A consistent research design for value relevance studies

Jian Kang · Catalin Starica

Abstract We argue that Ohlson's linear solution to the residual earnings (RE) equation, a crucial component of a widely used value relevance research design, is generally not a linear regression. Moreover, its coefficients are firm-dependent. As such, its empirical specifications, the price-levels regression and the returns-earnings regressions are *structurally* ill-suited for consistent inference in cross-sections.

To address this issue we, first, prove the existence of a regression solution to the RE equation and, second, introduce a valuation-based research design that builds on such a solution and warrants a consistent estimation of the empirical specification (which takes the form of a non-linear regression). Its estimation turns out to be an optimal implementation of the price-to-book (P/B) multiple valuation, a technique that is easy to implement and familiar to the accounting community. The regression view on multiple valuation identifies P/B value with a price that incorporates earnings expectations formed only on the basis of the current levels of the RE drivers.

Using a large sample of US non-financial firms over an almost 40 year-period, we document the usefulness of the alternative research design through a comparative testing of four economically-motivated and intuitively-appealing predictions: size, earnings predictability and volatility, and the quality of accruals are value-relevant. While the current research design does not validate

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them, the approach based on the regression solution shows a significant association between prices and the four attributes for most of the years in the sample.

Keywords Non-linear association · value relevance · price-to-book valuation · nonparametric regression

1 Introduction

Value relevance research examines the association between accounting amounts and equity market values. This approach requires a research design composed of three elements: a valuation model to designate the firm attributes that affect value and their relation to value, a practical stipulation of the model for empirical tests and a measure of association.

A significant part of the value relevance papers belong to the category of *relative association studies*. Holthausen and Watts (2001) give a synthesis of their *modus operandi*: "*Relative association studies* compare the association between stock market values (or changes in values) and alternative bottom-line measures [...]. These studies usually test for differences in the R^2 of regressions using different bottom line accounting numbers. The accounting number with the greater R^2 is described as being more value-relevant." A quarter of the 62 papers under discussion in Holthausen and Watts (2001) perform a relative association study.

Currently, a frequently employed specification of the research design triad for a relative association study consists of Ohlson's linear solution to the RE equation[1] (the valuation model), price-levels or returns-earnings regressions estimated on cross-sectional data (empirical stipulations of the model), and regression's R^2 (the measure of association).

Extant literature has highlighted issues related to all the three elements of this particular research design. The aim of this paper is to discuss an alternative based on the Residual Earnings equation that addresses them.

The shortcomings of the Ohlson model are tied to its linear dynamic assumptions (Holthausen and Watts (2001)). First, any test of the Ohlson model is a joint test of the residual earnings valuation model, one one hand, and the assumed information dynamics, on the other[2]. Second, the linear nature of the relations between market value and current earnings, book value

[1] Twenty-nine of the sixty two studies, that is 47% of the studies, under discussion in Holthausen and Watts (2001) base the specification of their empirical tests on the Ohlson model.

[2] As a consequence, "variation in association between earnings based on different accounting methods and value, or between different countries earnings and value, could be

and dividends does not allow for the existence of options. Third, the linear form of the information dynamics assumption[3] is inconsistent with expected rents, i.e. expected positive net present value projects, for investments subsequent to an initial period[4].

The estimation of price-levels and returns-earnings regressions is potentially impaired by bias due, on one hand, to error terms correlated to the independent variables (Lo (2005), Barth and Clinch (2009)) and, on another hand, to coefficients that are not cross-sectionally constant, i.e. functions of firm-specific risk characteristics and industry-specific dynamic of the residual earnings (Kothari and Shanken (2003)). In the sequel we argue that these two causes of inconsistency are structural and hence not easily avoidable in an empirical setting. In particular, Ohlson's linear solution to the RE equation is generally not a linear regression. Moreover, its coefficients are firm-dependent. In other words, Ohlson's linear specification of the relation between value and accounting numbers is not well suited for consistent empirical estimation in cross-sections *by construction*[5].

Finally, the use of regression's explanatory power as an association measure[6] is invalidated by the fact that R^2 combines parameters relevant to the economic relation estimated (the variance of the error term) with the sample property (the variability of the dependent variable), making it difficult to trace whether a change in the explanatory power is due to a change in the economic relation or to differences between samples. Even in the absence of

due to variation in the extent to which the information dynamics assumptions fit across accounting methods or countries."(see also Lo and Lys (2000)).

[3] Empirical evidence against the linear specification of the information dynamics is provided, among others, by Biddle et al (2001) which document convex relations between future and current residual earnings, and between unrecorded goodwill (the difference between market and book value) and current residual earnings. Myers (1999) and Callen and Morel (2001) investigate the fit of various alternative formulations of the linear information dynamics and find that they severely underestimate the market expectation of future residual earnings under-performing book value alone in estimating equity values. Morel (2003) tests the Ohlson model at the firm level using methodologies that mitigate the weaknesses in prior studies and rejects the internal consistency of the model.

[4] To see this note that the abnormal earnings have unconditional mean equal to zero which implies that the unconditional mean of goodwill is zero (Biddle et al (2001), Lo and Lys (2000)).

[5] To estimating a linear regression by the model of Ohlson's linear solution using cross-sectional or panel data, as it is typically done, one needs to further assume first, that all firms have identical persistence parameter in abnormal earnings, second, that firms have identical discount rates, and third, that non-accounting information either affects all firms in exactly the same way or is value-irrelevant. These highly restrictive assumptions are not part of the original RE equation and are not made in the alternative research design we propose.

[6] Regression's coefficients, if biased, cannot serve as an association measure either.

bias, the R^2s are incomparable across samples. For two samples drawn from different populations, a difference in the R^2s could arise even if the underlying economic relation in the two samples is the same (Gu (2007)).

We take the following steps to address the mentioned shortcomings. First, we argue that the reason for which empirical specifications of Ohlson's model cannot yield unambiguous inferences about the relevance and reliability of financial statement variables is structural. The Ohlson model is not a regression and, as such, it is *structurally* ill-suited for consistent empirical estimation. We assert that this issue is consequent on the information dynamics assumption and on the definition of "information other than (past) abnormal earnings". While enabling a linear solution to the RE equation, the time-series linear structure assumptions invalidate the necessary condition for consistent estimation of empirical regressions motivated by such a solution.

Second, we prove the existence of a solution to the RE equation that is a (non-linear) regression. Value is expressed as the sum of a non-linear function of the realized RE drivers plus a correction term for which the condition necessary for consistent estimation holds *by construction*. We achieve this by doing without the information dynamics assumptions of the Ohlson model and by re-defining the "information other than abnormal earnings". While in Ohlson's case, the "other information" is a contribution that complements the current RE in the time series dynamics of abnormal earnings, for us, it is the correction term in the equation specifying how current RE best project future RE for the purpose of price formation. The two definitions differ greatly in their goal. In Ohlson's case "other information" is part of the additional time series assumptions needed to obtain a linear solution to the RE equation. In contrast to that, our definition explicits the RE expectation formation process aiming at obtaining a regression solution to the RE equation. The proposed model retains the non-linear[7] nature of the original RE equation and hence

[7] Empirical evidence of a non-linear relation between value and bottom-line accounting items include, among others, Hayn (1995) and Collins et al (1999) who report asymmetric valuation effect of earnings (between positive and negative earnings) or Burgstahler and Dichev (1997) and Bernard (1994) who document a convex dependence of the P/B on earnings to book ratio and realized accounting profitability, respectively.
In the RE modeling context, Biddle et al (2001) found that period-ahead residual income as well as unrecorded goodwill (the difference between the market value and the book value of equity) are convex functions of current residual income. Such evidence is inconsistent with models which assume that the two elements of value, earnings and book values, are simply additive (like the Ohlson model).

the intuition that prices and bottom-line items are related in a non-linear fashion[8].

In the proposed regression valuation model, the regression function represents the price setting contribution of expectations about future earnings informed only by the current levels of accounting profitability and book growth. Since the persistence of abnormal earnings is determined mainly by industry-specific factors, the regression function should be similar for firms within the same industry. Most importantly, the error term is by construction uncorrelated with the independent variables. Consequently, various non-parametric inference technique can be used to consistently estimate the empirical specifications of the regression solution.

Third, we argue that the K-Nearest-Neighbor algorithm is a natural choice for consistent estimation. Its operational form turns out to be an optimal implementation of the price-to-book multiple valuation, a technique that is easy to implement and familiar to the accounting community. In the regression model set-up, the P/B value can be interpreted as a consistent estimate of what the price of equity would be if future earnings expectations were formed using only the information contained in the current levels of the RE drivers.

Fourth, we propose an alternative to regression's explanatory power. The value-relevance empirical tests are performed on regression's error term which has an appealing intuitive interpretation. It measures the extent to which expectations incorporated in prices are formed using information other than the realized bottom-line items in the balance sheet and income statement. The median absolute error is used as an alternative association measure to regression's R^2.

The paper contributes to two strands of accounting literature. We enrich the literature on multiple valuation by showing how results from the fields of data mining and predictive modeling together with theoretical models of valuation literature can inform and structure the choices in the implementation of multiple valuation. More concretely, we show that multiple valuation can be formulated as an application of the k-Nearest Neighbor, a popular prediction algorithm in data mining and statistical learning. This identification validates the multiple approach to valuation, often criticized in the academic literature as 'ad-hoc', and offers rigorous guidance for its implementation. In particular, it motivates the need to construct an optimal set of peers.

Secondly, the paper adds to the significant body of accounting research on the relation between financial statement information and security prices. In

[8] Section C in the Appendix provides some graphical evidence based on the sample we analyze which further supports the suitability of a non-linear specification linking current accounting information to prices.

particular, our contribution is relevant to the strand of literature informed by the paradigm which considers accounting data that better explain contemporaneous prices more value-relevant. Our contribution is largely methodological. We propose an alternative to the current value-relevance research design based on specifications of the Ohlson linear solution to the RE equation. The new design tests empirical predictions using a regression solution to the RE equation paired with a valuation-based association measure as an alternative to linear regression's coefficients or regression's R^2.

The new research design is easy to implement and intuitively appealing. It assesses the value relevance by the level of accuracy of a (statistically optimal) price-to-book relative valuation. The valuation gap is an indication of the extent to which future earnings expectations incorporated in prices are formed using information other than the realized bottom-line items in the balance sheet and income statement.

Most importantly, the proposed design is useful. Using a large data set covering the period 1967-2013 we evaluate four economically motivated predictions using the two research designs. The predictions are that firms size is value relevant and that the predictability and the volatility of earnings as well as the quality of their accrual component are associated with prices. We measure earnings predictability as the error variance from an autoregressive model of order one $AR(1)$ for annual earnings. The volatility is measured by the standard deviation of earnings. We define our measure of accrual quality based on the firm-level specification of the model of current accruals proposed by Dechow and Dichev (2002). Tests based on empirical specifications of the Ohlson model with R^2 as value relevance measure do not confirm the predictions. An analysis based on the proposed methodology finds that the four attributes have been constantly associated to prices for practically all the years in the sample. As the economic intuition has it, the alternative research design confirms that realized values of the RE drivers do contribute more to the price setting expectations formation for larger firms, for firms with more predictable or less volatile earnings, and for firms reporting higher quality accruals. Based on the presented evidence, we believe that the proposed design can successfully complement the current approach to value relevance testing, providing researchers in the field with a consistent frame for their analyses.

The rest of the paper is organized as follows. Section 2 presents the motivation for the alternative research design. Section 3 discusses (in broad strokes) the proposed design and contrast it to the current framework based on the Ohlson model. Section 4 derives the regression solution to the RE equation and introduces the empirical specification for the study of association between capital market variables and financial data. Section 5 focuses on the estimation of the non-linear practical specification and establishes the connection to P/B multiple valuation methodology. Section 6 presents some empirical evidence of the usefulness of the alternative research design while section 7 concludes.

2 Motivation for the alternative research design

This section presents a number of theoretical considerations that frame the econometric issues of the different components of the conventional value relevance research design. By highlighting the problems, they also suggest ways of addressing them to be developed in the sequel.

2.1 Why not trust the price-levels and returns-earnings regressions

price-levels regression is possibly marred by the issue of inconsistent estimation due, on one hand, to omitted variable bias (Barth and Clinch (2009)) and, on another hand, to coefficients that are not cross-sectionally constant (functions of firm-specific risk characteristics and industry-specific dynamic of the residual earnings) (Kothari and Shanken (2003)). In the sequel we argue that these two causes of inconsistency are structural and hence not easily avoidable in an empirical setting. Ohlson's linear specification of the relation between value and accounting numbers is not a regression and, as such, it is not well suited for consistent empirical estimation *by construction.*

2.1.1 Background

Consider a random pair (X,Y). A fundamental result in probability states that Y can be decomposed into a piece that is "explained by X" and a piece left over which is orthogonal to (i.e., uncorrelated with) any function of X:

Proposition (Decomposition property)

$$Y = \mathbb{E}(Y|X) + \epsilon, \quad (1)$$

where

$$\mathbb{E}(\epsilon|X) = 0 \quad (\textit{the orthogonality condition}). \quad (2)$$

Condition (2) implies $\mathbb{E}(h(X)\epsilon) = 0$ for any function h (which explains its name).

The conditional expectation of Y given X is, generally, a non-linear function of X. It is a good summary of the relationship between Y and X for a number of reasons. First, we are used to thinking of averages as providing a representative value for a random variable. The conditional expectation is hence a way of expressing how Y varies with given X. Second (and more formally), the expected value of Y conditional on X is the best predictor of Y given X as stated by the following result.

Proposition (Prediction property) *The function that minimizes*

$$\mathbb{E}(Y - m(X))^2$$

is $m(X) = E(Y|X)$.

The decomposition property ties closely to the definition of a regression. We say that the pair (X, Y) is related by a linear regression[9] iff $\mathbb{E}(Y|X) = \beta_0 + \beta_1 X$, i.e. the expected value of Y conditional on X is a *linear* function of X. More generally, a decomposition:

$$Y = f(X) + \epsilon$$

is called a regression if $f(X) = \mathbb{E}(Y|X)$ or, equivalently, if the orthogonality condition $\mathbb{E}(\epsilon|X) = 0$ holds.

The orthogonality condition (2), besides being part of the definition of a regression, is necessary for the consistent estimation of the regression in (1) (see Stock and Watson (2012), Györfi et al (2002)). It implies $corr(\epsilon, X) = 0$ which, in the case of the linear regression, ensures that no omitted variables bias the estimation of the coefficients.

In the sequel we argue that provision $corr(\epsilon, X) = 0$ and implicitly the orthogonality condition (2) are not guaranteed to hold for the empirical regressions motivated by the Ohlson model. The reason lies in the particular form of the information dynamics of the model. The estimation of such regressions, i.e. price-levels or returns-earnings regressions, would, generally, be biased. In other words, Ohlson's specification of the relation between prices and accounting measures, while formally convenient, is not befitting statistical estimation.

The Ohlson model is a linear solution to the RE equation, relating $V_{i,0}$, the value of firm i at time t, to bottom-line items of financial statements:

$$V_{i,0} = B_0 + \sum_{t=1}^{\infty} \frac{\mathbb{E}_0(NI_t - r_E \times B_{t-1})}{(1 + r_{E,i,0})^t} = B_0 + \sum_{t=1}^{\infty} \frac{\mathbb{E}_0(RE_{i,t})}{(1 + r_{E,i,0})^t} \quad (3)$$

[9] The relation between the components of any random pair (X, Y) can be represented in a linear form as: $Y = \beta_0 + \beta_1 X + (Y - \beta_0 + \beta_1 X) := \beta_0 + \beta_1 X + \varepsilon$. However, the relation is a linear regression iff $\mathbb{E}(\varepsilon|X) = \mathbb{E}(Y - \beta_0 + \beta_1 X|X) = 0$, i.e. $\mathbb{E}(Y|X) = \beta_0 + \beta_1 X$.

($\mathbb{E}_t$ denotes the expectation conditional on all the information available at time t), that explicits prices as a linear combination of current book values and residual earnings:

$$P_{i,0} = B_{i,0} + k_{i,0} r_{i,0}^{-1} \times RE_{i,0} + \alpha_{i,0} \times \nu_{i,0}. \tag{4}$$

It is obtained by making two additional assumptions on the dynamics of RE:

$$\begin{aligned} RE_{i,t} &= \omega_i RE_{i,t-1} + \nu_{i,t-1} + \epsilon_{1,i,t}, \\ \nu_{i,t} &= \gamma_i \nu_{i,t-1} + \epsilon_{2,i,t}, \end{aligned}$$

where $0 \leq \omega_i, \gamma_i < 1$ are two constants determined exogenously by firms economic environment and its accounting practices, $k_{i,0} = \omega_i r_{i,0}/(1 + r_{i,0} - \omega_i)$, $\alpha_{i,0} = 1 + r_{i,0}/(1 + r_{i,0} - \omega_i)(1 + r_{i,0} - \gamma_i)$. ν_t is "information other than abnormal earnings" (i.e. events that have not affected current B_0 and NI_0) while $\epsilon_{1,t}$ and $\epsilon_{2,t}$ are unpredictable (zero mean conditional on the information at time t: $\mathbb{E}_t(\epsilon_{t+j}) = 0$, $\mathbb{E}_t(\epsilon_{2,t+j}) = 0$) "disturbance" terms.

The RE dynamics fully specify how current RE project future RE's in the process of price formation:

$$\begin{aligned} \mathbb{E}_0(RE_{i,j}) &= \omega_i^j RE_{i,0} + \mathbb{E}_0\, \nu_{j-1} + \omega\, \mathbb{E}_0\, \nu_{j-2} + \omega^2\, \mathbb{E}_0\, \nu_{j-3} + \ldots + \omega_i^{j-1}\, \mathbb{E}_0\, \nu_{i,0} \\ &= \omega_i^j RE_{i,0} + (\gamma^{j-1} + \omega\gamma^{j-2} + \omega^2\gamma^{j-3} + \ldots + \omega_i^{j-1})\nu_{i,0}. \end{aligned} \tag{5}$$

Expected future RE are a linear function of the current RE plus a correction term. Noticeably, the correction is proportional to current "information other than abnormal earnings" $\nu_{i,0}$. Paralleling this, the non-linear valuation model discussed in section (4) defines the "information other than abnormal earnings" to be the correction to the best prediction of $RE_{i,j}$ given the current RE, $\mathbb{E}_0(RE_{i,j}|RE_{i,0})$ (see equation (15)).

2.1.2 Omitted variable bias in price-levels regression

To use the linear solution to the RE equation (4) as motivation for linear empirical specifications one would need to be able to regard it as a linear regression, i.e. the condition $\mathbb{E}(\nu_t|RE_t) = 0$ (and hence implicitly $corr(\nu_t, RE_t) = 0$) should hold. Without the validity of this condition the coefficients estimates of its empirical version would not be consistent. However, Ohlson (1995), page 668 states: "We attach no significance to the possibility of relating ν_t (or $\epsilon_{2,t}$) to current or past accounting data [...]." Since RE_t is an expression of current and past accounting data, this statement implies that ruling out $corr(\nu_t, RE_t) \neq 0$ (and implicitly $\mathbb{E}(\nu_t|RE_t) \neq 0$) is of no significance for the model and no assumptions are made in that sense. However, while a non zero correlation between ν_t and RE_t does not interfere with obtaining a linear solution of the RE equation, it makes it unfit for consistent estimation.

In the sequel we argue that, as the model makes no assumptions[10] on the second moment structure of the disturbance terms or on the relation between them, the orthogonality condition does not generally hold. As such, relation (4) cannot be interpreted as a linear regression.

Formally, note that the linear dynamics assumptions imply (we suppress the index making the quantities firm-specific):

$$RE_t = \nu_{t-1} + \omega\nu_{t-2} + \omega^2\nu_{t-3} + \ldots + \epsilon_{1,t} + \omega\epsilon_{1,t-1} + \omega\epsilon_{1,t-2} + \ldots.$$

and, for all t

$$\begin{aligned} cov(\nu_t, RE_t) &= cov(\gamma\nu_{t-1} + \epsilon_{2,t}, \nu_{t-1} + \omega\nu_{t-2} + \omega^2\nu_{t-3} + \ldots \\ &\quad + \epsilon_{1,t} + \omega\epsilon_{1,t-1} + \omega\epsilon_{1,t-2} + \ldots) \\ &= \gamma Var(\nu_{t-1}) + \gamma\omega \times cov(\nu_{t-1}, \nu_{t-2} + \omega\nu_{t-3} + \ldots) \\ &\quad + \gamma \times cov(\nu_{t-1}, \epsilon_{1,t} + \omega\epsilon_{1,t-1} + \omega\epsilon_{1,t-2} + \ldots) \\ &\quad + cov(\epsilon_{2,t}, \nu_{t-1} + \omega\nu_{t-2} + \omega^2\nu_{t-3} + \ldots) \\ &\quad + cov(\epsilon_{2,t}, \epsilon_{1,t} + \omega\epsilon_{1,t-1} + \omega\epsilon_{1,t-2} + \ldots). \end{aligned}$$

Unless clear assumptions on the second order structure of the disturbance terms and on their interaction are made we see no obvious reason why suppose that this covariance is equal to zero.

To better see this, assume, as it is customary for disturbance terms, that they are white noises and, moreover, the correlation between the two disturbance terms at different time points is also zero. Then the previous expression simplifies to:

$$cov(\nu_t, RE_t) = \gamma/(1 - \omega\gamma) \times Var(\nu).$$

This makes $\gamma = 0$ the only choice for which $corr(\nu_t, RE_t) = 0$ holds at the expense of rendering the second equation of the dynamics of RE in Ohlson model ineffectual (see also Lo and Lys (2000)). For all cases for which the second equation of the dynamics of RE is non-trivial, $corr(\nu_t, RE_t) \neq 0$.

Also at an intuitive level[11], Ohlson's dynamics for the RE is inconsonant with the constraint $\mathbb{E}(\nu_t|RE_t) = \mathbb{E}(\nu_t|\omega RE_{t-1} + \nu_{t-1} + \epsilon_t) = 0$ as ν_{t-1}, and

[10] "Assumption (A3) (the information dynamics - n.n) places no restrictions on the variance and covariances of the disturbance terms." (Ohlson (1995), pg. 668).

[11] This second argument covers also the case $\gamma = 0$. Since no restrictions on the variance and covariances of the disturbance terms are made, it is possible that $\gamma = 0$ and $corr(\nu_t, \nu_{t-1}) \neq 0$.

hence the term $\omega RE_{t-1}+\nu_{t-1}+\epsilon_t$ that includes it, likely contains information about ν_t. It seems reasonable to assume, for example, that the size of the contribution of "information other than abnormal earnings" to determining RE could be similar in consecutive years if the economic conditions in which the firms operates do not evolve much and the firm characteristics are stable, i.e. $corr(\nu_t, \nu_{t-1}) > 0$. A large/small correction to previous RE to obtain current RE this year is likely to be followed by a large/small correction to get next year's RE. Unless $corr(\nu_t, \omega RE_{t-1}+\epsilon_t)$ is negative and compensates exactly $corr(\nu_t, \nu_{t-1})$, the condition $corr(\nu_t, RE_t) = 0$ is not fulfilled. We see no obvious reason why such a perfect compensation would occur. Without extra assumptions on the parameters of the information dynamics, the linear solution to the RE equation in (4) cannot be viewed as a linear regression.

In the same line of thought, there is no reason to believe that $\mathbb{E}(\nu_t|B_t, NI_t, D_t) = 0$ where $D_{i,t}$ stands for dividends payed. This is so since $\mathbb{E}(\nu_t|B_t, NI_t, D_t) = 0$ is a sufficient condition for $\mathbb{E}(\nu_t|RE_t) = 0$ as

$$\mathbb{E}(\nu_t|RE_t) = \mathbb{E}(\mathbb{E}(\nu_t|B_t, NI_t, D_t)|RE_t).$$

As a consequence, the form of the linear solution to the RE equation commonly taken as motivation for the price-levels regressions

$$P_{i,0} = (1-k_{i,0}) \times B_{i,0} + k_{i,0}(1+r_{i,0}^{-1}) \times NI_{i,0} - k_{i,0} \times D_{i,0} + \alpha_{i,0} \times \nu_{i,0}, \quad (6)$$

is not, generally, a linear regression. Estimation of its empirical version would generally yield biased coefficients.

2.1.3 Omitted variable bias in returns-earnings regression

The previous argument can be extended to include the earnings-returns regression. This alternative specification of the Ohlson model often used as a robustness check for the empirical findings based on the price-levels regression is commonly motivated (see Easton (1999) and Ota (2003)) by taking first differences in the expression (6), invoking the clean surplus assumption and re-arranging terms:

$$\begin{aligned} P_{i,t} - P_{i,t-1} + D_{i,t} = {} & (1-k_{i,t}) \times NI_{i,t} + k_{i,t}(1+r_{i,t}^{-1}) \times (NI_{i,t} - NI_{i,t-1}) \\ & - k_{i,t} \times D_{i,t} + \alpha_{i,t} \times \nu_{i,t} - \alpha_{i,t-1} \times \nu_{i,t-1}. \end{aligned} \quad (7)$$

Once again, we see no obvious reason why suppose that the equality

$$\mathbb{E}(\alpha_{i,t} \times \nu_{i,t} - \alpha_{i,t-1} \times \nu_{i,t-1}|NI_{i,t}, NI_{i,t-1}, D_{i,t}) = 0 \quad (8)$$

holds. Inferring a regression by the model of the expression in (7) would yield inconsistent coefficients estimates. Moreover, even if extra appropriate assumptions would be made on the dynamics of RE turning model (7) into a regression, i.e. condition (8) is fulfilled, dividing by previous period price $P_{i,t-1}$ to get the operational form of the earnings return linear regression would, most likely, invalidate the necessary condition for a consistent estimation as $\mathbb{E}(U|V) = 0$ does not guarantee $\mathbb{E}(U/P|V/P) = 0$.

2.1.4 Why the omitted variable bias remedies typically employed in value relevance research might not be sufficient

There could be many reasons for the orthogonality condition (2) not to hold for the price-levels or the returns-earnings regressions. Value relevance literature discussed extensively one scenario: that of a variable that affects all of the analysis variables (dependent and independent) or scale. Different treatments of scale were proposed to mitigating the different ensuing inference problems: coefficient bias, R^2 bias, and heteroscedasticity (Barth and Kallapur (1996), Brown et al (1999), Easton (1998), Easton and Sommers (2003), Lo (2005)). Considerable disagreement still exists over what is the best, acceptable, or appropriate specification of variables to use (inclusion of an independent scale proxy, deflation by some dependent variable). Besides, many other scenarios leading to the failure of the orthogonality condition can be envisaged (Barth and Clinch (2009)). Consequently, there is little hope for a general fix for the issue of inconsistent estimation of Ohlson's linear solution to the RE equation in empirical applications.

A viable alternative would be to base empirical specifications on a solution of the RE equation that is a regression, i.e. a decomposition of the price into a sum of a function of realized bottom-line items and a correction term that satisfies the orthogonality condition (2). In section 4 we prove the existence of such a valuation model derived from the RE equation. We achieve this by giving up the information dynamics restrictions but keeping and re-defining Ohlson's "other information". More concretely, using the decomposition property (1) we express expected future REs as their best projection by the current RE plus an "orthogonal" correction term that becomes our "information other than abnormal earnings". Consequently, in contrast to the Ohlson mode, the re-defined "other information" complies with the orthogonality condition (2). The resulting valuation model is a non-linear regression whose empirical specifications can be consistently estimated using techniques from the field of non-parametric statistics.

2.1.5 Cross-sectional differences in regression's parameters

Besides not satisfying the definition of a regression, the linear expression (6) displays coefficients that are not constant in cross-sections. They explicitly depend on the riskiness of the business as well as on firm's economic environment and its accounting practices. As such, cross-sectional estimation of a regression motivated by (6), common in the valuation literature, would yield coefficients hard to interpret. As a confirmation of the theoretical observation, (Kothari and Shanken (2003)) document empirically significant variation in the coefficients related to proxies for changing market growth expectations and discount rates and additional variation consistent with time-varying correlated omitted variables. They conclude that such findings make it difficult to draw unambiguous inferences about the relevance and reliability of financial information from value-relevance linear regressions.

In contrast to the linear solution of Ohlson model, the non-linear regression valuation model derived in section 4 has discount rates as one of the independent variables. Moreover, changing market growth expectation find an expression in the time-varying shape of the functions describing how current RE project future RE (see expression (15)).

To summarize, we have argued that Ohlson's linear specification of the relation between value and accounting numbers is not well suited for consistent empirical estimation *by construction*. We traced this back to the linear dynamics assumptions of the model and to the definition of "information other than (past) abnormal earnings". While it allows for a linear solution to the RE equation, it interferes with the necessary condition for consistent estimation of empirical regressions motivated by such a solution.

2.2 Why consistency matters

price-levels regressions or earnings return regressions are often used on competing sub-samples and then conclusions are drawn by comparing regression coefficients or their R^2s. Suppose that the necessary condition for consistent estimation is not fulfilled, i.e. $\mathbb{E}(error|regressor) \neq 0$, as the error term contains a factor F that determines prices or returns and is correlated with the regressor, $corr(regressor, F) \neq 0$. The estimated coefficient $\hat{\beta}$ of the regressor will then converge to the true coefficient β plus the ratio between the covariance of the regressor and the factor F and the variance of the regressor:

$$\hat{\beta} \rightarrow \beta + cov(regressor, F)/Var(regressor). \qquad (9)$$

Suppose now that the true coefficient β is the same for the two populations but the covariance of the regressor and the factor differs from one sample to the other. As a consequence of expression (9) the estimated $\hat{\beta}$ will be different in the two samples. A comparison based on the inconsistent estimation would conclude that the relation of the regressor to prices or returns differs from one sample to another when the truth is that it is the same.

Similarly, inconsistent estimation can induce differences in R^2s while the relation between the regressor and the independent variable stays constant, i.e. the regression coefficient and the variability of the error term are the same. Recall that the (adjusted) R^2 is defined as:

$$R^2 = 1 - \widehat{Var(error)}/\widehat{Var(Y)},$$

that is one minus the estimated proportion of the variance of prices or returns not explained by the accounting variables. Differences between the covariances of the factor F with the regressor in the two competing samples imply different estimated coefficient $\hat{\beta}$ (according to equation (9)) resulting possibly in error terms of different variances and hence in different R^2s for the two regressions.

2.3 Why R^2 is not a desirable measure of value relevance

The comparison based on R^2 can give erroneous conclusions due to differences in the variability of the independent variable in the competing samples (Gu (2007)). To see this, suppose that regression's coefficients as well as regression's accuracy, i.e. $Var(error)$, are the same in the two competing samples but that the variability of the independent variable is different[12]. The regression for the sample with a higher variance of the independent variable will show a lower explanatory power. In other words, for two competing samples, drawn from two different populations, a difference in the R^2s could formally arise due to differences in populations' parameters (more precisely in the variance of the independent variable) even if the economic relations underlying the two samples are identical.

One possible solution to this issue is to acknowledge the pricing function of the empirical specifications of a valuation model. As such, their fit is more suitably measured by the accuracy of the valuation they yield rather than by the amount of the variability of the independent variable explained by the regressor (see also Gu (2007)). Appropriate statistics of the distribution of the error term would serve as measures of value relevance.

[12] These assumptions imply that the variability of the regressor changes in sync with that of the independent variable, a situation that fits well the case of the price-levels regression.

Mechanisms similar to the ones described above can, of course, distort value relevance conclusions by hiding differences that exist or even reversing the direction of the true differences between competing samples.

3 The alternative research design at a glance

This section discusses in broad strokes a research design that employs a regression valuation model and a non-linear specification for the empirical tests. The details about its development and the precise articulation of its different parts are discussed in sections 4 and 5.

3.1 Ohlson's linear RE solution vs. the regression valuation model

Both models assume the RE equation (3). Next we put side to side the most salient differences between the two valuation models.

3.1.1 Valuation

In Ohlson's solution to the RE the price is a linear combination of realized book values, earnings and dividends plus an error term ν_0 whose coefficients are firm-specific, i.e. the coefficients are functions of firm's risk and the parameters that govern firm's information dynamics (see its expression in (6)) where, generally, $\mathbb{E}(\nu_0|B_0, NI_0, D_0) \neq 0$, i.e. Ohlson's linear solution is not a linear regression. As such, the estimation of an empirical linear regression specification would be biased.

The regression solution to the RE equation states the price-to-book ratio as non-linear regressions on the current values of the RE drivers, i.e. realized accounting profitability, book growth, (book) and risk:

$$\textbf{P/B regression}: \; P_{i,0}/B_{i,0} = \mathfrak{m}_{i,0}(ROE_{i,0}, r_{i,0}, B_{i,0}/B_{i,-1}) + \epsilon_{i,0}, \tag{10}$$

where

$$\mathbb{E}(\epsilon_{i,0} \mid ROE_{i,0}, r_{i,0}, B_{i,0}/B_{i,-1}) = 0.$$

As such, the empirical non-linear regression specification can be consistently estimated using techniques from the field of nonparametric statistics. The unbiased inference is guaranteed *by construction*.

The two terms of the regression valuation models have clear, intuitive meanings. The function $\mathfrak{m}$ represents the price setting contribution of future earnings expectations informed only by current values of the RE drivers. Its functional form is prescribed by the RE valuation model and by the way current abnormal earnings project future abnormal earnings. As such, it is not explicit but can be consistently estimated. The error terms represent the correction to pricing brought by other information than earnings and book values. The larger the size of the error term, the bigger the adjustment other information brings to expectations about future earnings and hence, the less useful the current values of the drivers for pricing purposes.

3.1.2 How current RE project future RE

Current levels of earnings and book values are associated to prices to the extent to which current values project future values and inform the formation of expectations about future value creation. Hence the importance of detailing, for the given models, of the mechanism that incorporates the current levels of the RE drivers into prices.

For the linear solution to the RE equation, future REs are a fraction of the realized RE plus a correction term that is proportional to Ohlson's "information other than abnormal earnings":

$$\mathbb{E}_0(RE_{i,j}) = \omega_i^j RE_{i,0} + (\gamma^{j-1} + \omega\gamma^{j-2} + \omega^2\gamma^{j-3} + \ldots + \omega_i^{j-1})\nu_{i,0}.$$

Note that the correction term changes with the horizon only through the change of the proportionality to current "information other than abnormal earnings".

For the regression solution to the RE equation, future REs (deflated by the current book value) are decomposed into the best projection given the current RE, possibly a non-linear function of RE (that depends on the horizon) plus a correction term that is our re-definition of the "information other than abnormal earnings":

$$\begin{aligned}\mathbb{E}_0(RE_{i,j}/B_{i,0}) &= \mathbb{E}[RE_{i,j}/B_{i,0} \mid RE_{i,0}] + \varepsilon_{i,0}(j)\\ &=: f_{i,0}(j, RE_{i,0}) + \varepsilon_{i,0}(j).\end{aligned}$$

The functions $f_{i,0}(j,\cdot)$ are expressions of market expectations (at time 0, for the firm i, at the horizon j) for future growth in value creation. They are horizon-specific and may change from a time mark to the next one reflecting changing growth expectations ($f_{i,1}$ might be different from $f_{i,0}$). Differences captured by the horizon variable, i.e. $f_{i,0}(j,\cdot)$ vs. $f_{i,0}(k,\cdot)$, model dissimilarities in the way current RE projects future RE at various horizons (the projections are more informative for smaller j's, i.e. closer future time instances, than for larger j's). Moreover, the correction term $\varepsilon_{i,0}(j)$ changes with the horizon: different horizon forecasts given current RE are corrected by horizon specific "other information" terms.

Motivated by the fact that the persistence of abnormal earnings is determined mainly by industry-specific factors, the empirical specifications will assume the relative homogeneity of the functions $f_{i,0}$ (and hence $\mathfrak{m}_{i,0}$) within industries, i.e. $f_{i,0} \simeq f_{h,0}$ if the firms i and h belong to the same industry and have comparable sizes.

3.2 Nonparametric estimation of regression error

The non-linear empirical specification of the valuation regression solution to the RE equation is consistently inferred using techniques from the field of nonparametric regression. Concretely, the P/B multiple P_0/B_0 of a given firm is predicted as the average ratio corresponding to firms most similar in the dimensions of return on equity, book growth, cost of equity and size.

The resulting estimating procedure is formally close to a P/B valuation, an approach familiar to the accounting community. In the inference frame, the P/B price is a consistent estimate of what the value of equity would be if expectations about future earnings were to be formed using only the information contained in the current levels of the RE drivers.

While the economic relation expressed by the function $\mathfrak{m}$ is of interest in itself, in our research design, the estimates serves mainly to consistently infer the error term ϵ in (10) which we interpret as a value relevance measure. The details of the nonparametric inference methodology are given in Section 5.

3.3 Regression error as value relevance measure

Besides a valuation model that yields empirical specifications for testing, association analysis calls for a measure. The literature on comparative value relevance, earnings timeliness and accounting conservatism has privileged the explanatory power of various linear regressions. In the value relevance setting, a number of studies have taken issue with the reliability[13] of R^2 as an association measure (Brown et al (1999), Gu (2005)). In particular, Gu (2007) argues that the price-levels regression is more than a linear model whose power to explain variability might be measured by R^2. As an empirical specification of a valuation model, its fit is more suitably measured by the accuracy of the valuation it yields. He proposes the standard deviation of the price-levels regression's errors (with proper control for scale) as an association measure.

We employ an alternative measure of dispersion, the median value of absolute relative errors from the regression equation (10). Unlike standard

[13] See also the brief discussion in section 2.3 in the Appendix.

deviation, this measure is robust to outliers and allows for accurate statistical testing of change.

4 Derivation of a regression valuation model

In this section we prove the existence of a valuation model derived from the RE equation that can be consistently estimated empirically, i.e. for which the orthogonality condition (2) on the error term holds. We achieve this by doing without the information dynamics assumptions of the Ohlson model and by re-defining the "information other than abnormal earnings".

Succinctly, our approach works as follows. "Information other than abnormal earnings" is introduced in the context of price setting RE expectation formation. It is defined via the decomposition property in (1) as the correction[14] to the best (possibly non-linear) forecast of future RE given current RE. As such, it complies *by definition* with the orthogonality constraint. Consequently, the price, obtained as the sum of discounted future RE, decomposes into the sum of discounted best forecasts of future RE at all time horizons plus a correction term due to "other information". Since it is the sum of discounted "other information" corrections at all time horizons and since each "other information" complies with the orthogonality constraint, the correction term in the price fulfills the condition for being a regression error term. The resulting valuation model is hence a non-linear regression that can be consistently estimated using techniques from the field of non-parametric statistics that we discuss in section 5.

Motivated by the RE model, it is convenient to think of prices as being set through the same discounting approach as value with the sole difference that the likelihood given by the market to different growth scenarios of future value creation might differ from the ones used to establish value. Denoting by $RE_{i,t} := (ROE_{i,t} - r_{i,0}) \times B_{i,t-1}$, the residual earnings of the firm i at time t, we write:

$$
\begin{aligned}
P_{i,0} &= B_{i,0} + \sum_{t=1}^{\infty} \frac{\mathbb{E}_0^M(RE_{i,t})}{(1 + r_{i,0})^t} \\
&= B_{i,0} \left(1 + \sum_{t=1}^{\infty} \frac{\mathbb{E}_0^M(RE_{i,t}/B_{i,0})}{(1 + r_{i,0})^t} \right),
\end{aligned}
$$

[14] In the case of Ohlson's model, the "information other than abnormal earnings", while introduced by the time-series dynamics of the model, was proportional to the correction to the best *linear* forecast of future RE given current RE (equation (5)).

where the notation $\mathbb{E}^M$ indicates that market expectations incorporated in prices are formed by weighting the various RE growth scenarios with possibly different weights from those used to form the expectations yielding the value. The expectation formation[15] in the case of value is denoted by $\mathbb{E}$. Our main result can be stated as:

Proposition (Valuation regression solution to the RE equation) *The equation*

$$P_{i,0}/B_{i,0} = 1 + \sum_{t=1}^{\infty} \frac{\mathbb{E}_0^M(RE_{i,t}/B_{i,0})}{(1+r_{i,0})^t} \tag{11}$$

admits a regression solution relating price-to-book ratio $P_{i,0}/B_{i,0}$ to the current values of the RE drivers, i.e. current ROE, current book growth, and equity risk, $RE\ DR_{i,0} := (ROE_{i,0}, B_{i,0}/B_{i,-1}, r_{i,0})$:

$$P_{i,0}/B_{i,0} = \mathfrak{m}_{i,0}(RE\ DR_{i,0}) + \epsilon_{i,0}, \tag{12}$$

where $\mathfrak{m}_{i,0}$ is a possibly non-linear function and

$$\mathbb{E}^M(\epsilon_{i,0} \mid RE\ DR_{i,0}) = 0. \tag{13}$$

The function $\mathfrak{m}$ represents the price setting contribution of expectations about future earnings given the current levels of accounting profitability and book growth. The error term is a value correction grounded in other information and beliefs.

The choice of independent variables in the previous proposition could be different. i.e. the statements can be adapted for other research designs. Examples of alternative specifications include

$$RE\ DR_{i,0} = (NI_{i,0}, B_{i,0}, B_{i,0}/B_{i,-1}, r_{i,0}),$$

$$RE\ DR_{i,0} = (CFO_{i,0}, B_{i,0}, B_{i,0}/B_{i,-1}, r_{i,0})$$

$$RE\ DR_{i,0} = (CFO_{i,0}, TACC_{i,0}, B_{i,0}, B_{i,0}/B_{i,-1}, r_{i,0})$$

or

$$RE\ DR_{i,0} = (CFO_{i,0}/B_{i,0}, TACC_{i,0}/B_{i,0}, B_{i,0}/B_{i,-1}, r_{i,0}),$$

where CFO stands for cash flow from operations while $TACC$ denotes total accruals.

In the sequel we argue that the functions $\mathfrak{m}_{i,0}$ are industry-specific. That is, they are approximatively equal for firms of comparable size in the same

[15] Technically, the likelihood of prices incorporating different expectations is modeled by the measure under which the expectations are taken. The expectations with respect by the market measure are denoted by E^M.

industry. As such, their estimation becomes feasible using any consistent non-parametric estimation approach.

Although formally the results of the proposition are direct consequences of the decomposition property (1 and 2) we split the derivation in a couple of steps to better convey the intuition behind the stated decomposition.

4.1 Realized abnormal earnings project future abnormal earnings

The future RE (deflated by book value of equity) can be expressed as a function of the drivers of abnormal earnings accounting profitability, risk and book growth:

$$RE_{i,t}/B_{i,0} = (ROE_{i,t} - r_{i,0}) \times (B_{i,t-1}/B_{i,0}) = (ROE_{i,t} - r_{i,0}) \\ \times (B_{i,t-1}/B_{i,t-2}) \times (B_{i,t-2}/B_{i,t-3}) \times \ldots \times (B_{i,1}/B_{i,0}).$$

The main results formalize the following intuitive mechanism that associates realized accounting items to market prices. Realized earnings and book values are associated to prices to the extent to which their current values project[16] future earnings and book values. In doing so they inform the process of formation of expectations about future value creation. This two-step process that shapes association can be rendered rigorous as follows.

First, apply the decomposition property in (1) to the pair $(RE\ DR_{i,0}, RE_{i,t}/B_{i,0})$ to formalize the projection of future RE by current RE drivers, i.e. current ROE, current book growth, and equity risk. For the firm i, we write:

$$\begin{aligned} RE_{i,t}/B_{i,0} &= \mathbb{E}^M[RE_{i,t}/B_{i,0} \mid RE\ DR_{i,0}] + \delta_{i,0}(t) \\ &=: f_{i,0}(t, RE\ DR_{i,0}) + \delta_{i,0}(t). \end{aligned} \tag{14}$$

(Recall that the notation $E^M(Y|X)$ stands for the expected value of Y given X, the best predictor of Y given X which is a non-linear function of X.) In words, we decompose the future RE t time units ahead, into its best projection by current RE, $\mathbb{E}^M(RE_{i,t}|RE\ DR_{i,0})$ and a correction term, orthogonal to the projection. The orthogonality condition reads:

$$\mathbb{E}^M[\delta_{i,0}(t) \mid RE\ DR_{i,0}] = 0.$$

To see the implication of the previous decomposition for the process of expectation formation condition with the set of information available at time

16 Bernard (1994), Penman (1991), Nissim and Penman (2001), among others, show that realized ROE's predict future ROE's, while Nissim and Penman (2001) documents the relation between realized and future book growth.

0 to get:

$$\begin{aligned}\mathbb{E}_0^M(RE_{i,t}/B_{i,0}) &= f_{i,0}(t, RE\ DR_{i,0}) + \mathbb{E}_0^M(\delta_{i,0}(t)) \\ &:= f_{i,0}(t, RE\ DR_{i,0}) + \varepsilon_{i,0}(t),\end{aligned} \tag{15}$$

since $\mathbb{E}_0^M(f_{i,0}(t, RE\ DR_{i,0})) = f_{i,0}(t, RE\ DR_{i,0})$. (Formally this expression can be compared to the corresponding one in the Ohlson model given by (5).)

This decomposition reflects the fact that expectations are formed taking into account not only the realized levels of the RE drivers $RE\ DR_{i,0}$ but also other information available at time 0. The contribution of "other" information to the expectation formation process is captured by the correction term $\varepsilon_{i,0}(t)$. This term is orthogonal on the best projection by current RE. To see this, note that, by the theorem of iterated expectations,

$$\begin{aligned}\mathbb{E}^M(\varepsilon_{i,0}(t) \mid RE\ DR_{i,0}) &= \mathbb{E}^M(\mathbb{E}_0^M(\delta_i(t)) \mid RE\ DR_{i,0}) \\ &= \mathbb{E}^M(\delta_i(t) \mid RE\ DR_{i,0}) = 0.\end{aligned}$$

Its orthogonality (on the best projection of $RE_{i,t}$ by current RE) formalizes the intuition that, in the process of expectation formation, "other" information is complementary to that contained in the levels of bottom items. Consequently, in reference to the Ohlson model, we call the correction term $\varepsilon_{i,0}(t)$ "other information than current abnormal earnings" contributing to the formation of expectations about the RE t times units ahead. Most importantly, the "other information" term is orthogonal on the vector of current values of the drivers *by construction*.

The functions $f_{i,0}$ describe the value-creation growth for the firm i given the level of the RE drivers at time 0. They model the persistence of abnormal earnings and are an expression of the factors that determine RE: firm size, product-type, capital intensity, barriers-to-entry, accounting practices (see also section 4.3). The empirical specifications of the valuation regression solutions will assume that they are roughly similar for firms of comparable size within the same industry. Examples of such functions include:

$$\begin{aligned}f_{i,0}(t, ROE_{i,0}, B_{i,0}/B_{i,-1}, r_{i,0}) &= (1 + \mathfrak{g}_{i,B})^{t-1} \times (\mathbb{E}[ROE_{i,t} \mid ROE_{i,0}] - r_{i,0}) \\ &\quad \times B_{i,0}/B_{i,-1},\end{aligned}$$

when growth expectations are modeled by a stable growth in book value $B_{i,s}/B_{i,s-1} = 1 + \mathfrak{g}_{i,B}$.

The term $\varepsilon_{i,0}(t)$ describes the impact of information other than current book and earnings on growth expectations. It represents the correction to expectations formed only on the basis of current bottom-line items which is due to information other than the level of realized RE drivers. In other words, the curve $\varepsilon_{i,0}(t)$ makes adjustments to the growth curve $f_{0,i}(t, \cdot)$ (which incorporates only partial information) reflecting the larger pool of information available at time 0. Consequently, $|\varepsilon_{i,0}|$ is a measure of the utility of current book and earnings for expectations formation and hence for price setting. The larger $|\varepsilon_{i,0}(t)|$ is, the less current values of the RE drivers shape expectations about future earnings at time t.

4.2 Firm-specific P/B regression valuation model

The expression of the P/B ratio in (11) together with the proposed decomposition of the expected RE in equation (15) imply:

$$\begin{aligned} P_{i,0}/B_{i,0} &= 1 + \sum_{t=1}^{\infty} \frac{f_{i,0}(t, RE\ DR_{i,0})}{(1+r_{i,0})^t} + \sum_{t=1}^{\infty} \frac{\varepsilon_0(t)}{(1+r_{E,0})^t} \\ &=: \mathfrak{m}_{i,0}(RE\ DR_{i,0}) + \epsilon_{i,0}, \end{aligned}$$

where the errors ϵ_0 verify:

$$\mathbb{E}^M(\epsilon_{i,0} \mid RE\ DR_{i,0}) = 0,$$

In words, the contribution to price of all discounted future RE over book value, decomposes into the sum of discounted best forecasts of future RE (by the current level of RE drivers) at all time horizons plus a correction term. This term is the sum of discounted "other information" corrections to expectations about future RE at all time horizons. It represents a correction to a ratio set upon expectations informed only by the current levels of the RE drivers. Since each "other" information term complies with the orthogonality constraint, their sum fulfills the condition for being a regression error term as stated in our main result:

$$\mathbb{E}^M(\epsilon_{i,0} \mid RE\ DR_{i,0}) = 0.$$

The expression above states the relation between market value P_0 and realized book value, B_0, and return on equity, ROE_0, in the frame of non-linear regression. It represents the P/B ratio as the sum of a non-linear regression function and an error term ϵ with a zero mean, conditional on the regressors.

4.3 The determinants of $f_{\cdot,0}$

Although the valuation regression solution in (12) are firm-specific, i.e. without other assumptions, the regression function is different for every firm, economic considerations suggest that the regressions functions are similar for firms with common characteristics. Recall that the building blocks of the regression function, the functions $f_{\cdot,0}$, model the persistence of abnormal earnings (see definition (14)) and as such are an expression of the factors that determine it. Economic arguments point towards the fact that the persistence of abnormal earnings is determined mainly by industry-specific factors. Consequently, one could assume that the regression functions for firms within the same industry are similar. The relative homogeneity of the regression functions within industries is an assumption needed for the empirical specification of the valuing regressions.

The economics and strategic management literatures regularly identify four observable traits with an impact on profits persistence which in turn affect the evolution of abnormal earnings: firm size, product-type, barriers-to-entry, and capital intensity (Lev (1983), Baginski et al (1999)).

Larger firms have more financial resources to diversify and hence to stabilize growth which leads to a more persistent earnings flow (Scherer (1973), Martin (1988)). The less stable patterns of demand for durable goods firms result in less sustainable residual earnings relative to nondurable goods firms (Friedman (1957), Darby (1972), Zarnowitz (1972), Caves (1987)). Capital-intensive firms display more volatility of earnings relative to the smoother earnings stream of low capital-intensive firms, possibly due to operating leverage reflected by the proportion of fixed cost to total cost (Scherer (1973), Lev (1983)). As the persistence of abnormal earnings is a function the market pressures facing the firm and its production technology, higher barriers-to-entry decrease competition by limiting entry into an industry which in turn leads to market share stability, and to sustainable earnings growth (Stigler (1963), Mueller (1977), Kamerschen (1968)).

Accounting practices have also an effect on the persistence of abnormal earnings (Feltham and Ohlson (1995), Feltham and Ohlson (1996), Zhang (2000), Cheng (2005)). While under unbiased accounting and perfect competition a firm's residual earnings equals its cost of equity, if the competition is imperfect, the firm can charge prices higher than its costs, resulting in economic rents and abnormal ROE that is no longer zero. Under conservative accounting, accounting measures depart from economic measures and a firm's abnormal ROE can be different from zero even if the firm operates under perfect competition. While accounting practices vary widely between firms, it is reasonable to assume a certain homogeneity within the same industry.

Besides size, the main economic and accounting factors that influence the persistence of abnormal earnings (and hence determine the functions $f_{i,0}$ and $g_{i,0}$) are industry-specific. Moreover, Cheng (2005) in an economic-theory-motivated investigation of the firm characteristics that determine abnormal

RE documents that firm differential abnormal ROE increases with market share, firm size, firm level barriers to entry, and firm conservative accounting factors. For the empirical specifications of the regression valuation model we will assume that firm level barriers to entry and firm conservative accounting factors vary mainly between industries being relatively constant within industries. We will also suppose that size is a good proxy for market share.

To summarize, based on the economic considerations above, we will assume that, for all firms of a comparable size in the same industry I, the predictions of future RE given realized RE have roughly the same functional form:

$$f_{i,0}(t,\cdot) \simeq f_{I,0}(t,\cdot).$$

(Some empirical evidence supporting this hypothesis is provided in Appendix, section C.)

This hypothesis is essential for the empirical specification of the valuation regression (12). The relative homogeneity of the regression functions of firms of similar size within industries is needed for the estimation of the nonparametric regressions. It is worth noting that in the empirical application, the homogeneity assumption is practically required to hold for a small number of "similar" firms (on average three), i.e. the "neighbors" from which the regression function is inferred. As a consequence, the firm and the neighbors that contribute to the estimation belong to a narrowly-defined industry (three or four digit SIC code) and are reasonable close in size. This empirical fact makes the assumption less of a constraint.

4.4 The P/B regression valuation model

Consequently, for firm i in the industry I, at moment 0, we can state the first operational form of the non-linear specification, the **P/B regression**, as:

$$\begin{aligned} P_{i,0}/B_{i,0} =& 1 + \sum_{t=1}^{\infty} \frac{g_{I,0}(t, RE\ DR_{i,0})}{(1+r_{i,0})^t} + \epsilon_i \\ :=& \mathfrak{m}_{I,0}(RE\ DR_{i,0}) + \epsilon_{i,0}. \end{aligned} \tag{16}$$

The function $\mathfrak{m}$ represents the price setting contribution of expectations about future earnings given the current levels of accounting profitability and book growth. The error term is a value correction grounded in other information and beliefs.

Note that condition (13) implies that the errors and the predictors are uncorrelated, an essential condition for the unbiased estimation of the regression. In consequence, the function $\mathfrak{m}$ can be consistently estimated using results from the field of nonparametric regression.

To summarize, the non-linear specification avoids the issue of inconsistent inference that affects the linear frame by working with a more general form of the economic link. The lack of correlation between the errors and the predicting variables, a condition central to the consistency of the estimation, is guaranteed *by construction*. This is possible by appropriately re-defining Ohlson's "other information than abnormal earnings" as the orthogonal correction term to expectations about future RE given the current level of abnormal earnings. The non-linear specifications can be consistently estimated in the frame of nonparametric regression under the economically-motivated assumption of homogeneity of the regression functions for firms of similar size within the same industry.

The quantities

$$B_0 \times \mathfrak{m}_{I,0}$$

are valuations based on current levels of the RE drivers. They represent a (fictitious) price that incorporates earnings expectations built only on the current levels of earnings and book values. The differences

$$P_0 - B_0 \times \mathfrak{m}_{I,0}$$

are the pricing errors of the empirical specification of the valuation regressions. These valuation errors measure the extent to which prices are informed by other information than realized bottom-line items. More precisely, they represent the correction brought by information other than the realized RE drivers to the fictitious price incorporating expectations formed only on the basis of current values of bottom-line items. The size of the pricing errors will allow us to, first, chose the specification to be used in a particular empirical analysis, and second, to measure the strength of association.

5 Estimation of the non-linear specification

The fields of statistical learning, data mining and predictive modeling have developed a wealth of approaches to the estimation of a non-linear relation as the one in equation (16). The k-Nearest-Neighbor (kNN) is one of the widely used algorithms with many successfully applications in medical research, business applications, etc. aiming at estimating a non-linear regression function and at making predictions of the dependent variable. It belongs to the wide class of local averaging algorithms that create on-demand predictions from close data. The predictions are produced through an averaging process, where the value proposed is the average of the values corresponding to the k closest data points to the point where the prediction is sought (also called 'training points'). A similarity measure is used to locate close data.

There is no set rule for choosing the optimal value for k. Usually, to find the right k, a search through a grid of different values of the parameter is performed and the best choice is made based on cross validation results. Section 5.2 discusses the choice of the optimal number of peers according to the guidelines of the cross-validation methodology.

5.1 kNN approach - non-linear estimation by local averaging

The expression in (16) indicates that to construct a local averaging estimate for the P/B ratio for a firm i with profitability R, book growth g and risk r, one should average the P/B ratios corresponding to firms with returns on equity, book growth and cost of equity that are "close" to the values (R, r, g). Since the considerations in section 4.3 indicate size (denoted by S) as an important determinant of the evolution of abnormal earnings, we add it as one of the criteria for determining peers. If we re-order the sample according to the proximity of firms to the value (R, r, g, S) and denote by (j) the j-th closest firm to the target (from industry I in the cross-section at time 0), then the kNN regression function estimate is defined as:

$$\widehat{\mathfrak{m}}_{i,0} = \widehat{\mathfrak{m}}_{I,0}(R, r, g, S) = \frac{1}{k} \sum_{j=1}^{k} P_{(j),0}/B_{(j),0}. \tag{17}$$

One can prove that, under the essential condition in equation (13), the estimator is consistent. Under mild conditions on the smoothness of the function $\mathfrak{m}$ the rate of convergence is also known (Györfi et al (2002)). We emphasize once again the importance of condition (13) which guarantees an unbiased estimation of the non-linear regression function $\mathfrak{m}$.

We recognize in expression (17) the definition of the predicted multiple according to the multiple valuation approach as described in section A of the Appendix. Expressions in (16) and (17) establish a close connection between the non-linear empirical specification under discussion and the methodology of multiple valuation.

In particular, the estimated (fictitious) value of equity that incorporates earnings expectations built only on the current levels of earnings and book values, $B_0 \times \widehat{\mathfrak{m}}_{i,0}$, is precisely the value predicted by the P/B valuation.

Regression's errors $P_0 - B_0 \times \widehat{\mathfrak{m}}_{i,0}$, at the core of our inference on value relevance, coincide with the pricing errors of the P/B multiple valuation.

Note that the non-linear regression (16) provides clear guidance for selecting the features that inform the choice of peers. Its predictor variables specify the characteristics defining comparable firms: similarities are to be searched in firm's profitability, book growth and riskiness. To fully determine the set of comparable companies, only the number of peers k need to be specified.

To summarize, multiple valuation can be viewed as the implementation of the kNN approach for the non-linear regression in equation (16). To value a firm, a prediction of its P/B multiple is required. The predicted multiple is constructed through local averaging: the proposed value is the average of the multiples of k "closest" firms. Similarity is defined through the distance in the space of the predictors. k is the size of the set of peers.

5.2 Optimal choice of k

Choosing the optimal model is an important and well-understood issue in the fields of data mining and predictive modeling. A number of different effective model selection methodologies have been developed and researched including cross-validation and bootstrapping. For the nearest neighbor algorithm the cross-validation is a natural choice. According to this method, the optimal k is the one that minimizes the empirical mean square error defined as follows. For the firm i denote by $\hat{\mathfrak{m}}_{0,i}^{(k)}$ the predicted value of the function $\mathfrak{m}$ using exactly k nearest neighbors. The empirical mean square error corresponding to this choice of the number of neighbors is defined by:

$$MSE(k)^2 = \frac{1}{n} \sum_{i=1}^{n} (P_{i,0}/B_{i,0} - \hat{\mathfrak{m}}_{0,i}^{(k)})^2, \tag{18}$$

where n is the total number of firms in the cross-section under study. The optimal number of nearest neighbors, k_{opt}, is the one that minimizes the function $k \to MSE(k)$.

One can show that, under the condition (13), this data driven choice of the optimal number of neighbors converges to the best deterministic choice of the parameter (Györfi et al (2002)).

5.3 Estimated errors

In the non-linear regression-based research design under discussion, the value relevance of earnings and book values is proportionate to the size of the error term that records the extent to which the expectations of future earnings are based on information other than realized bottom-line items. Following Easton and Sommers (2003)[17] as well as the multiple valuation literature, we focus our analysis on the absolute value of the relative errors defined as:

$$E_{0,i} := \frac{P_{0,i} - B_{0,i} \times \hat{\mathfrak{m}}_{i,0}}{P_{0,i}}. \tag{19}$$

This relative error represents the proportion of the price corresponding to earnings expectations founded on information other than the realized earnings and book values.

We note that the relative error defined in (19) coincides with the relative pricing error of the statistically optimal P/B multiple valuation. In other words, in the non-linear regression-based research design we propose, the value relevance of earnings and book values is commensurate to the pricing errors of a statistically optimal version of P/B multiple valuation. The discussion of empirical results on value relevance can hence be framed in valuation terminology.

6 Why use the alternative research design - empirical evidence

This section provides evidence of the usefulness of the alternative research design introduced in this paper. Towards this end, we test four empirical predictions using, one one hand, the conventional value relevance research design based on price-levels and returns-earnings specifications of the Ohlson model with regressions' R^2 a value relevance measure and, on the other hand, the alternative research design. First prediction is that bottom-line items are more value-relevant for larger firms than for smaller firms. The second and third predictions state that prices of firms with historically more predictable earnings and those whose earnings stream display lower volatility are more associated to current values of earnings than those of firms with opposite characteristics. The fourth prediction is that earnings whose accrual component is of higher quality are more value relevant than earnings with lower quality accrual component.

We chose the four predictions for their solid economic motivation and for their intuitive appeal. We document that the tests based on the two research designs yield contrasting answers. Counter-intuitively, tests based on

[17] "We observe that it is difficult to support an argument that any variable is a better measure of scale than market capitalization especially in view of the central role of market prices in market-based accounting research."

the price-levels regression specification find higher value relevance of the bottom items for smaller firms and firms with lower quality accrual component of earnings while tests based on the returns-earnings regression do not find significant differences between firms with contrasting attributes. Contrary to that, the alternative research design provides evidence supporting all four predictions: size, earnings predictability, earnings volatility, and accrual quality have been constant determinants of value relevance through the years of the sample.

We also chose our examples such that they include a prediction previously discussed in the widely accepted paradigm where stock prices appear as dependent variable and contemporaneously accounting data appear as independent variables and three novel ones. Collins et al (1997) mentions size as one of the factors determining value relevance. While Francis et al (2004) and Francis et al (2005) show that earnings predictability and accrual quality impact cost of debt and equity capital, to the best of our knowledge, the earnings attribute predictions have not yet been tested in the price-accounting variable frame.

6.1 Development of empirical predictions

Previous research has shown that earnings of smaller companies tend to be harder to forecast than those of larger ones. Big firms have more resources, have highly trained and well compensated management, their products are often better diversified. As a result they produce more predictable, steadier earnings over time. A less predictable future earnings means more uncertainty in valuation, i.e. less association between prices and current earnings.

Furthermore, accounting theory predicts that the accounting earnings of firms with higher risk or growth measure future cash flows with greater error and bias (see Skinner (1993) for a contracting explanation). Hence, the extent to which current RE drivers project future earnings is likely to be smaller for riskier and higher growth firms. As smaller firms are riskier than larger ones, one could expect differences in the accuracy of valuation between the two classes of companies. Hence our first prediction:

P1: The association of prices with realized earnings and book values is stronger for larger firms.

Prices are associated with realized earnings to the extent to which current values project future values. As such, prices of firms with more predictable earnings should be informed to a larger extent by the realized earnings than prices of firms whose earnings are more difficult to predict. Hence our second prediction:

P2: Association between prices and realized earnings is increasing with earnings predictability.

Dichev and Tang (2009) argues that earnings volatility mainly arises from two factors, volatility due to economic shocks and volatility due to problems in the accounting determination of income, and that both factors reduce the predictability of earnings. They bring empirical evidence that earnings volatility provides reliable discrimination on relative earnings predictability up to five-years ahead. In other words, earnings of firms with less volatile earnings can be forecasted more accurately. Hence our third prediction:

P3: Earnings of firms with less volatile earnings streams are more value relevant than those of firms with higher earnings volatility.

Accruals inform investors about the mapping of accounting earnings into cash flows and as such, their quality is essential to the process of expectation formation that leads to prices. Francis et al (2004) and Francis et al (2005) bring evidence that firms with poor accruals quality have higher costs of debt as well as of equity capital than firms with good accruals quality. Our third prediction extends their findings to the value relevance frame:

P4: The value relevance of bottom line items is increasing in the quality of the accrual component of earnings.

6.2 Definition of the attributes

The four attributes that appear in the empirical predictions are size, earnings predictability, earnings volatility, and accrual quality. In the sequel we discuss how they are defined. A summary description of all variables is given in the Appendix. The base earnings measure is net income before extraordinary items (NI). Total accruals (ACC) is calculated as $ACC = \Delta CA - \Delta CL - \Delta CASH + \Delta STDEBT - DEPR$, where the variables are change in current assets, change in current liabilities, change in cash, change in short-term debt, and depreciation in the fiscal year ending at t. Cash flow from operations (CFO) is calculated as $CFO = NI - ACC$. Current accruals (CACC) is computed as $CACC = \Delta CA - \Delta CL - \Delta CASH + \Delta STDEBT$. The earnings predictability and accrual quality measures are estimated for each firm and year for rolling 10-year periods $t - 9$ to t.

Size is defined as the market value of the firm. Following Francis et al (2004), we define predictability as the ability of earnings to predict itself. Predictability is a desirable earnings attribute from the perspective of both standard setters and analysts and an essential component of valuation (Lee (1999)). Following previous research (Lipe (1990), Francis et al (2004), Perotti and Wagenhofer (2014)) we measure earnings predictability as the error variance from an autoregressive model of order one $AR(l)$ for annual earnings (measured as firm's net income before extraordinary items in year t) scaled by the book value of equity at the beginning of period t:

$$NI_{i,t} = \phi_{i,0} + \phi_{i,1} NI_{i,t-1} + u_{i,t}. \tag{20}$$

Large (small) values of predictability, i.e. $Var(u)$, imply less (more) predictable earnings.

Earnings volatility is measured by taking the standard deviation of the deflated earnings for the most recent ten years. To unify the presentation we use the inverse of the standard deviation as the measure of the attribute: the higher the inverse of the standard deviation, the more favorable the outcome.

We believe that uncertainty in accruals is best captured by the measure of accruals quality developed by (Dechow and Dichev (2002)). In their model, accruals quality is measured by the extent to which working capital accruals map into operating cash flow realizations. Motivated by the assumption that accruals quality is affected by the measurement error in accruals the model regresses working capital accruals on cash from operations in the current period, prior period and future period. The unexplained portion of the variation in working capital accruals is an inverse measure of accruals quality (a greater unexplained portion means poorer quality).

In line with Dechow and Dichev (2002) and Francis et al (2005) we define our measure of accrual quality (AQ) based on the firm-level specification[18] of the model:

$$CACC_{i,t} = b_{i,0} + b_{i,1} CFO_{i,t-1} + b_{i,2} CFO_{i,t} + b_{i,3} CFO_{i,t+1} + \nu_{i,t}. \tag{21}$$

6.3 Sample description

Our sample consists of US non-financial firms drawn from Compustat and CRSP over a 47-year period from 1967 to 2013. Some of our analyses require measures of three earnings attributes. The construction of the measures is based on prior research. We adopt the convention that larger values of the attribute indicate more favorable outcomes. We measure the attributes on a firm- and year-specific basis, making use of the relevant accounting information for rolling ten-year windows, $t-9, \ldots, t$. The use of the firm as its

[18] (Dechow and Dichev (2002)) state that the firm-level specification of the model has a better theoretical grounding and better empirical fit.

own benchmark mitigates concerns that differences among firms in a given industry give rise to noisy measures of the attributes, as would be the case if we measured the attributes relative to industry norms. However, since the three earnings quality measures are computed over a 10-year rolling estimation period from a larger selection of accounting variables, the corresponding empirical predictions are tested over the shorter period 1976-2013 and on a smaller sample of firm-year observations. To avoid excluding too many firms, we do not require data availability for each firm over the full 47-year period. As a consequence, the composition of firms in the yearly samples varies. The data requirements constrain the smaller sample to larger and more successful than firms that do not meet the time-series data requirement. Overall, we believe that the benefits afforded by the use of the firm as its own benchmark offset the sample bias towards more stable and longer-lived firms. All accounting data are winsorized at the 1% level to control for outliers.

The total sample (from 1967 to 2013) includes 125,255 firm-year observations with the number of firms in each year varying between 1,002 and 4,805 with an average of 2,665 (median of 2,521). The smaller samples (from 1976 to 2013) for which we report the results contains 112,364 firm-years for the size attribute and 43,957 firm-year observations for the earning attributes with the number of firms in each year varying between 1,322 and 4,805 with an average of 2,957 (median of 3,064) and between 705 and 1,668 with a mean of 1,127 (median of 1,086) respectively (see also Figure 6 in the Appendix). Table 1 gives descriptive statistics of the main variables used to implement the alternative research design while Table 2 displays the descriptive statistics of the variables used to calculate the three measures of earnings quality. More details about the construction of the sample are presented in section B in the Appendix.

Variable	Mean	S.D.	10%	25%	50%	75%	90%
P_0/B_0	2.55	2.50	0.72	1.11	1.77	2.99	5.11
B_0/B_{-1}	1.17	0.98	0.78	0.98	1.08	1.20	1.50
ROE_0	0.05	0.33	-0.25	0.01	0.11	0.18	0.28
E_{-1}/P_{-1}	0.02	0.15	-0.11	0.01	0.05	0.08	0.13
$log(MV_{-1})$	5.31	1.99	2.77	3.80	5.16	6.68	8.08

Table 1: Descriptive statistics of the main variables used to implement the alternative research design.

Variable	Mean	S.D.	10%	25%	50%	75%	90%
$CACC$	0.01	0.06	-0.05	-0.02	0.00	0.03	0.07
CFO	0.08	0.11	-0.03	0.04	0.09	0.14	0.19
$Predictability$	0.11	0.14	0.02	0.03	0.06	0.13	0.24
$Volatility$	0.13	0.16	0.02	0.04	0.08	0.15	0.27
$Acc.Quality$	0.02	0.02	0.00	0.01	0.02	0.03	0.05

Table 2: Description statistics of the variables used to calculate the three measures of earnings quality.

6.4 Conventional research design analysis

In this section we perform an analysis of the value relevance of size, earnings predictability, earnings volatility, and accrual quality employing the standard approach in relative associations studies. We test for differences in the R^2 of regressions for firms with contrasting attributes. The value of the attribute with the greater $R^2$2 is described as being more value-relevant. Concretely, we estimate two regression specifications of the Ohlson model, the price-levels regression and the returns-earnings regression. In doing so, we follow a practice common in the literature which complements the results of a plain-vanilla price-levels regression with those of the flow specification of the Ohlson model as a robustness check as well as a way of mitigating the potential for scale bias. While another possibility to address the bias issue would be to express each of the variables in ratio form by deflating with a proxi for scale, the lack of consensus on the choice of the deflator makes this alternative less appealing.

The pragmatic approach that pairs the price-levels and the returns-earnings regressions overcomes the differences between two perspectives on the econometric issues of the Ohlson model empirical specifications. Barth and Kallapur (1996) and Barth and Clinch (2009) argue that scale is unobservable and depends on the research context. The second article compares five different scaled price-levels regressions (deflation by the number of shares, book value, price of shares one year before the valuation, and market value) together with the returns-earnings regression and conclude that share-deflated and undeflated specifications generally perform the best[19], regardless of the type of

[19] For each specification, the authors compare frequency of correct rejection that the coefficients equal zero, coefficient bias and absolute error, and regression explanatory power.

scale effect. On the other hand, Easton and Sommers (2003) argue that, due to the central role of market prices in accounting research, the best measure of scale is market capitalization (instead of sales revenue-as suggested by Brown et al (1999)). The consequent course of action for researchers is to use the return model[20], since its variables are deflated by the lagged market value of equity and therefore scale-free.

Motivated by Barth and Clinch (2009) and in line with a large number of papers in the value relevance literature (Collins et al (1997), Barth and Clinch (1998), Lev and Zarowin (1999), Ely and Waymire (1999), Barth et al (2012), Barth et al (2014) among many others) we estimate share-deflated specifications for the price-levels regression. In the returns-earnings regression the change in earnings divided by previous price is calculated as change in net income scaled by the market value of equity at the end of the previous fiscal year. In all regressions we removed the 1% of the most extreme values for each of the variables.

As common in the relative association studies, the metric we use is the adjusted R^2 from the regressions. Concretely, we run separated regressions for sub-sample of firms with contrasting values of the attribute (size, predictability and volatility of earnings, and accrual quality) and compare their explanatory power. The attribute is value relevant if one can document a monotonously increasing relation between its level and the explanatory power of the regression, i.e. higher the attribute, higher the R^2 of the regression.

We perform both pooled and annual regressions. For the pooled regressions the observations are separated in deciles conditional on the size of the attribute (market value, earnings predictability, accrual quality) and the two regression types are run for each one of the ten deciles. We display the R^2 of the regressions as a function of the decile (1 to 10). The deciles are ordered from low to high value of the attribute, i.e. from low to high size, from least to most persistent earnings, from high volatility to low volatility and from lowest to highest accrual quality. The attribute is value relevant if the R^2 is an increasing function of the decile.

For the annual regressions, the yearly cross-sections are split into two equal subsamples according to the magnitude of the values of the attribute. One subsample contains the firms with lower values and the other contains the firms with higher values. Every year, the two regression types are run for each of the sub-samples. We displays the yearly difference between the R^2 of the regressions for the competing sub-samples: R^2 of the regression

[20] Easton and Sommers (2003) state that "returns studies add to the price-levels studies inasmuch as they address the timeliness of the accounting summary. This advantage, coupled with the evidence of the pervasive effects of scale in price-levels regressions suggests that the returns regression specification should be used whenever possible."

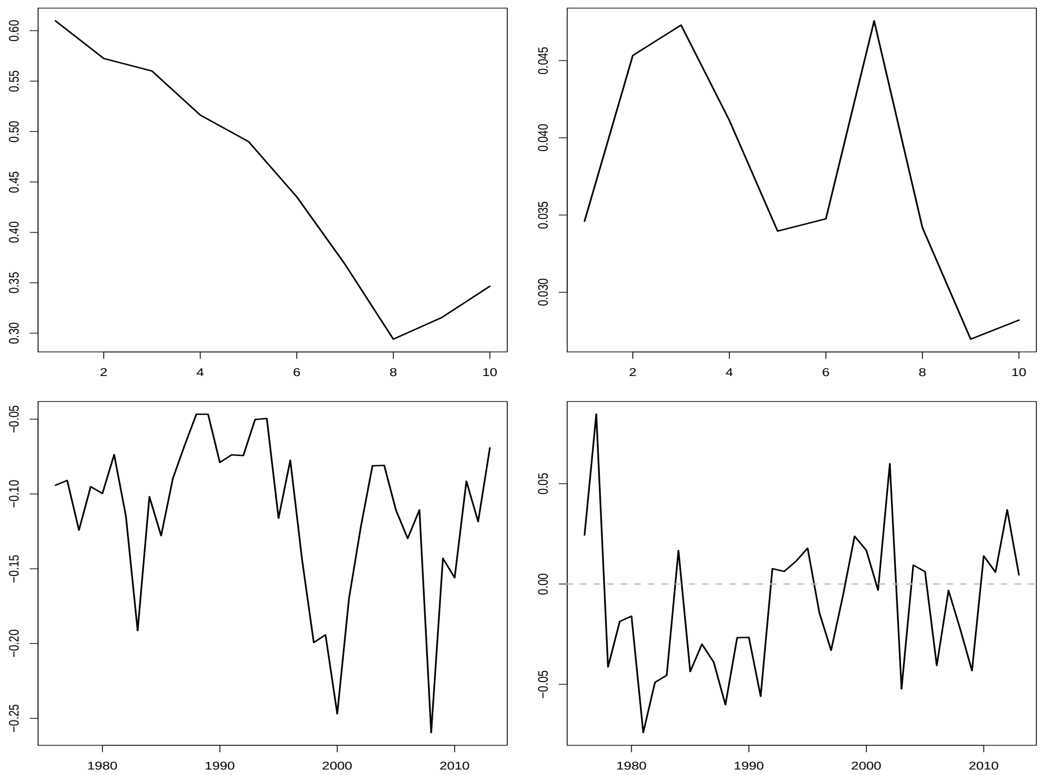

Fig. 1: **Size factor.** *(Top) - Pooled regressions:* The sample is partitioned in deciles conditional on firm size and the two type of regressions are run for each decile. The graphs display R^2 as a function of the decile. On the $x-axis$: deciles (1-10) from low to high market value. On the $y-axis$: R^2 of the price-levels regression (*left*) and returns-earnings regression (*right*). Size is value relevant if the R^2 is an increasing function of the decile. None of the two methods seem to confirm the relevance of size. *(Bottom) - Annual regressions:* Two subsamples are constructed for each yearly cross-section containing the firms with contrasting market values. Each subsample contains 50% larger/smaller firms of the cross-section. The graphs display the yearly difference between the R^2 of the regressions for the two competing sub-samples: larger market value minus smaller market value. On the $x-axis$: year. On the $y-axis$: differences between the R^2 of the yearly price-levels regressions (*left*) and returns-earnings regressions (*right*). Size is value relevant if the differences are significantly positive. None of the two methods seem to confirm the relevance of the attribute.

corresponding to firms with larger attributes minus R^2 of the regression corresponding to firms with smaller attributes. The attribute is value relevant if the differences are significantly positive. We also test the hypothesis that the mean R^2s for the two competing sub-samples are equal against the alternative that they are different.

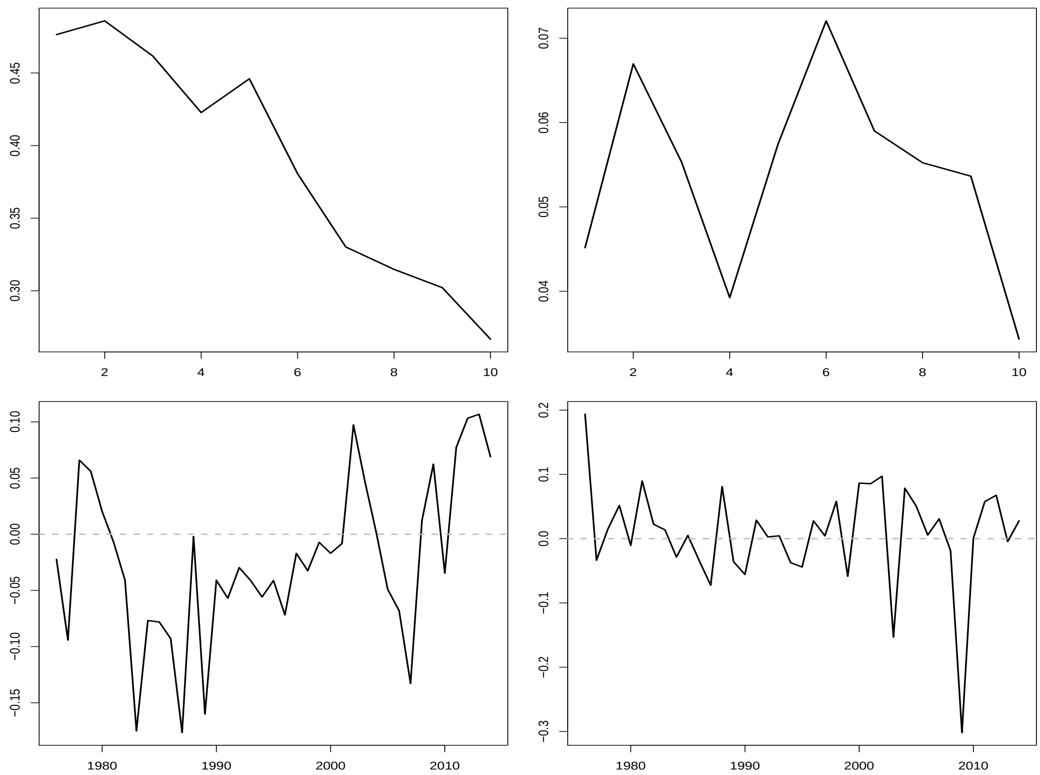

Fig. 2: **Earnings predictability.** *(Top) - Pooled regressions:* The sample is partitioned in deciles conditional on the level of predictability of earnings and the two type of regressions are run for each decile. The graphs display R^2 as a function of the decile. On the $x-axis$: deciles (1-10) from low predictability to high predictability. On the $y - axis$: R^2 of the price-levels regression (*left*) and returns-earnings regression (*right*). Level of predictability is value relevant if the R^2 is an increasing function of the decile. None of the two methods seem to confirm the relevance of predictability measure. *(Bottom) - Annual regressions:* Two equal subsamples are constructed for each yearly cross-section each containing the firms with lower/higher values of the predictability measure. The graphs display the yearly difference between the R^2 of the regressions for the two competing sub-samples: higher predictability minus lower predictability. On the $x-axis$: year. On the $y-axis$: differences between the R^2 of the yearly price-levels regressions (*left*) and returns-earnings regressions (*right*). Predictability measure is value relevant if the differences are significantly positive. None of the two methods seem to confirm the relevance of the attribute.

Figures 1, 2, 3, and 4 report the results of the current design value relevance analysis for the attributes size, earnings predictability, earnings volatility, and accrual quality, respectively. Table 3 gathers the results of the statistical tests of equal R^2 of the regressions ran on competing sub-samples.

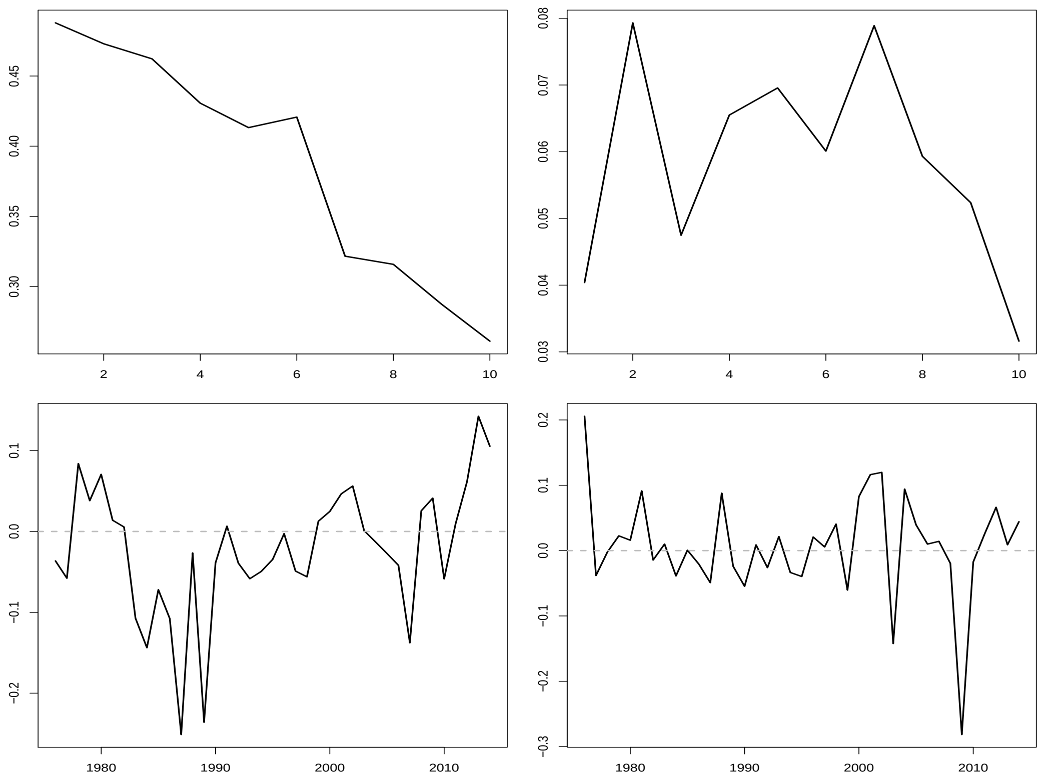

Fig. 3: **Earnings volatility.** *(Top) - Pooled regressions:* The sample is partitioned in deciles conditional on the level of volatility of earnings and the two type of regressions are run for each decile. The graphs display R^2 as a function of the decile. On the $x - axis$: deciles (1-10) from high volatility to low volatility. On the $y - axis$: R^2 of the price-levels regression (*left*) and returns-earnings regression (*right*). Volatility level is value relevant if the R^2 is an increasing function of the decile. None of the two methods seem to confirm the relevance of the volatility measure. *(Bottom) - Annual regressions:* Two equal subsamples are constructed for each yearly cross-section each containing the firms with lower/higher values of earnings volatility. The graphs display the yearly difference between the R^2 of the regressions for the two competing sub-samples: lower volatility minus higher volatility. On the $x - axis$: year. On the $y - axis$: differences between the R^2 of the yearly price-levels regressions (*left*) and returns-earnings regressions (*right*). Volatility of earnings is value relevant if the differences are significantly positive. None of the two methods seem to confirm the relevance of the attribute.

None of the two empirical specifications of the Ohlson model seem to confirm the relevance of any of the four attributes. The null hypothesis of no difference in the R^2 of the regressions on the sub-samples of contrasting attributes either cannot be rejected or it is rejected for the counter-intuitive alternative. Concretely, the price-levels regressions seems to indicate that the

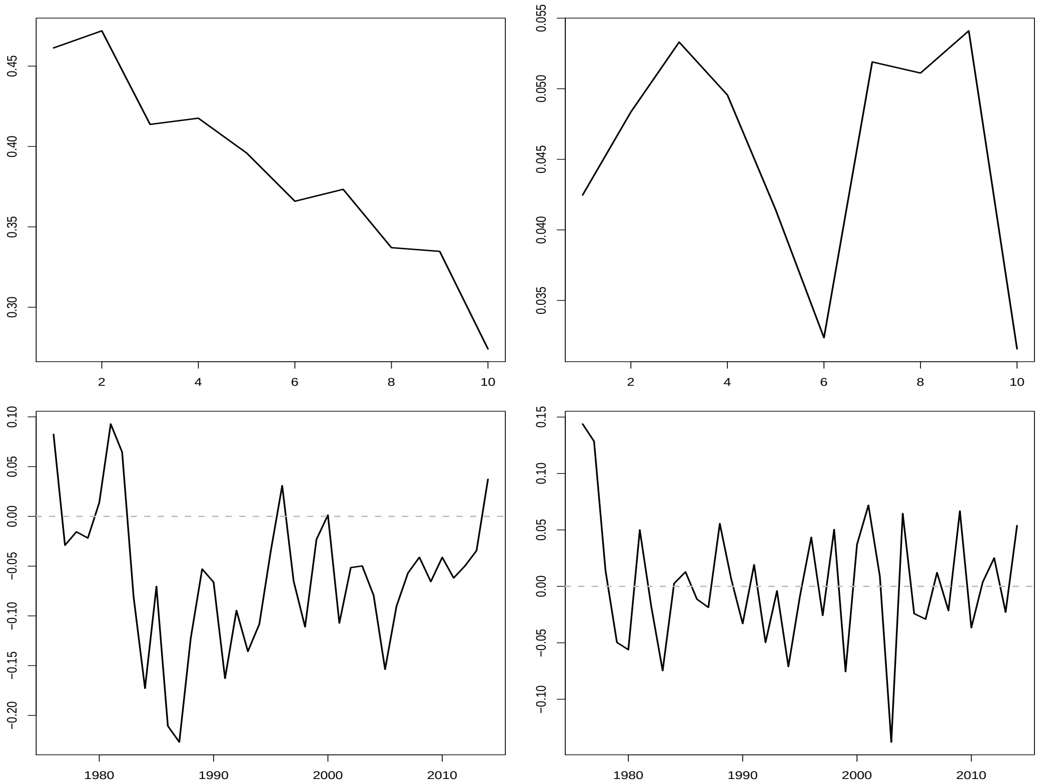

Fig. 4: **Accrual quality.** *(Top) - Pooled regressions:* The sample is partitioned in deciles conditional on accrual quality and the two type of regressions are run for each decile. The graphs display R^2 as a function of the decile. On the $x-axis$: deciles (1-10) from low accrual quality to high accrual quality. On the $y-axis$: R^2 of the price-levels regression (*left*) and returns-earnings regression (*right*). Accrual quality is value relevant if the R^2 is an increasing function of the decile. None of the two methods seem to confirm the relevance of accrual quality measure. *(Bottom) - Annual regressions:* Two subsamples are constructed for each yearly cross-section containing the firms with most extreme values for accrual quality. Each subsample contains 50% most extreme-valued firms of the cross-section. The graphs display the yearly difference between the R^2 of the regressions for the two competing sub-samples: higher accrual quality minus lower accrual quality. On the $x-axis$: year. On the $y-axis$: differences between the R^2 of the yearly price-levels regressions (*left*) and returns-earnings regressions (*right*). Accrual quality is value relevant if the differences are significantly positive. None of the two methods seem to confirm the relevance of the attribute.

smaller the size or lower the quality of accruals, the better the explanatory power of the regression. The intriguing quality of this finding matches that of the results reported in Figure 2(c) of Collins et al (1997). The graph shows the same counter-intuitive relation between firm size and value relevance as

Attribute	Price-levels regression	Returns-earnings regression
Size	-5.74 (0)	-0.91 (36%)
	(less relevance for larger size)	(equal relevance)
Earnings predictability	-1.12 (27%)	0.54 (59%)
	(equal relevance)	(equal relevance)
Earnings volatility	-1.09 (28%)	0.53 (60%)
	(equal relevance)	(equal relevance)
Accrual quality	-2.74 (1%)	0.20 (84%)
	(less relevance for higher quality)	(equal relevance)

Table 3: **Tests of equal R^2 for sub-samples with contrasting attributes.** For annual regressions, the cross-section is split into two equal subsamples. One contains the firms with values of the attribute lower than the cross-section median, the other the firms with values of the attribute higher than the cross-section median. The two types of regressions are run for each of the sub-samples. The yearly differences R^2 of the regression corresponding to firms with larger attributes minus R^2 of the regression corresponding to firms with smaller attributes are calculated. The table reports the t-statistic and their p-values (in parenthesis) of the tests of equal mean R^2 for the two competing sub-samples, i.e. the difference of the R^2s of the competing sub-samples equals 0 (see details in section D of the Appendix).

the one displayed in Figure 1: the higher the MVE, the lower the explanatory power of earnings and book values. In other words, the larger the firm, the less relevant its book value and earnings to price formation.

The standard research design analysis rejects hence the value relevance of size, predictability of earnings as measured by the standard deviation of the residuals of the regression (20), earnings volatility, and accrual quality as measured by the standard deviation of the residuals of the regression (21). According to the results of this analysis and contrary to our expectations framed by the hypothesis in section 6.1 market prices does not seem to acknowledge different levels of the four attributes.

6.5 Alternative research design analysis

This section shows that an analysis based on the alternative research design developed in this paper yields convincing empirical proof in favor of the predictions formulated in section 6.1.

6.5.1 Implementation choices

To estimate the error term reflecting the level of value relevance one needs to infer the function $\mathfrak{m}$. The estimation procedure, described in Section 5, depends first, on a similarity measure used to locate close data and second, on the number of nearest neighbors to use in prediction.

Specification (16) indicates that 'similar' companies should resemble the target firm in their cost of equity, accounting rate of return and realized book growth. Moreover, considerations in section 4.3 extend the resemblance to patterns of future RE growth. In the sequel we explain how these constraints have been implemented.

Risk parameter plays an important role in the estimation of the economic model (Botosan et al (2014)). We make use of two alternative risk proxies[21] in our research design to reduce concerns regarding the sensitivity to the choice of proxy: firm size and lagged earnings/price ratio. For the industry criterion, the peers are firms matched on the basis of four-digit SIC codes if the resulting industry contains enough many peers. Otherwise the definition of a firm's industry is progressively broadened until enough peers are identified. By choosing the neighbors (mostly) from the same three/four-digit SIC code industry we try to match the expectations about the persistence of residual earnings as well as other characteristics like the cost of equity, the level of conservatism or the size of intangibles relative to the book value. The past price P_{-1} is also a proxy for size. As explained in section 4.3 its role is to ensure, together with the industry criterion, a choice of peers with similar patterns of future RE evolution.

To summarize, in our implementation, 'similar' companies are defined as belonging to the same industry, and being close in geometrical distance to the vector $(ROE_0, B_0/B_{-1}, P_{-1}, NI_{-1}/P_{-1})$ of the target firm.

[21] Berk (1995) argues that the market value of equity and risk are inherently inversely related. Larger firms are less risky than smaller as they produce more predictable, steadier earnings over time. Prior research also suggests that earnings/price ratio is a reasonable proxy for risk (for example, Fama and French (1992) use it as a risk proxy in their study). Moreover, under certain assumptions (i.e. zero growth rate and 100% dividend payout ratio) the earnings to price ratio is equal to the firm's cost of equity capital. We did not consider other common proxies as market beta or implied cost of equity capital in order to keep the sample as large and as representative as possible.

As explained in Section 5.2, the optimal choice of k, the number of nearest neighbors is made via cross-validation. Figure 9 in the Appendix indicates cleary that the optimal number of peers (for the larger sample) is equal to three. The low number of peers used in prediction guarantees a good match in the values of the RE drivers and RE growth patterns.

6.5.2 Hypothesis testing methodology

In the valuation-based research design under discussion differences in value relevance between two competing samples are signaled by variation in the valuation accuracy between samples. In the case of the empirical predictions under investigation the competing samples are two subsamples of firms (from a given year) with contrasting values of a given attribute: size, earnings predictability, earnings volatility, and accrual quality. The sub-samples are the lower half and the upper half of the yearly cross-section ordered by the values of the attribute under investigation.

The hypothesis tests compare the distribution of the two valuation error terms: one corresponding to firms with high values of the attribute, the other to firms with low values. The errors measure the divergence between market prices on one hand and valuations incorporating earnings expectations informed only by RE drivers' current values on the other. The null hypothesis is that of an equal gap for the two competing samples. The alternative is that the price correction based on other information is larger for firms with lower attribute values. Rejecting the null would provide evidence of lower utility of bottom-line items for the process of price formation for firms of smaller size, reporting less predictable or more volatile earnings or with a lower quality of the accrual component of earnings. The test statistic is the median absolute error as a robust measure of accuracy.

The tests are performed for all years in the sample helping to determine if the attribute is a constant-through-time determinant of the level of association and if the strength of its effect changes across time.

Hypothesis testing based on the median yields the same qualitative results as a more complete analysis based on the concept of stochastic dominance which compares the overall distribution of errors. Such an analysis employs a comprehensive statistic which takes into account the whole distribution of errors and not only a particular quantile. Intuitively, the distributions of error terms are close if and only if their cumulative distribution functions (cdf) are almost identical. This is the case if both the minimum and the maximum of the difference between the estimated cdfs corresponding to the two error terms are almost zero. Hence, the comprehensive statistics to be used into the hypothesis test are the minimum and maximum statistics. Although not reported, the complementary analysis guarantees that the median is a sufficient statistic as developments in the level of association across time could potentially be visible in other parameters than dispersion. We privilege the median absolute value for its simplicity and because, qualitatively, the conclusions of the analysis are unchanged. The details of the more complete analysis are available upon request.

6.5.3 Empirical evidence

This section presents empirical proof in favor of the predictions formulated in section 6.1 following a value relevance analysis based on the alternative research design developed in this paper. The evidence consists in a battery of hypothesis tests performed successively for all the years in the sample. Each test compares the distribution of two error terms, i.e. the valuation errors corresponding to firms (within the running cross-section) with lower/higher attributes.

The null hypothesis is that the distribution of the error terms (measuring the divergence between market prices and valuations informed by earnings expectations constructed only on current levels of the RE drivers) is the same for the two competing sub-samples. A rejection of the null indicates that the relative contribution to pricing of bottom-line items is higher for firms reporting higher quality accruals than for those reporting lower quality accruals. The test statistic is the median of the absolute value of errors. The tests are performed for all years in the sample helping to determine if the given characteristic is a constant-through-time determinant of the level of association and if the strength of its effect changes across time.

Owing to the large number of tests we perform the results are presented as graphs that show the values of the median absolute error as a function of the year as well as the confidence interval bounds for each year in the sample. This results in displays with three curves: one that follow the time evolution of the test statistic and the other two that trace the time evolution of the confidence bands obtained by bootstrapping. Note that, since the confidence intervals are function of the sizes of the two samples of errors under comparison, their width vary from year to year and from a series of tests to another. Test statistics outside (within) the confidence bands signal (no) significant differences in the degree of association for the two competing sub-samples. Figure 5 displays the results of the yearly hypothesis tests evaluating the difference in the level of value relevance due to size (*Top-Left*), earnings predictability (*Top-Right*), earnings volatility (*Bottom-Left*) and accrual quality (*Bottom-Right*). The top left-hand graph indicates that the size factor is a permanent determinant of value relevance with a significant favorable im-

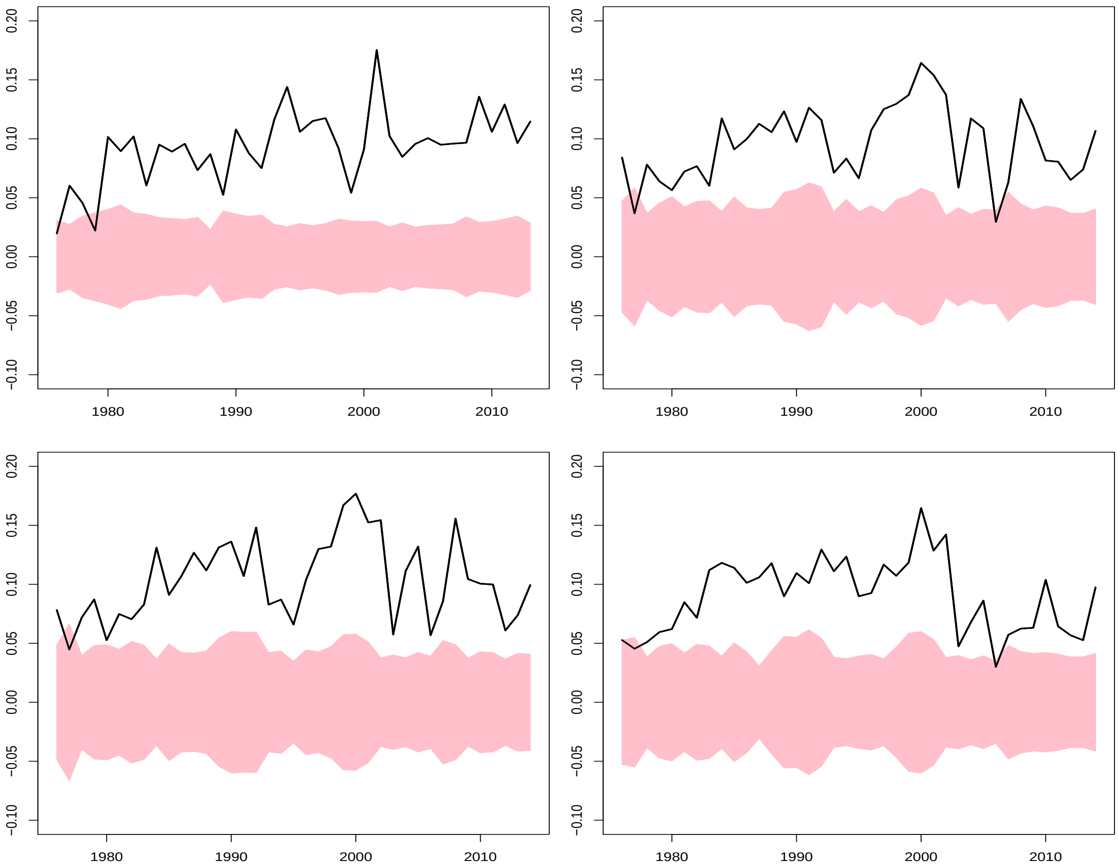

Fig. 5: **Differences in valuation accuracy of firms with contrasting attributes.** The competing sub-samples contain the firms with the 40% more extreme values (one sample of lower values, the other of higher values) of size (*Top-left*), earnings predictability (*Top-right*), earnings predictability (*Bottom-left*), and accrual quality measure (*Bottom-right*). The lines mark the median error for lower attribute value firms minus median error for higher attribute value firms (solid) and the bootstrap 95% confidence interval (filled). A significant positive value identifies the years with a less accurate valuation of firms with lower attribute value. For most of the years, larger firms and earnings that are more predictable, less volatile and with a higher quality accrual component command a higher value relevance.

pact on association's strength of larger firms for most of the years in the sample. The difference in the median accuracy is large at around 15% and seems to increase slightly through the sample. The graphs on the top-right and bottom-left show that current earnings inform prices of firms with more predictable/less volatile earnings to a larger extent than those of firms with harder-to-predict or more volatile net incomes. The accuracy gap at an average of 10% is significant in almost all years. The bottom-right graph shows that accrual quality commands more precise valuation for most years in the sample with a valuation gap between high and low quality accruals of around 10%. These findings confirm our empirical predictions.

To summarize, we have documented that value relevance analyses performed following the current standards in the literature negate economically motivated and intuitively acceptable predictions which, in contrast, are confirmed by analyses conducted according the alternative research design. Since one can argue that estimation of price-levels and returns-earnings linear regressions is likely to be biased while our estimation approach yields consistent results, we interpret the contrasting evidence as proof in favor of the alternative research design and against the current standard.

7 Conclusions

We argued that Ohlson model is structurally ill-suited for consistent empirical estimation. The reason is that its linear solution to the RE equation is not a regression.

We proved the existence of a solution to the RE equation that is a non-linear regression. Value is expressed as the sum of a non-linear function of the bottom-line items plus a correction term for which the condition necessary for consistent estimation holds by construction. We accomplish this by giving up the information dynamics assumptions of the Ohlson model and by redefining the "information other than abnormal earnings".

We demonstrate that the P/B multiple relative valuation can be framed as a consistent estimation of the non-linear empirical specification of the valuation regression.

In a research design based on the valuation regression solution to the RE equation the measure of the level of association of financial information to prices is the accuracy of an optimally-implemented multiple valuation. A lower level of association would substantiate in a less accurate multiple valuation. In this context, the pricing error term measures the extent to which price setting expectations about future earnings are formed on the basis of information other than the current levels of RE drivers.

The alternative research design is flexible, easy to implement and useful. In a direct comparison, an analysis of the type of a standard relative association study did not validate a number of economically motivated and intuitively appealing predictions while the alternative design did.

Based on the presented evidence, we believe that the proposed design can successfully complement the current approach to value relevance testing, providing researchers in the field with a consistent frame for their analyses.

Appendix

A Predicted price in multiple valuation

The value of the multiple $\mathcal{M}$ is defined as the ratio between P, the stock price and Acc, the value taken by the driver of the firm:

$$\mathcal{M} := P/Acc. \tag{22}$$

To predict the price of a firm, the method first predicts its multiple $\widehat{\mathcal{M}}(C)$ as the mean/median of the multiples of a set C of comparable firms (peers). The predicted price of the firm is given by:

$$\widehat{P}(\mathcal{M}, C) = Acc \times \widehat{\mathcal{M}}(C), \tag{23}$$

The notation in (23) emphasizes that a multiple valuation method is the result not only of a choice of a multiple $\mathcal{M}$ but also of a set of peers C. The value driver we consider in this paper is the book value.

B The sample

The accounting data originate from 125,255 financial annual reports covering the period between 1967 and 2013. The larger sample was obtained starting with all the annual reports available in the CRSP/Compustat merged database by removing all the firm-years for which

1. SIC code is from 6000 to 6799 (division Finance, Insurance and Real Estate),
2. at least one value of the variables needed to construct the multiple and to define the comparable companies was missing,
3. the book value was 0 or negative,
4. the P/B multiple was among the largest and smallest 1% values,
5. the 1st digit SIC code industry contains less than 20 companies.

Figure 6 displays that time evolution of the size of the cross-sections for the larger sample (size attribute) (full line) and the smaller sample (earnings attributes) (dotted line). Each yearly cross-sections of the smaller sample is the intersection of the current cross-section of the larger sample with the yearly cross-sections of the previous nine years, i.e. it contains all firms in the current cross-section that were also present in the previous nine yearly cross-sections.

Fig. 6: **Time evolution of the cross-sectional sample size.** The sample for size attribute analysis (full line), the sample for earnings attributes (dotted line).

C Supplementary empirical evidence

C.1 Non-linear relationship between prices and bottom-line accounting items

Figure 7 adds some concise visual evidence of a non-linear convex relationship between prices and bottom-line accounting items to the empirical proofs cited in section 2. It displays the empirical relation between market value and earnings keeping book value constant. The graph on the left (right) shows that, at median (low) levels of earnings the relation with prices is fairly flat. However, as the level of earnings decreases/increases (increases), the slope of function describing the market value decreases/increases (increases). The graphs in Figure 7 suggest that the linear price-levels regression is possibly mis-specified.

C.2 The determinants of $f_{.cdot,0}$ - empirical evidence

Figure 8 displays the time evolution of the median RE for the one digit SIC code industries (left) and two digit SIC code industries within the Transportation, Communications SIC 4 group (right). The graphs follow Nissim and Penman (2001) and are obtained by forming industry portfolios in year 0 and then tracking median values of RE for each portfolio for the following five years. The operation is done ten times, every five years starting in 1963. The figures give the mean of portfolio medians over the ten sets of calculations. The patterns depicted are quite

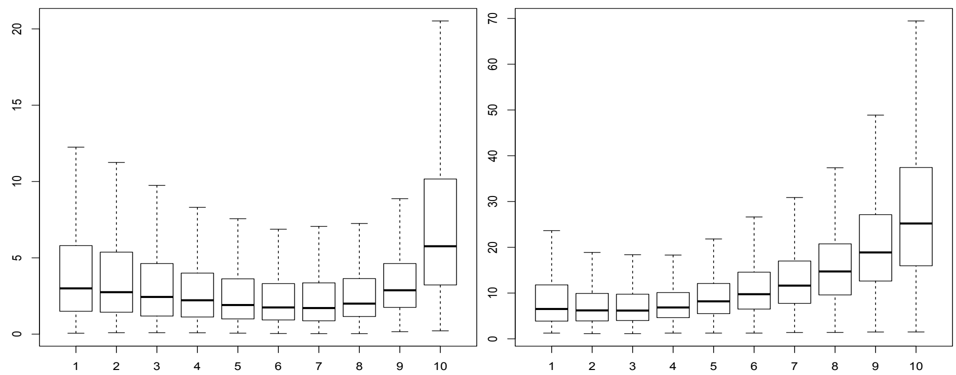

Fig. 7: **Market value as a function of earnings.** The graph displays market value conditional on earnings keeping book values constant: book value per share less than $2 (18,281 observations) (left), book value per share between $4 and $6 (15,553 observations) (right). The firm-years in the sample are grouped in deciles based on the size of earnings and the boxplot of market value of the firms in each decile is plotted. The functional form of the link between market value and earnings for small and medium book value per share is convex in contrast to models which assume a linear additive relation with earnings and book values.

robust over the ten time periods, however. The figure shows that RE evolve following distinct industry patterns supporting the assumption that the RE dynamic is industry-specific.

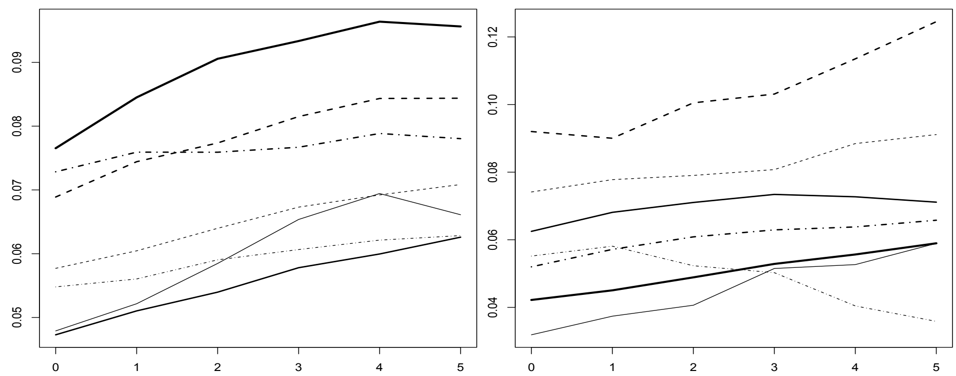

Fig. 8: **Evolution of RE over time.** The figure displays the dynamic over 5 years of median RE deflated by book in year 0 for industry portfolios built on 1-digit SIC code (left) and 2-digit SIC code within the Transportation, Communications SIC 4 group (right). The graphs show that RE evolve following distinct industry patterns.

C.3 Cross-validation choice of the optimal number of peers to estimate the P/B multiple

As explained in Section 5.2, the optimal choice of k, the number of nearest neighbors is made via cross-validation. Figure 9 displays the mean over all years of the

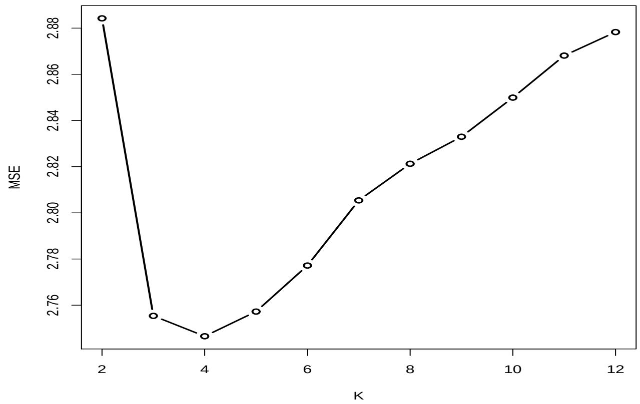

Fig. 9: **MSE of P/B regression as a function of k, the number of neighbors.** Mean of yearly MSE (18) of P/B regression as a function of k the number of neighbors used to predict P/B ratio. The function has a clear minimum at 3.

MSE (18) as a function of k, the number of neighbors used in the prediction of the P/B ratio (for the larger sample under discussion). The function has a clear minimum at 3. The low number of peers used in prediction guarantees a good match in the values of the RE drivers and RE growth patterns.

D Statistical details of the test for equal explanatory power in Table 3

The observed yearly R^2s that are used in the hypothesis tests on the difference of the explanatory power of the Ohlson model empirical specification regressions for sub-samples with contrasting attributes are based on large samples (larger than 400) and hence we assume that they are drawn from the same distribution, i.e. the asymptotic distribution. The large sample sizes remove the need to apply the results in Cramer (1987) which deal with small and moderate samples.

Moreover, the number of realizations of the R^2 fulfill the sample size conditions that guarantee that a normal model provides an accurate approximation to the sampling distribution of the sample mean, i.e. sample size ten times greater than the kurtosis squared and the absolute value of the skewness (results available upon request). This justifies the use of the t-test as reported in Table 3.

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