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The Stochastic Parameter Approach to Residual Income Valuation¹

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Abstract:

In residual income valuation the information dynamics (ID) provides a connection between current observable information and unobservable forecasts of future residual income (RI). Traditionally the ID is formulated as multivariate auto-regressive processes, where the auto-regressive parameters (persistence parameters) are assumed fixed and known. For this reason uncertainty (risk) is captured in a zero-mean noise term, and risk does not affect the process of expected RI. Put differently, future projects accepted by a firm are by assumption zero-NPV undertakings. Even without information of a specific firm's future activities, one should acknowledge the fact that some firms will outperform the industry average, while some will underperform. Ignoring the existence of risk that systematically affects RI by applying a linear ID, a downward valuation bias will occur. In this paper we treat the persistence parameters as stochastic variables in order to capture the overall effect of "systematic risk" on firm level. The realization of the stochastic term will be positive for firms succeeding in business and negative for failing firms. Based on *OWAM* a valuation model is developed, where analysts' forecasts embed available information (accounting information and "other information") at the time of valuation.² Consistent with several recent empirical studies on ID, the revised model predicts a positive relationship between "systematic risk" and expected return.

Key words: Residual income, Valuation, Information Dynamics, Capital Markets.

¹ I appreciate valuable comments of Tron Foss and Patrick Stark.

² OWAM: Ohlson's weighted average model (Ohlson 95).

Introduction

Ever since the early works of Graham and Dodd (1934), Gordon & Shapiro (1956), and Edwards and Bell (1961), a substantial number of competing valuation models have been developed.³ One way of grouping these models is according to accounting relationship. Basically, the dividends -, earnings -, and free cash flow approaches exist.⁴ The various models differ in appearance, but they are, under certain conditions, theoretically equivalent. Put differently, the models are accounting translations of each other.⁵

The earnings approach to valuation may be preferable to the dividend approach for at least two reasons. Firstly, earnings are related to creation of wealth, while dividends are wealth distribution. Secondly, abnormal earnings (residual income) most likely converge over time, while dividends do not.⁶ Today, in academia, the residual income models (RIM) are probably the most applauded. These models predict equity value as contemporaneous book value of equity plus the NPV of future abnormal earnings, also called residual income. The first generation of these models did not capture the structure connecting observable variables to unobservable forecasts of future residual income (RI).⁷ For this reason RIM lacked validity and practical use involved the same prediction problems as for the dividend and cash flow approaches to valuation.

Ohlson (1995) provided a linear information dynamics (LID) in order to make a connection between current and future value relevant information. He assumes that there is persistence in RI and that some information is not yet captured in accounting data. On this basis he formulates a modified auto-regressive process (AR1), where next period RI is explained by this period's RI and "other information".

Recently, several empirical studies have questioned the validity of LID. Dechow, Hutton and Sloan (1999) evaluate the empirical implications of Ohlson's RIM, also called the Ohlson weighted average model (OWAM), relative to competing, accounting-based valuation models. In general, their findings support LID, but show that the *OWAM* provides only small improvements over traditional models. Moreover,

³ According to Graham and Dodd (GD) the fundamental value of a stock is explained by the firm's ability to generate future income. GD assumed that the stock prices would deviate occasionally from its fundamental value, but over time would return to the this value. Moreover, they assumed that investors had heterogeneous expectations and that some investors were better informed than others. Gordon and Shapiro were the first to develop a formula for equity valuation, which despite of strong and unrealistic assumptions has become a benchmark for equity valuation. Edwards and Bell (EB) developed a theory of business income in order to improve decisions under uncertainty. EB aimed to reconcile the subjective concepts of income derived from expectations of future events with the objective concepts of financial accounting, basically related to historic events. See also Canning (1929) and Preinreich (1938).

⁴ The dividend model (DM) calculates equity value as the present value of all future dividends, while the free cash flow model (FCFM) calculates the firm value as the present value of all future free cash flows. The two most prominent earnings approaches to valuation are properly the residual income model (RIM) and the economic value added model (EVAM). The RIM calculates the value of equity as the present value of all future abnormal earnings plus the book value of equity. In the EVAM the firm value is calculated as the present value of all future economic value plus the book value of total capital.

⁵ See Feltman and Ohlson (1995), Penman (1997), and Levin (1998).

⁶ According to Miller & Modigliani (1961) dividends displace market value in a one to one relation without affecting current earnings and the expected abnormal earnings sequence. In consequence dividend irrelevancy applies and a paradox appears. Is it meaningful to predict a firm's dividend in the years to come when all dividend policies generate the same market value?

⁷ See Canning (1929), Edey (1957), Salomons (1965), Anthony (1973), Kay (1976) and Peasnell (1981 and 1982).

the *OWAM* consistently underestimates the value of equity relative to market value. Consistent with Dechow et al. (1999) studies by Frankel and Lee (1998), Myers (1999) and Lee et al. (1999) show that empirical estimates of fundamental value by means of RIM devalue stock price with 10 to 40 percent on average. Myers' (1999) findings also show that four different specifications of LID do not outperform book value in explaining value of equity. Biddle, Chen and Zhang (2000) argue that the LID fails to capture the effect of capital investments subsequent to the initial period and propose a non-linear investment dynamics where investments (divestments) follow profitability. Empirical results in this study are consistent with a convex process for RI. Furthermore, they give support for non-constant persistence parameters, which challenges a crucial assumption in Ohlson's LID.

We are in this paper providing a link between the non-linear investment dynamics (NID) in Biddle et al. (2000) and a less restricted information dynamics originated from LID by removing Ohlson's assumptions of persistence parameters known and fixed. We are also proposing a new valuation model that implicitly takes into account the NPV of future capital investments (divestments) opportunities.

The remainder of this paper is organized as follows: Section two and three review the *OWAM* and the NID in Biddle et al. (2000), respectively. In section four we compare the two different dynamics and propose a link. Section five presents the new valuation model. Section six deals with central properties of the new model and section seven concludes.

Ohlson's weighted average model

OWAM is based on three assumptions. Following Ohlson (1995), these are:

Equity value equals the net present value of expected dividends in a world with risk neutrality, time constant interest rates, and homogenous beliefs.

$$P_t = \sum_{i=1}^T R_f^{-i} E_t[d_{t+i}] + R_f^{-T} E_t[P_{t+T}] \quad (\text{A1})$$

$$P_t = \sum_{i=1}^{\infty} R_f^{-i} E_t[d_{t+i}]$$

where P_t is the market value of equity at date t , R_f is one plus the risk free rate of return (assumed to be constant over time), $E_t[\bullet]$ is the expectation conditional on information at time t , and d_{t+i} is dividend paid at date $t+i$.

Accounting is based on a clean surplus relation (CSR). A clean surplus relation in accounting means that end-of-period book value equals beginning-of-period book value plus the period's earnings minus dividend. Since CSR in (A2a) is a weak condition that inflicts no boundaries otherwise on the relation between dividend, earnings, and book value of equity, two restrictions are imposed. Dividends reduce book value, but have no impact on contemporaneous earnings.

$$y_t = y_{t-1} + x_t - d_t \quad (\text{A2a, A2b})$$

$$\frac{dy_t}{dd_t} = -1, \quad \frac{dx_t}{dd_t} = 0$$

where y_t is date t book value of equity and x_t is the period $(t-1 - t)$ earnings

Residual income is defined as earnings minus risk-adjusted rate of return on book value.

$$x_t^a \equiv x_t - (R_f - 1)y_{t-1} \quad (\text{D1})$$

Iterative substitution of equation (A2a) into (A1) provides the residual income approach to valuation, abbreviated *RIM*.⁸ The deduction of *RIM* from *DDM* given (A2) and (D1) is shown in appendix 1.

$$P_t = y_t + \sum_{i=1}^{\infty} R_f^{-i} E_t [x_{t+i}^a] \quad (\text{M1})$$

Market value is in *OWAM* explained by book value of equity today and the present value of future RI. In order to connect the unobservable forecasts of RI to the observable book value of equity, Ohlson proposes a linear information dynamics (LID) for RI and “other information” (information not yet captured in accounting data). As shown in (A3), RI follows a linear stochastic process (modified AR1).

The parameters of the process are fixed, none-negative, and less than one. In consequence, it is assumed that competitive forces will reduce the company's abnormal earnings over time.⁹

$$\begin{aligned} \tilde{x}_{t+1}^a &= \omega x_t^a + v_t + \mathbf{e}_{1,t+1} \\ \tilde{v}_{t+1} &= \gamma v_t + \mathbf{e}_{2,t+1} \end{aligned} \quad (\text{A3})$$

where ω and γ are resistance parameters, and $\mathbf{e}_{1,t+1}$ and $\mathbf{e}_{2,t+1}$ are zero expectation random noise terms.

Since the information dynamics are formulated by means of a linear model, *OWAM* has a linear solution.

$$\begin{aligned} P_t &= y_t + \mathbf{a}_1 x_t^a + \mathbf{a}_2 v_t \\ \mathbf{a}_1 &= \mathbf{w} / (R_f - \mathbf{w}) \geq 0 \\ \mathbf{a}_2 &= R_f / [(R_f - \mathbf{w})(R_f - \mathbf{g})] > 0 \end{aligned} \quad (\text{M2})$$

⁸ See Peasnell 1982.

⁹ When the persistence parameters are assumed constant, it follows that RI next period is systematically effected by this period RI and “other information” only. Future changes in strategy and future capital investments are thus effecting the process of RI unsystematically.

Dividend irrelevancy and capital investments

The *OWAM* is consistent with dividend irrelevancy in the sense that dividends displace market value on a dollar-for-dollar basis. Additionally, dividends paid today have a negative impact on future earnings. Ohlson (95) formulates these properties as shown in (P1) and (P2).

$$\frac{dP_t}{dd_t} = -1, \quad (P1)$$

$$\frac{dE_t \left[\tilde{x}_{t+1} \right]}{dd_t} = -(R_f - 1) \quad (P2)$$

As claimed by Biddle, Chen and Zhang (2000), the dividend irrelevance in Ohlson (1995) is obtained by assuming that capital investments (net dividends) succeeding the initial period yield zero NPV. In contrast, Miller & Modigliani (1961) claim that dividend policy does not influence capital investment decisions, and therefore allows for subsequent investments with positive and negative net present value.¹⁰

In order to relax for the capital investment restrictions in *OWAM*, Biddle et al. (2000) propose a residual income dynamics, which predicts a convex relationship between current and future RI. The rationale for this non-linear process is that capital investments follow profitability. In short, Biddle et al. (2000) propose the following structure:

Consider a multi-period setting in which capital investment decisions are made in each period conditional on profitability signals. Profitability (spread) is defined as the difference between return on equity and cost of capital. Denoting profitability q and using Ohlson's notation, that is:

$$q_t \equiv \frac{x_t}{y_{t-1}} - (R_f - 1) \quad (D2)$$

Investments (negative net dividend) are separated from divestments (positive net dividend) by denoting investments I_t^+ ($I_t > 0$) and divestments I_t^- ($I_t < 0$). Spread is assumed to exhibit persistence in the sense of a stationary and stochastic AR1. The process and its net present value are formulated in (A4).

$$\begin{aligned} \tilde{q}_{t+1} &= \mathbf{q}q_t + \mathbf{e}_{t+1} \\ E \left[NPV \{q_{t+i}\}_{i=1, \dots, \infty} \right] &= \frac{q_t \mathbf{q}}{R_f - \mathbf{q}} \equiv \Theta q_t \end{aligned} \quad (A4)$$

¹⁰ If the Fisher separation principle holds, future earnings distributed as dividend or retained by the company are equivalents as to valuation. Empirical evidence supporting the separation principle is among others provided by Fama (1974) and Smirlock & Marshall (1983).

The expectation in (A4) represents the expected NPV of one dollar incrementally invested at time t . Biddle et al. (2000) assume that a firm will expand its capital base if the marginal value of investment is positive and reduce the capital base if the marginal value is negative. Formally, the firm's investment behavior is stated in (A5).

$$\begin{aligned} I_t^+ &= \mathbf{p}_1 y_{t-1} \Theta q_t & \text{if } \Theta q_t > 0 \\ I_t^- &= -\mathbf{p}_2 y_{t-1} \Theta q_t & \text{if } \Theta q_t < 0 \end{aligned} \quad (\text{A5})$$

$\mathbf{p}_1 > 0, \mathbf{p}_2 > 0$

π_1 is a parameter reflecting the firm's achievable investment opportunity at the end of period t

π_2 is a parameter reflecting the firm's achievable divestment at the end of period t .

t

Based on (A4) and (A5) the RI contingent on positive and negative marginal value of investment is given by (M3).

$$\begin{aligned} \tilde{x}_{t+1}^a &= y_t q_{t+1} = (y_{t-1} + I_t^+)(q q_t + \tilde{\mathbf{e}}_{t+1}) = \mathbf{q} x_t^a + \mathbf{p}_1 y_{t-1} \mathbf{q} \Theta q_t^2 + \tilde{\mathbf{e}}_{t+1} \\ \tilde{x}_{t+1}^a &= y_t q_{t+1} = (y_{t-1} - I_t^-)(q q_t + \tilde{\mathbf{e}}_{t+1}) = \mathbf{q} x_t^a + \mathbf{p}_2 y_{t-1} \mathbf{q} \Theta (-q_t)^2 + \tilde{\mathbf{e}}_{t+1} \end{aligned} \quad (\text{M3})$$

where $\tilde{\mathbf{e}}_{t+1} = y_t \tilde{\mathbf{e}}_{t+1}$

Differentiating (M3) two times with respect to RI at time t yields:

$$\begin{aligned} \frac{dE_t \left[\tilde{x}_{t+1}^a \right]}{d\mathbf{x}_t^a} &= \mathbf{q} \left[1 + \frac{2I_t^+}{y_{t-1}} \right] > 0, & \frac{d^2 E_t \left[\tilde{x}_{t+1}^a \right]}{d\mathbf{x}_t^{a2}} &= \frac{2\mathbf{p}_1 \mathbf{q} \Theta}{y_{t-1}} > 0 \quad \forall \Theta q_t > 0 \\ \frac{dE_t \left[\tilde{x}_{t+1}^a \right]}{d\mathbf{x}_t^a} &= \mathbf{q} \left[1 - \frac{2I_t^-}{y_{t-1}} \right], & \frac{d^2 E_t \left[\tilde{x}_{t+1}^a \right]}{d\mathbf{x}_t^{a2}} &= \frac{2\mathbf{p}_2 \mathbf{q} \Theta}{y_{t-1}} > 0 \quad \forall \Theta q_t < 0 \end{aligned} \quad (\text{P3})$$

P3 shows that in the case where the marginal value of investment is positive, expected RI one period ahead is a positive and convex function of RI today. In the opposite case the function is convex, but not necessarily positive. As can be seen from (P3), linearity is obtained in the case where net investment is zero, as assumed in *OWAM*. For further details see Biddle et al. (2000).

By means of Compustat data Biddle et al. (2000) obtained results in favor of (P3). In brief, some of their findings can be summarized as follows: (1) Future capital growth is positively related to current profitability. (2) The residual income dynamics evolve in a convex manner. (3) Slopes increase (decrease) and convexity of future RI increases in investment (divestment) opportunities. Furthermore, by using piece-wise linear regression they gain support for a time variant persistence parameter in the LID of *OWAM* (excluding "other information").

Biddle et al. (2000) are not proposing an alternative valuation model. In order to do so at least one process for profitability has to be formulated, which of course is not an easy task.¹¹

What's missing?

As discussed above, it is counterintuitive that the persistence parameters in the *OWAM* are fixed and known. For a specific firm, it is likely and consistent with the findings of Biddle et al. (2000) that both internal factors, such as strategic and operational changes, and external factors, such as investment opportunities, will lead to shifts in the parameters over time. These factors will in the following as a common term be called risk factors or simply risk. The profitability or spread in Biddle et al (2000) is closely connected to risk, as we will see later in this section. An investor's ability to foresee risk is rather small, especially in a distant future. Moreover, the risk factors tend to erase the expectations of the persistence parameters for a specific firm when built on history, especially if the firm in question has no relevant history or no history at all.¹² As to equity valuation, the possible existence of time variant parameters, given known parameter expectations, inflicts no problems within the AR1-frame in *OWAM*.¹³ On the other hand, if this expectation for a specific firm is unknown and for example the expected parameters for the related industry is used as a proxy, the valuation will most likely suffer from a downward bias. In this case one should consider all possible deviations for a specific firm from the overall industry expectation, due to the risk factors mentioned above.¹⁴

Is it possible and meaningful to make a link between the LID in *OWAM* and the none-linear ID in Biddle et al. (2000)? Without any adjustments of the LID in *OWAM*, the answer is no. Through the assumption of fixed and known persistence parameters in *OWAM*, the impact of risk is ignored in the process of expected RI.¹⁵ However, relaxing for this assumption and treating the parameters as stochastic variables, the impact of risk is captured and the process turns increasing and convex. The proof of convexity is given in appendix 3. A link between the two RI dynamics should therefore be developed within this context.

In treating the persistence parameters in *OWAM* as stochastic variables we exclude the variable for "other information" in the first part of the analysis but reintroduce it later. Biddle et al. (2000) assumes that the persistence parameter for

¹¹ The profitability on capital investments (spread) is time variant in (M3).

¹² In practice the persistence parameters have to be estimated on the basis of pooled data in order to obtain robust estimates.

¹³ The effect of time variant persistence parameters, given known expectation and zero NPV-activities, is captured by the noise term in *OWAM*. See appendix 4 for details.

¹⁴ In appendix 2 a simple example illustrates the valuation bias, which will occur if the persistence parameters are wrongfully assumed to be known.

¹⁵ The LID in Ohlson (1995) is stochastic in the sense that RI for a particular year can deviate from the long-term trend. However, the noise term has a zero mean and is IID. In economic terms all future projects are zero NPV undertakings. Thus, the expected RI is not effected by risk. When the term unsystematic risk is used in the following, we refer to risk not effecting the expected RI and which is captured by the noise term in *OWAM*. Unsystematic risk is caused by occasional changes in relevant accounting data due to white noise. On the other hand systematic risk will be used when risk effects the expected RI. Such risk may be caused by a capital investments and/or other activities that typically have none-zero NPVs.

spread in (A4) is known and fixed. Realistically, this parameter is unknown when it comes to specific firms and future spread. In consequence the NPV of one dollar incrementally invested at time t from (A4) is a stochastic variable and will be treated as such from now on. For the sake of analytical simplicity we pool the two expressions for expected RI in (M3) and denote the RI one period ahead from Biddle et al. (2000) with the subscript B:

$$\begin{aligned} x_{B,t+1}^a &= \mathbf{q}x_t^a + \mathbf{p}y_{t-1}\mathbf{q}\tilde{\Theta}q_t^2 + \mathbf{e}_{B,t+1} \\ q_t &> 0 \text{ if } I_t > 0 \text{ and } q_t < 0 \text{ if } I_t < 0 \end{aligned} \quad (\text{M4a})$$

Before we introduce a stochastic persistence parameter in *OWAM*, some formalities have to be put in place. In accordance with the empirical tradition we assume that there exist estimated parameter values on aggregate levels, but not for specific firms. These values may be substitutes for aggregate level expectations. As mentioned above, risk makes the persistence parameters time variant. According to appendix 4 shocks over time in the persistence parameters do not effect the expectation of RI, given known parameter expectations. This would be the case if history repeats itself as to the distribution of risk and the firm in question fully represents the industry. For this reason we leave this phenomenon without any further discussion, and assume in the following that parameter values are unknown on firm level. For a specific firm the parameter values may be calculated as the aggregate level expectation plus a stochastic term that captures the overall effects of systematic risk on firm level.¹⁶ The realization of this term will be positive for firms succeeding in business and negative for failing firms. Since events not yet included in the current information set will determine the realization of the stochastic term, valuation should be performed by means of this stochastic term. Of course a distribution for this term would be needed. This problem will be addressed in the next section. From now on the traditional persistence parameter for RI in LID (ω) denotes the expected persistence parameter for the industry in general. Lambda denotes a firm specific shock in the general parameter that captures the overall effect of systematic risk on firm level. As mentioned before risk is caused by future operational and strategic changes, including future investment (divestment) opportunities not part of the current information set.

Denoting RI one period ahead with the subscript O yields:¹⁷

$$x_{O,t+1}^a = \left(\mathbf{w} + \tilde{\mathbf{I}} \right) x_t^a + \mathbf{e}_{O,t+1} \quad (\text{M4b})$$

The zero-mean noise term in (M4b) represents unsystematic risk that affects RI over time. However, the process of expected RI is untouched. Lambda represents the overall effect of systematic risk, caused by none-zero strategic and operational activities.

Let us first consider the case where a firm through its existing capital investment portfolio is achieving abnormal earnings and is facing a future of certainty. When just one state of nature exists, the firm's future investment opportunities are common

¹⁶ The terms systematic and unsystematic risk are defined in footnote 13.

¹⁷ The LID in (M4b) originates from Ohlson (1995).

knowledge. By the same token, there exists a fully transparent set of firm strategies. In consequence the persistence parameter in (M4b) becomes known and fixed and the noise term will be zero.

Turning to (M4a), certainty will most likely erode competitive advantages on future capital investments and rule out the possibility for abnormal earnings on projects not yet taken on. Therefore the marginal value of new capital investments will vanish, and q and the noise term in (M4a) will approach zero. In this case (M4a) and (M4b) are reduced to (M5a) and (M5b), which not surprisingly should be equal.

$$\begin{aligned} x_{B,t+1}^a &= \mathbf{w}x_t^a \\ x_{O,t+1}^a &= \mathbf{q}x_t^a \end{aligned} \tag{M5a and M5b}$$

In the more general case where the future is uncertain the second and third terms on the right-hand side of (M4a) and (M4b) can not be ignored. In (M6a) the right-hand side of (M4a) equals ditto in (M4b):

$$\mathbf{p}y_{t-1}^a + \mathbf{p}y_{t-1}\mathbf{q} \tilde{\Theta} q_t^2 + \mathbf{e}_{B,t+1}^{\sim} = \mathbf{w}x_t^a + \tilde{\mathbf{I}} x_t^a + \mathbf{e}_{O,t+1}^{\sim} \tag{M6a}$$

The first terms on both sides are related to the case of certainty and are related to the industry as a whole. Firm specific risk is captured in the second and third terms on both sides. We assume that there is independence between these two groups of terms. For this reason the first terms in (M6a) eliminate each other, as shown in (M6b):

$$\mathbf{p}y_{t-1}\mathbf{q} \tilde{\Theta} q_t^2 + \mathbf{e}_{B,t+1}^{\sim} = \tilde{\mathbf{I}} x_t^a + \mathbf{e}_{O,t+1}^{\sim} \tag{M6b}$$

Substituting (D2) into (M6b) and solving (M6b) with respect to lambda, ignoring unsystematic risk yields (M6c):¹⁸

$$\tilde{\mathbf{I}} = \frac{\mathbf{p}\mathbf{q} \tilde{\Theta} x_t^a}{y_{t-1}} = \mathbf{p}\mathbf{q} \tilde{\Theta} q_t \tag{M6c}$$

Lambda in (M6c) is a persistence parameter premium (discount) that originates from systematic risk on firm level. Let us now go back to the starting point and see what this result means for the two competing RI dynamics. Prosperous firms will have positive NPV capital investment opportunities. Consistent with Biddle et al. (2000), tomorrow's expected RI will increase as a consequence of these opportunities. The higher achievable investment opportunities, NPV from these opportunities and persistence in profitability (spread), the higher the expected RI. Since the investment dynamic is not specified in *OWAM*, the persistence parameter is instead adjusted from ω to $\omega+\lambda$. Failing firms will take on negative NPV capital investments or, according to Biddle et al. (2000), divest and λ turns negative. In the *OWAM* this is accounted for by a downward adjustment of ω to $\omega-\lambda$.

¹⁸ The noise terms on both sides in (M6b) have zero expectations and are do not affect the persistence parameters.

As demonstrated above, the two competing RI dynamics do not exist in two different worlds. However, the difference appears, since one of them (Ohlson 1995) is restricted to state constant persistence parameters, where systematic risk is ignored. Biddle et al. (2000) is therefore consistent with the *OWAM* with stochastic persistence parameters. In search for a valuation model that captures risk in a realistic way and is limited to available information at the valuation point of time, we will relax the parameter restriction in Ohlson (1995) without loss of generality from Biddle's approach.

The expected weighted average model

Our version of the *OWAM* takes into account that the evolution of RI is a stochastic process not only through unpredictable zero-mean noise terms but additionally through a stochastic shift in the persistence parameters for RI and other information. In this way we separate risk that is correlated with the two explanatory variables in the LID from independent noise. We call the new model "The Expected Weighted Average Model", abbreviated *EWAM*. A critical assumption is, on the other hand, that RI follows the same auto-regressive, mean reverting process, as does the original *OWAM*.

Introducing uncertainty involves a new and rather complex problem. How are the shocks in the persistence parameters distributed? For two reasons we make use of a uniform distribution. Firstly, a shift in the persistence parameters caused by risk factors can in general not be foreseen. According to LID, future events that are known to the market, but not yet captured in RI, are counted for by the information variable "other information". Thus, a shift in the persistence parameter for RI must be caused by "news of tomorrow". A uniform distribution is consistent with no prior information regarding possibilities for future states of nature. Secondly, RI is assumed to follow a stationary process. In order for the series to converge, restrictions have to be put on the two parameters, as shown in (A6a). A uniform distribution makes this possible by limiting the persistence parameters to extreme values.

$$\begin{aligned} I_w &\in [I_{w0}, I_w^0], & w + I_{w0} &\geq 0, & w + I_w^0 &\leq 1 \\ I_g &\in [I_{g0}, I_g^0], & g + I_{g0} &\geq 0, & g + I_g^0 &\leq 1 \end{aligned} \tag{A6a}$$

As to the persistence parameter for "other information", a uniform distribution may also be appropriate for the same reason. The expectations and variance for the shocks in the two persistence parameters are defined and denoted¹⁹:

¹⁹ As can be seen from (A6b) the variance is determined by the upper and lower values for lambda. Since systematic risk most likely varies across industries, the variance and hence the upper and lower values could be estimated from industry-wide regression. Dechow et al. (1999) obtained empirical support for the fact that RI is a positive function of lagged industry-wide RI among other determinants.

$$\begin{aligned}
I_w &\sim U(0, \mathbf{s}_w^2), & E[\tilde{I}_w] &= \frac{I_{w0} + I_w^0}{2}, & \mathbf{s}_w^2 &= \frac{(I_w^0 - I_{w0})^2}{12} \\
I_g &\sim U(0, \mathbf{s}_g^2), & E[\tilde{I}_g] &= \frac{I_{g0} + I_g^0}{2}, & \mathbf{s}_g^2 &= \frac{(I_g^0 - I_{g0})^2}{12}
\end{aligned}
\tag{A6b}$$

Shifts in the parameter for “other information” in the presence of systematic risk are most likely caused by conservatism in accounting, as we will explain soon. Since this variable is hard to materialize, we apply the same definition as in Dechow et al. (1999)²⁰:

$$v_t \equiv E_t^f \left[\tilde{x}_{t+1}^a \right] - \mathbf{w}x_t^a \tag{D3}$$

where the first term on the right-hand side is the consensus analyst forecast of next period's RI.

Assume that (A1) and (A2) apply and that the persistence parameters vary stochastically according to (A6). The modified processes for RI and “other information” are formulated in (M7):

$$\begin{aligned}
\tilde{x}_{t+1}^a &= \left(\mathbf{w} + \tilde{I}_w \right) x_t^a + v_t + \mathbf{e}_{1t+1} \\
\tilde{v}_{t+1} &= \left(\mathbf{g} + \tilde{I}_g \right) v_t + \mathbf{e}_{2t+1}
\end{aligned}
\tag{M7}$$

Before we can proceed, the relation between the two parameters has to be established. In the following we will demonstrate that this relation is determined by accounting principles and of course by analysts' ability to interpret information.

There is a vast literature on analysts' forecast. Empirical studies that report evidence that analysts' forecasts are too optimistic include Brown (1997 and 98), Matsumoto (1998), and Richardson et al. (1999). Some recent studies have examined to what extent analysts learn from past bias. Mikhail et al. (1997), Jacob et al. (1999) and Clement (1999) report mixed results on the effect of experience on learning.

According to most accounting standards, accountants apply a conservative approach to profit measurement. Revenues and profits are not recognized until nearly all efforts have been expended and the customer is likely to pay while all actual and expected costs and losses are recorded immediately. For this reason we assume that there is a positive correlation between the shocks in the persistence parameters for RI and “other information”:

$$Cov \left[\tilde{I}_w, \tilde{I}_g \right] > 0 \tag{A7}$$

²⁰ Dechow et al. applied (D3) on suggestion from Jim Ohlson.

The rationale for (A7) is as follows. If $I_w > 0$ a firm will take on positive NPV projects. Since the gains from these projects typically are captured late in the books but to a certain degree is known to the market, the future contents of “other information” will increase. For the firm in question the industry’s persistence parameter for “other information” is adjusted with a positive shock. If $I_w < 0$ a firm will fail in business.²¹ Since losses are recognized immediately, the contents of “other information” will decrease which for a specific firm will imply a negative shock in the persistence parameter. Analysts’ attitude (optimism or pessimism) will also have relevance in this matter. In the case of analysts’ realism, the shock in the persistence parameter for “other information” could compensate exactly for the effects of conservatism in accounting.

Before we proceed with the specification of the *EWAM* let us see how systematic risk affects the process for “other information”. Substituting (D3) into the revised process in (M7) yields:

$$v_{t+1} = \mathbf{g} \left(E_t^f \left[x_{t+1}^a \right] - (\mathbf{w} + \tilde{\mathbf{I}}_w) x_t^a \right) + \tilde{\mathbf{I}}_g \left(E_t^f \left[x_{t+1}^a \right] - (\mathbf{w} + \tilde{\mathbf{I}}_w) x_t^a \right) + \mathbf{e}_{2,t+1} \quad (\text{M8})$$

The first term in (M8) is “other information” with respect to the industry average in period t+1, while the second term captures the firm specific part of “other information” in the same period due to systematic risk. Keeping in mind that accounting is conservative and assuming that there is persistence in firm specific “other information”, we can see from the second term in (M8) that “other information” one period ahead contains value adding information if analysts are realistic or optimistic.²² In these cases both terms in (M8) will be positive. A further discussion of the separation of value relevant information is provided in the next section.

We are now ready to specify the new valuation model. Since the valuation coefficients \mathbf{a}_1 and \mathbf{a}_2 are convex in both of the persistence parameters, expected values of the valuation coefficients have to be calculated in order to avoid downward bias in equity value.²³ The revised model is presented in (M9).

$$\begin{aligned} P_t &= y_t + E_t[\mathbf{a}_1]x_t^a + E_t[\mathbf{a}_2]v_t \\ a(\mathbf{I}_w, t) &\equiv \text{Exp}\{(\mathbf{w} + \mathbf{I}_w - R_f)t\} \\ b(\mathbf{I}_g, t) &\equiv \text{Exp}\{(\mathbf{g} + \mathbf{I}_g - R_f)t\} \\ E_t[\mathbf{a}_1] &= \iint_{\Omega} (\mathbf{w} + \mathbf{I}_w) a(\mathbf{I}_w, t) \frac{1}{\mathbf{I}_w^0 - \mathbf{I}_{w0}} d\mathbf{I}_w dt \\ \Omega &= [0, \infty] \times [\mathbf{I}_{w0}, \mathbf{I}_w^0] \end{aligned} \quad (\text{M9})$$

²¹ Firms failing in business are outperformed by the industry average.

²² Conservative accounting implies that RI in period t+1 (realistically or optimistically assessed) due to systematic risk $> (\mathbf{w} + \mathbf{I}_w) x_t^a$. Persistence in firm specific “other information” implies that $\mathbf{I}_g > 0$.

²³ The valuation coefficients are the same as in *OWAM*. See (M2).

$$E_t[\mathbf{a}_2] = R_f \int_0^\infty \left(\int_{I_{w0}}^{I_w^0} a(\mathbf{I}_w, t) \frac{1}{I_w^0 - I_{w0}} dI_w \times \int_{I_{g0}}^{I_g^0} b(\mathbf{I}_g, t) \frac{1}{I_g^0 - I_{g0}} dI_g \right) dt \\ + Cov \left[R_f \int_0^\infty a(\mathbf{I}_w, t) dt, \int_0^\infty b(\mathbf{I}_g, t) dt \right]$$

Integrating over states of nature and time provides the following solutions to the expected value coefficients in (M9)²⁴. *EWAM* has the following solution:

$$E_t[\mathbf{a}_1] = \frac{\dot{w}^0 - \dot{w}_0 + R_f (\ln\{R_f - \mathbf{w}^0\} - \ln\{R_f - \mathbf{w}_0\})}{\mathbf{w}_0 - \mathbf{w}^0} \\ E_t[\mathbf{a}_2] = \frac{R_f (\ln\{R_f - \mathbf{w}^0\} - \ln\{R_f - \mathbf{w}_0\}) \cdot (\ln\{R_f - \mathbf{g}^0\} - \ln\{R_f - \mathbf{g}_0\})}{(\mathbf{w}_0 - \mathbf{w}^0) \cdot (\mathbf{g}_0 - \mathbf{g}^0)} \\ + Cov \left[\frac{R_f}{R_f - (\mathbf{w} + \tilde{\mathbf{I}}_w)}, \frac{1}{R_f - (\mathbf{g} + \tilde{\mathbf{I}}_g)} \right] \quad (M10)$$

$$\mathbf{w}^0 \equiv \mathbf{w} + \mathbf{I}_w^0, \quad \mathbf{w}_0 \equiv \mathbf{w} + \mathbf{I}_{w0} \\ \mathbf{g}^0 \equiv \mathbf{g} + \mathbf{I}_g^0, \quad \mathbf{g}_0 \equiv \mathbf{g} + \mathbf{I}_{g0}$$

Some important properties of EWAM

Convexity

The *EWAM* is convex in the persistence parameters for RI and “other information”. This property implies that the process for expected RI is affected by systematic risk in a non-linear fashion, and that there is a positive relationship between systematic risk and expected return:

²⁴ $E[XY] = E[X] \cdot E[Y] + Cov[X, Y]$. Note that the following relations exist in (M9):

$$\int_0^\infty a(\mathbf{I}_w, t) dt = \frac{1}{R_f - (\mathbf{w} + \mathbf{I}_w)}, \quad \int_0^\infty b(\mathbf{I}_g, t) dt = \frac{1}{R_f - (\mathbf{g} + \mathbf{I}_g)}$$

$$\frac{d^2 E_t[\mathbf{a}_i]}{dw_t^2} > 0 \quad i = \{1,2\}$$

$$\frac{d^2 E_t[\mathbf{a}_2]}{dg_t^2} > 0$$
(P4)

Convergence

EWAM converges to *OWAM* when systematic risk is ruled out. Formally stated that is:

$$\lim_{(w^0 - w_0) \rightarrow 0} E_t[\mathbf{a}_1] = \frac{\mathbf{w}}{R_f - \mathbf{w}}$$

$$\lim_{\substack{(w^0 - w_0) \rightarrow 0 \\ (g^0 - g_0) \rightarrow 0}} E_t[\mathbf{a}_2] = \frac{R_f}{(R_f - \mathbf{w})(R_f - \mathbf{g})}$$
(P5)

This property shows that the convex process for expected RI is caused by shocks in the persistence parameters, and these shocks only.

Information limits

Based on (D3) the information set at time t is limited to knowledge held by financial analysts. Assume that RI follows the process defined in (M7) and substitute (D3) for “other information”. It follows then that:

$$E_t \left[x_{t+1}^{\tilde{a}} \right] = E_t^f \left[x_{t+1}^{\tilde{a}} \right]$$
(P6)

Value relevant information for subsequent periods is limited to analysts’ forecasts one period ahead and the persistence in this information.

Separation of information

The basis for all value relevant information determining the stock price is according to (P7) based on analysts’ forecasts at the time of valuation (time t). In *EWAM* this information can be traced to four different sources. These are: (1) industry information in the accounts, (2) firm specific information in the accounts, (2) industry information not yet captured in the accounts, and (4) firm specific information not yet captured in the accounts. The two latter groups constitute “other information”. Analysts’ forecasts embed all available information at the time of valuation. Since the information set is limited, there is a tradeoff between information captured in books and “other information”.

Persistence in information implies that a decreasing amount of the original information from analysts’ forecasts at time t has relevance for subsequent periods’ RI. RI can be separated into four parts according to source, where all parts are related to their common base. This property can be seen from the expression of RI in period $t+2$.

Based on (M7) and (M8) and a arbitrary realization of \tilde{I}_w and \tilde{I}_g ; I_w and I_g , the expected RI two periods ahead is:

$$E_t \left[\tilde{x}_{t+2}^a \right] = (\mathbf{w} + \mathbf{I}'_{\mathbf{w}}) E_t \left[\tilde{x}_{t+1}^a \right] + E_t \left[\tilde{v}_{t+1} \right] \quad (\text{P7a})$$

Making use of (D3) and substituting (M8) into (P7a) yields:

$$\begin{aligned} E_t \left[\tilde{x}_{t+2}^a \right] &= \mathbf{w} E_t^f \left[\tilde{x}_{t+1}^a \right] + \mathbf{I}'_{\mathbf{w}} E_t^f \left[\tilde{x}_{t+1}^a \right] \\ &+ \mathbf{g} \left(E_t^f \left[\tilde{x}_{t+1}^a \right] - (\mathbf{w} + \mathbf{I}'_{\mathbf{w}}) x_t^a \right) + \mathbf{I}'_{\mathbf{g}} \left(E_t^f \left[\tilde{x}_{t+1}^a \right] - (\mathbf{w} + \mathbf{I}'_{\mathbf{w}}) x_t^a \right) \\ &= \mathbf{w} E_t^f \left[\tilde{x}_{t+1}^a \right] + \mathbf{I}'_{\mathbf{w}} E_t^f \left[\tilde{x}_{t+1}^a \right] + \mathbf{g} v_t + \mathbf{I}'_{\mathbf{g}} v_t \end{aligned} \quad (\text{P7b})$$

As can be seen from the two latter terms in (P7b), “other information” feeds into accounts with a lag of one period.

Denoting “other information” as a fraction of analysts’ forecast “the other information ratio”, abbreviated OIR and the overall persistence in information χ it follows that:²⁵

$$\begin{aligned} OIR &\equiv \frac{v_t}{E_t^f \left[\tilde{x}_{t+1}^a \right]} \\ 0 &\leq OIR \leq 1 \\ \tilde{\mathbf{c}} &= \mathbf{w} + \tilde{\mathbf{I}}_{\mathbf{w}} + (\mathbf{g} + \tilde{\mathbf{I}}_{\mathbf{g}}) OIR \leq 1 \\ E_t \left[\tilde{x}_{t+2}^a \right] &= \tilde{\mathbf{c}} E_t \left[\tilde{x}_{t+1}^a \right] \end{aligned} \quad (\text{P7c})$$

In the case where OIR=0 analysts’ forecasts contain no information beyond book information and equity value is based on book information only. In the case where OIR =1 analysts’ forecasts and equity value are simply based on “other information”, since $\mathbf{w} + \mathbf{I}'_{\mathbf{w}} = 0$ due to (D3).

Summary and conclusions

Broadly speaking valuation of equity deals with the structuring and interpretation of value relevant information at a certain point in time. Some of this information is observable (current accounting numbers) and some is not (future numbers). The

²⁵ The overall persistence parameter provides the fraction of total information set (analysts’ forecast) that has value relevance for the next period RI.

information dynamics that provides a link between the two groups of numbers in the *OWAM* is a modified, stochastic AR1-process, where next period's RI is explained by this period's RI and information not yet captured in accounting data. The parameters of the process are assumed fixed and known. Thus all noise is captured in zero expectation noise terms and will not influence the expectation of the process. It follows that all risk is unsystematic or, put differently, that all future strategic and operational activities yield zero NPV.

One way to acknowledge the existence of systematic risk is to allow for shocks in the persistence parameters. In practice these parameters are broad industry estimates based on historic data. Assuming that the industry's historic performance has future relevance, about one half of the firms will outperform the industry average, while the other half will underperform. Since the consequences of risk by nature are hidden at the time of valuation, it is hard to range the firms as to future performance. Thus one knows that systematic risk exists, but no prior information is at hand as to how it will affect a specific firm.²⁶ For this reason valuation should be carried out within the frame of all possible states of nature. Since the evolution of systematic risk is not disclosed at the time of valuation and the persistence parameters are restricted by the stationary AR1, a uniform probability distribution is appropriate. The expectations of the two persistence parameters is the (estimated) industry average. For a specific firm, the realization of the parameters is the same average plus a shock determined by future strategic and operational activities.

Ignoring the existence of systematic risk by applying a linear information dynamics, a downward valuation bias will occur. This bias increases in the magnitude of systematic risk. In the *EWAM* systematic risk is not related to capital investments only. The shock in the persistence parameter for RI captures the overall effect of all value creating activities in the firm. Thus the model is general in this sense.

In common with its origin, the *OWAM*, the *EWAM* is restricted by a modified AR1. The challenge for further research is twofold: (1) The study of information dynamics without the AR1-frame. (2) The study of economic determinates of RI. In doing so the phenomenon of systematic risk could be replaced by the substance of firm specific risk in order to obtain better estimates.

Appendix 1

The dividend model – price/book model identity.

Assume that the price of equity is determined by the company's distribution of dividends in perpetuity:

$$(1a) \quad P_t = \sum_{i=1}^{\infty} R_f^{-i} E_t[d_{t+i}]$$

Assume furthermore that a clean surplus relation exists:

$$(1b) \quad y_t = y_{t-1} + x_t - d_t \quad \Leftrightarrow \quad d_t = x_t + y_{t-1} - y_t$$

²⁶ Since the regressed persistence parameters are based on aggregate data, firm specific information is not at hand, and is therefore represented by the stochastic term, lambda.

Finally, assume that abnormal earnings are defined as:

$$(1c) \quad x_t^a = x_t - (R_f - 1)y_{t-1}$$

It follows then that:

$$(1d) \quad P_t = y_t + \sum_{i=1}^{\infty} R_f^{-i} E_t [x_{t+i}^a]$$

Proof:

Substitute (1b) into (1a):

$$(1e) \quad P_t = \sum_{i=1}^{\infty} R_f^{-i} E_t [x_{t+i} + y_{t+i-1} - y_{t+i}]$$

Add and subtract normal earnings in (1e):

$$(1f) \quad P_t = \sum_{i=1}^{\infty} R_f^{-i} E_t [x_{t+i} + y_{t+i-1} - y_{t+i} + (R_f - 1)y_{t+i-1} - (R_f - 1)y_{t+i-1}]$$

Reorganizing the right-hand side in (1f) provides (1g):

$$(1g) \quad P_t = \sum_{i=1}^{\infty} R_f^{-i} E_t [R_f y_{t+i-1}] - \sum_{i=1}^{\infty} R_f^{-i} E_t [y_{t+i}] + \sum_{i=1}^{\infty} R_f^{-i} E_t [x_{t+i} - (R_f - 1)y_{t+i-1}]$$

Simplifying the first term on the right-hand side in (1g) provides (1h):

$$(1h) \quad P_t = \sum_{i=0}^{\infty} R_f^{-i} E_t [y_{t+i}] - \sum_{i=1}^{\infty} R_f^{-i} E_t [y_{t+i}] + \sum_{i=1}^{\infty} R_f^{-i} E_t [x_{t+i} - (R_f - 1)y_{t+i-1}]$$

The book value at time t is known and can be isolated from the first term on the right-hand side in (1h). The proof is completed.

$$(1i) \quad P_t = y_t + \sum_{i=1}^{\infty} R_f^{-i} E [x_{t+i}^a]$$

Appendix 2

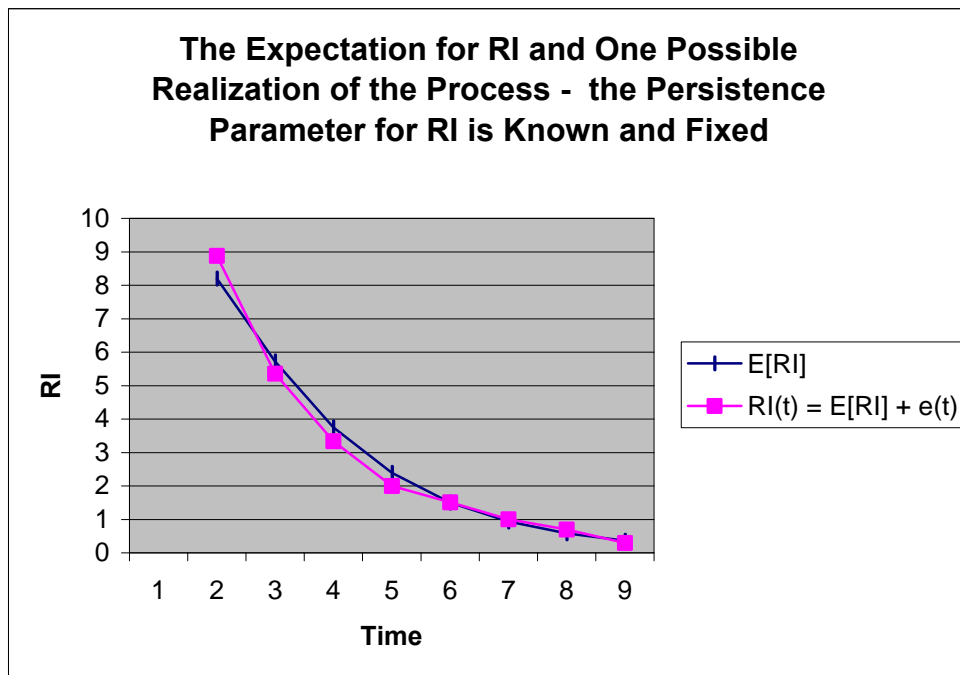
Assume that the following information applies for a specific firm:

- | | | |
|----|-------------------------------------------------------------------------------------|------------------------------------|
| 1. | RI (x_0^a) at time 0: | USD 10.00 |
| 2. | “Other information” at time 0:
($v_t \equiv E_t^f [x_{t+1}^a] - \omega x_t^a$) | USD 2.00 |
| 3. | Persistence parameter for RI: | $\omega = 0.62$ (industry average) |
| 4. | Persistence parameter for
“other information” ²⁷ : | $\gamma = 0.32$ (industry average) |

²⁷ According to estimates from Dechow et al. (1999).

5. Noise term for RI²⁸: $e_t \sim N(0, 0.2E(x_t^a)^2)$

Figure 1



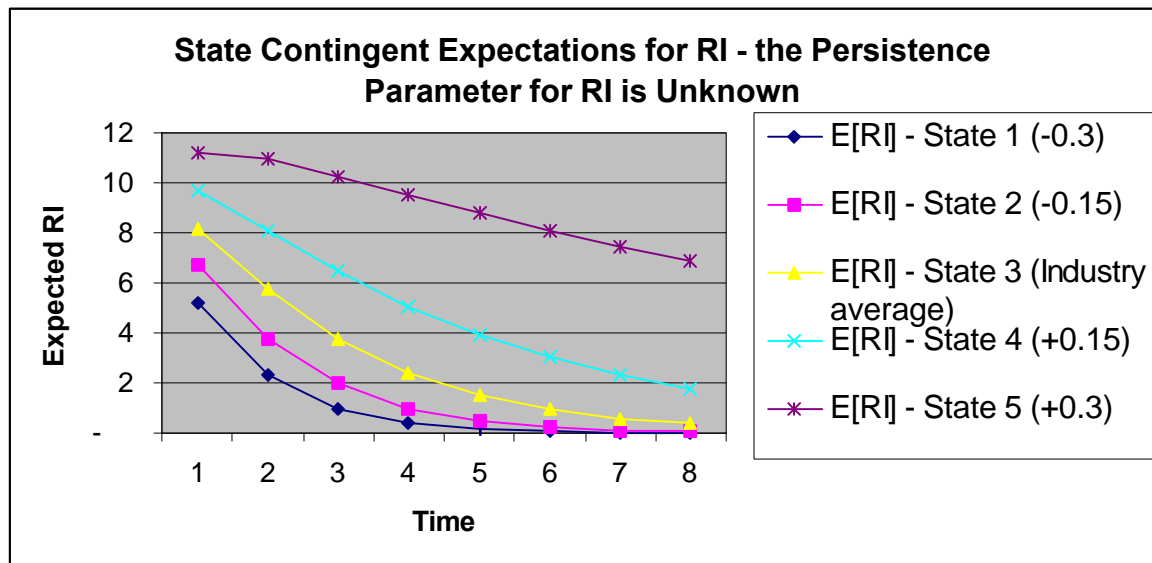
The process illustrated in figure 1 is consistent with the modified AR1 in OWAM, where all risk is unsystematic with respect to the expected RI.

Assume now that the persistence parameter for RI is a stochastic variable and that five states of nature exist for a specific firm.²⁹

²⁸ The standard deviation is fixed to 20% of expected value.

²⁹ In the general case discussed in this paper the model is continuous in state of nature and the persistence parameter for “other information” is also treated as a stochastic variable.

Figure 2



The processes illustrated in figure 2 are consistent with the *EWAM*. Possible realizations of processes for RI are excluded in the figure. Thus, unsystematic risk is not illustrated. Systematic risk with respect to the expected RI is represented by the presence of more than one possible persistence parameter.

Appendix 3

Necessary condition for convexity in the solution of the OWAM:

The linear solution of the Ohlson valuation model is:

$$(3a) \quad P_t = y_t + \mathbf{a}_1(\mathbf{w})x_t^a + \mathbf{a}_2(\mathbf{w}, \mathbf{g})v_t$$

$$(3b) \quad \mathbf{a}_1 = \mathbf{w}/(R_f - \mathbf{w}) \geq 0$$

$$(3c) \quad \mathbf{a}_2 = R_f / [(R_f - \mathbf{w})(R_f - \mathbf{g})] > 0$$

$\alpha_i(\omega, \gamma)$ is convex in S if $Q''(\omega, \gamma)$ is semi-definite in S .

Define $Q_i''(\omega, \gamma)$ as the matrix of two times partial derivatives of α_i , $i = 1, 2$

$$(3d) \quad Q_1''(\mathbf{w}, \mathbf{g}) = \mathbf{a}_1''_{11} = \frac{2R_f}{(R_f - \mathbf{w})^3} > 0$$

$$0 \leq \mathbf{w} \leq 1 \leq R_f \quad \forall \mathbf{w} \in S$$

$$\Rightarrow \mathbf{a}_1 \text{ is convex in } S.$$

$$(3e) \quad Q_2''(\mathbf{w}, \mathbf{g}) = \begin{pmatrix} \mathbf{a}_2''_{11} & \mathbf{a}_2''_{12} \\ \mathbf{a}_2''_{21} & \mathbf{a}_2''_{22} \end{pmatrix} = R_f \begin{pmatrix} \frac{2}{(R_f - \mathbf{g})(R_f - \mathbf{w})^3} & \frac{1}{(R_f - \mathbf{g})^2(R_f - \mathbf{w})^2} \\ \frac{1}{(R_f - \mathbf{g})^2(R_f - \mathbf{w})^2} & \frac{2}{(R_f - \mathbf{g})^3(R_f - \mathbf{w})} \end{pmatrix}$$

$$0 \leq \{\mathbf{w}, \mathbf{g}\} < 1 \leq R_f \quad \forall \{\mathbf{w}, \mathbf{g}\} \in S.$$

$$(3f) \quad \mathbf{a}_2''_{11} > 0, \quad \mathbf{a}_2''_{22} > 0, \quad \mathbf{a}_2''_{11} \mathbf{a}_2''_{22} - (\mathbf{a}_2''_{12})^2 = \frac{3R_f}{(R_f - \mathbf{g})^4 (R_f - \mathbf{w})^4} > 0$$

$$\Rightarrow \mathbf{a}_2 \text{ is convex in } S.$$

Appendix 4

Assume that the following LID exists:

$$(4a) \quad x_{t+1}^a = \mathbf{w}x_t^a + \mathbf{e}_{t+1}$$

Moreover, assume that ω is time variant and unknown, and that $\mathbf{e}_t \sim IID(0, \mathbf{s}_e^2)$.

Define ω as the related industry's persistence parameter for residual income (RI). Also define $\tilde{\mathbf{I}}_w$ as a firm specific shock in ω , capturing the overall effect of the firm's future activities that effects $\{x_{t+i}^a\}$ systematically over time, and $\tilde{\mathbf{I}}_{w+i}^U$ as a zero mean, firm specific shock in ω at time t+i, due to risk effecting $\{x_{t+i}^a\}$ unsystematically over time.

Incorporating the shock terms in (4a) yields (4b):

$$(4b) \quad x_{t+1}^a = (\mathbf{w} + \tilde{\mathbf{I}}_w + \tilde{\mathbf{I}}_{w+1}^U)x_t^a + \mathbf{e}_{t+1}$$

The stochastic components of the firm specific persistence parameter can be separated, as shown in (4c):

$$(4c) \quad \begin{aligned} \tilde{x}_{t+1}^a &= (\mathbf{w} + \tilde{\mathbf{I}}_w)x_t^a + \tilde{e}_{t+1} \\ \tilde{e}_{t+1} &= \mathbf{e}_{t+1} + \tilde{\mathbf{I}}_{w+1}^U x_t^a \end{aligned}$$

Since unsystematic risk is captured by the noise term, it does not affect the expectation of the process.

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