatory variable of the economic value of firms, which is unjustified according to our model, and in [55] the variable that can be considered a proxy of the organization capital has an estimated coefficient with negative sign, difficult to interpret, and the coefficient of the interaction variable is not always statistically significant.

The results from the model estimation presented in this paper must be understood as a test of the theory that, if confirmed, proposes that firms actually behave in a value-maximizing way, as presumed by the theory. This approach limits the managerial recommendations to be drawn from the results, since managers make the right decisions by assumption. However, the results of the paper for the average bank still offer some information relevant for bank management. For example, we provide a decomposition of the sources of economic value for the representative banks, and we find no evidence that IT is a source of product differentiation/economic rents. Papers of this kind are particularly useful for regulators, since the evidence of market power indicates that there may be some social dead-weight cost from equilibrium prices for bank products above their marginal costs but, at the same time, market power has been considered positive from the point of view of financial stability [36].

Although we believe that the paper contributes to the existing literature on IT Business Valuation and to the literature on intangibles and IT capital, it is important to bear in mind certain limitations. First, the formal modeling used in the paper imposes a trade-off between mathematical tractability and reality. Future research should make advances in integrating features of other, less abstract models [48], and relax some technical assumptions (in particular the assumption of linear homogeneity of the cash flow function). Second, the only proxy of organizational capital available for the empirical analysis is the expenses of banks on training workers, so it would be worthwhile to use more desegregated training data and additional organization capital variables. Third, our data come from a single industry, although an important one in terms of intensity in the use of IT-related assets, and therefore we cannot test for industry effects in the relationship between IT and economic value.

[15] From Table 1, the average economic value of banks in the sample is 799; 7% of this value is equal to 55.93. Also from Table 1, the average stock of IT capital per bank is 7.38. Dividing the two numbers (55.93/7.38) we obtain the figure of 7.6.

Appendix A

The optimization problem of the firm is to choose ***I***, ***K*** and ***M*** such that

$$\text{Maximize } V_t = E_t\left\{\sum_{s=t}^{\infty}\beta_s^t \cdot \Pi(K_s,\ M_s,\ I_s,\ e_s)\right\}$$

subject to Eqs. (1), (2), (3) and (4) given in the main text.

If $\lambda_{j,t+s}$ is the multiplier of the respective constraint in Eq. (1) and $z_{j,t+s}$ the respective multiplier of Eq. (3), the first order conditions of the maximization problem are, respectively for I, K and M:

$$-\Pi'_{Ijt}(K_t,\ M_t,\ I_t,\ e_t) = p_{jt} + C'_{Ijt} - z_{jt} f'_{Cjt} C'_{Ijt} = \lambda_{jt} \tag{A1}$$

$$\begin{aligned}\lambda_{jt} &= \left(\frac{\partial \Pi_t}{\partial K_{jt}}\right) + \left(1-\delta_j\right)\beta_{t+1}^t E_t\left[\lambda_{j,t+1}\right] \\ &= E_t\left[\sum_{s=0}^{\infty}\beta_s^t\left(\left(1-\delta_j\right)^s\left(\frac{\partial \Pi_{t+s}}{\partial K_{j,t+s}}\right)\right)\right] \forall j = 1,\ldots,N\end{aligned} \tag{A2}$$

$$\begin{aligned}z_{jt} &= \left(\frac{\partial \Pi_t}{\partial M_{jt}}\right) + \left(1-x_j\right)\beta_{t+1}^t E_t\left[z_{j,t+1}\right] \\ &= E_t\left[\sum_{s=0}^{\infty}\beta_s^t\left(\left(1-z_j\right)^s\left(\frac{\partial \Pi_{t+s}}{\partial M_{j,t+s}}\right)\right)\right] \forall j = 1,\ldots,N.\end{aligned} \tag{A3}$$

If price is a function of quantity, for any time period t we have $\frac{\partial \Pi}{\partial J} = p(Q)\frac{\partial Q}{\partial J} + Q\frac{\partial p}{\partial Q}\frac{\partial Q}{\partial J} - \frac{\partial C}{\partial J}$ for $J = K,\ M$. Let $\varepsilon = -\frac{\partial Q}{\partial p}\frac{p}{Q}$ be the price elasticity of demand with change of sign (positive value). If $Q = F(K,M)$ is linear homogeneous in K and M then,

$$\sum_j K_j \frac{\partial \Pi}{\partial K_j} + \sum_j M_j \frac{\partial \Pi}{\partial M_j} = p(Q)Q - \frac{1}{\varepsilon}p(Q)Q - \sum_j K_j \frac{\partial C}{\partial K_j}. \tag{A4}$$

Since $C\,(\,)$ does not depend on M multiplying both sides of Eq. (A2) by K_j and adding and subtracting $\lambda_{jt} I_{jt}$ we have:

$$\lambda_{jt} K_{jt} = \left(\frac{\partial \Pi_t}{\partial K_{jt}}\right) K_{jt} + \lambda_{jt} I_{jt} - \lambda_{jt} I_{jt} + \left(1-\delta_j\right)\beta_{t+1}^t E_t\left[\lambda_{j,t+1}\right] K_{jt}.$$

Table A1
Sources of data in the computation of capital stocks at replacement cost.

	Investment flow	δ = economic depreciation	Price index
Material			
Buildings	Difference between book value at *t* and *t-1* from balance sheet data	0.03	Residential (Ministerio de Vivenda)
Non-IT equipment	Book value	0.15	Market services (INE)
Immaterial			
IT equipment	Book value	0.35	Price Index = 1 (see the text)
IT services	Expenditures flow from income statement	0.35	Price Index = 1 (see the text)
Advertising	Expenditures flow from income statement	0.35	Market services (INE)
Training	Expenditures flow from income statement	0.20	Educational services (INE)
Financial assets	Difference between book value at *t* and *t-1* from balance sheet data	0.00	Consumption price index (INE)

Making use of Eq. (A1) and arranging the terms,

$$\lambda_{jt}\left(K_{jt}-I_{jt}\right) = \left(\frac{\partial \Pi_t}{\partial K_{jt}}\right)K_{jt} + \left(\frac{\partial \Pi_t}{\partial I_{jt}}\right)I_{jt} + \left(1-\delta_j\right)\beta^t_{t+1}E_t\left[\lambda_{j,t+1}\right]K_{jt}.$$

Repeating the exercise with M_j in Eq. (A3),

$$z_{jt}M_{jt} = \left(\frac{\partial \Pi_t}{\partial M_{jt}}\right)M_{jt} + \left(1-x_j\right)\beta^t_{t+1}E_t\left[z_{j,t+1}\right]M_{jt}.$$

Since the adjustment cost function $C_t(\,)$ in Eq. (2) is also linear homogeneous in K and I, summing over all j and taking into account Eq. (A4) we have,

$$\sum_j\lambda_{jt}\left(K_{jt}-I_{jt}\right) + \sum_j z_{jt}M_{jt} = \Pi_t - \frac{1}{\varepsilon}p_t(Q)Q_t + \sum_j\left(1-\delta_j\right)\beta^t_{t+1}E_t\left[\lambda_{j,t+1}\right]K_{jt} + \sum_j\left(1-x_j\right)\beta^t_{t+1}E_t\left[z_{j,t+1}\right]M_{jt}.$$

Solving recursively,

$$\sum_j\lambda_{jt}\left(K_{jt}-I_{jt}\right) + \sum_j z_{jt}M_{jt} = \sum_{s=t}\beta^t_s\frac{1}{\varepsilon}p_t(Q)Q_t = E_t\left(\sum_{s=0}^{\infty}\beta^t_{t+s}\Pi_{t+s}\right) = V_t.$$

Finally, the economic value at the optimal solution is equal to,

$$V_t = \sum_j^M\lambda_{jt}\left(K_{jt}-I_{jt}\right) + \sum_j z_{jt}M_{jt} + \sum_{s=t}^{\infty}\beta^t_s\frac{1}{\varepsilon}p(Q(K_s,M_s))\cdot Q(K_s,M_s) \quad \text{(A5)}$$

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