Resource Margin Accounting: A Theoretical Perspective

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Abstract: in this paper a valuation framework known as Resource Margin Accounting (*RMA*) is described and elucidated. The framework overcomes a number of the deficiencies of traditional cash-flow methods, and is methodologically superior to Economic Value Added (*EVA*). Resource margins have their origins in the microeconomics of industrial structure, and are robust performance measures well-captured by accounting systems. Through the adoption of clean-surplus accounting, resource margins may be made entirely compatible with financial portfolio theory, and at the level of individual companies they may be the focus of value creation through competitive strategy initiatives. In a further paper empirical evidence to validate this new approach to valuation of companies and strategies will be presented.

1. Introduction

The objective of the research[1] presented in this paper is to develop a robust way of valuing companies and strategies that overcomes the deficiencies of discounted cash flow techniques (*DCF*), and that has a rigorous foundation in theory. The origins of this work lie in the consensus shared by senior managers, consultants and financial officers that existing cash-flow valuation methods are flawed and open to manipulation.[2]Such a theory would be of significant practical value to economists, bankers and strategists.

In Section 2, the drawbacks of *DCF* methods are reviewed and the overall conceptual approach that underlies resource margin accounting (*RMA*) is outlined. The next section of the paper develops certain resource margin performance measures and relates them to strategy and industrial economics. The relative merits of *RMA* as compared with economic value-added (*EVA*) are discussed in Section 4. In Section 5, explicit formulations of four families of *RMA* models are developed, each family corresponding to a simple auto-regressive or moving-average process on either levels or differences for resource margins scaled by value-added. The paper concludes with a summary and a description of the empirical testing to be covered in the second paper.

2. Deficiencies in Cash Flow Methods

It is easy to list some of the difficulties associated with *DCF* valuation methods: predicting events very far away; deciding over what horizon to evaluate the performance of the business; the choice of discount rate and terminal values. Ancillary difficulties relate to the prediction of exogenous variables, for example inflation, tax and interest rates. As consultants and bankers are well aware, the valuations produced are largely judgements based upon experience, and so are not different in principle to methods which employ price-earnings or other multiples. This is not to say that the construction of complex *DCF* models is entirely without merit: these tools have heuristic value and explicitly capture interdependencies and sensitivities. It is wrong, however, to conclude speciously that these models produce the correct valuation of a company, project or strategy.

Besides these internally-oriented difficulties, other subtler assumptions are often made. It is usually assumed that ownership is constant; *DCF* often overlooks strategic degrees of freedom created by good performance, or constraints imposed by short term disappointments. More sophisticated modellers attempt to address some of these weaknesses by blitzing us with a myriad of scenarios. Too often, the models assume management of the business by auto-pilot, including scenarios which are not credible. Real

[1] I am grateful to Professors Colin Mayer, Kenneth Peasnell and John O'Hanlon for their support and guidance in carrying out this research, and to the Said Business School and the Rector and Fellows of Exeter College for funding it. I am also very appreciative of the hard work put in by my research assistants Neil Marson and Jane Tucker of Balliol College.
[2] For an optimistic modern account of cash-flow methods see Copeland, Koller and Murrin (1995).

options may be grafted on, but without a methodology for determining which options are appropriate, there is no basis for accepting these capricious elements of value. Providing a methodology, on the other hand, assumes that one has a complete, realistic set of future scenarios for the company or business in order to select options, in which case, one may ask why the real options are required.

DCF represents a "crystal ball" view of valuation. An alternative, dubbed the "c.v." view, may be available. To see how, consider the case of employment. In deciding how much to pay a person, theoretically one could calculate, using *DCF* scenario methods, the financial contribution the employee could be expected to make to the firm over the period of employment. This would require a tremendously detailed set of assumptions and scenarios about clients, wages, profits etc. In practice we do not do this: besides the effort involved, any answer would be considered very precarious. Instead we analyse the c.v. of the applicant, paying particular attention to the key elements that might have an impact on remuneration. Implicitly we then compare the performance of the candidate on these key elements to the performance of other personnel for whom we have pay information. In this way we reach a conclusion about the general level of remuneration, which might be subject to some final negotiation.

In like fashion, the author proposes that companies and strategies be valued through the extraction of measures of historic performance that are salient to valuation. Given that a company, or business is on a particular trajectory, we can then ask how such trajectories are valued currently. An understanding of the valuation metric for given trajectories will allow us to be able to predict over a sensible horizon, how today's future performance will be valued retrospectively when the future arrives. A sensible horizon would be one that co-incides with typical management tenure, planning horizons and accountability: probably three to four years in most cases. In this way, one would be able to assess future strategies based upon their expected impact on value, without the need to consider events which are too distant to be confident about and which cannot be controlled or influenced. The critical question is what are the relevant measures of performance.

3. Resource Margins

Value-added, often called net output by economists, is an important factor in the determination of competitive success. Normally, value-added is taken to be defined as firm revenues minus the cost of raw materials and purchases.[3] The structure of an industry and how it evolves can be well captured by the

[3] Clearly there are questions of the value-added boundary of a firm. For instance, should factory electricity costs be included in value-added? The author believes these questions might settled based upon considerations of "returnability". Where input factors might immediately be returned without price erosion, the factors may be held to be a purchase. Those inputs which are not returnable, or which suffer price erosion, entail a degree of specificity to the firm in question which warrants their inclusion in the value-added structure. Under normal circumstances, imported factory electricity cannot normally be re-exported and hence would be included in value-added.

analysis of the distribution of value-added between different industry participants and how it shifts over time. Similarly, within what strategy consultants call a *strategic segment* of an industry[4], or what academics call *mobility groups*, much competitor activity can be considered to be a struggle to control and safeguard profitable value-added through strategies based upon relative cost position, superior price realisation through differentiation, or through technological advantage.[5] Within the firm, value-added corresponds to the resource base which managers control and which they use to implement strategies - it is the platform in which reside core competences.[6] Since the term "value-added" is much used, and gives rise to confusion between the value added to the net worth of a company beyond the contribution towards book capital, and value-added as understood by tax authorities and economists, we will prefer to use the term **resources**.

Two key imperatives for competitive success are to grow the resources of the firm, and to achieve a satisfactory level of return (economic rent) on those resources. We represent the growth of resources for a firm by g_R, and return on resources by *RM*.

$$\text{Resource margin} \quad = RM = \frac{Economic\ \mathrm{Pr}ofit}{Economic\ \mathrm{Re}sources\ Consumed}$$

Many studies in industrial organisation (*IO*) have examined the relationship between profitability and resources in different structural contexts.[7] These studies have shown that significant linkages exist between profitability, resources and industry structure. A measure often chosen for this research is the Price-Cost-Margin or *PCM*, which is defined as

$$\frac{\text{Net output - employee compensation}}{\text{Net output}}$$

If employee compensation represents a large majority of resource costs, then the numerator in the above expression will be approximately equal to profit and

$$RM \approx PCM$$

A focus on average levels of *RM* within an industry is also consistent with the Structure-Conduct-Performance model elucidated by Bain (1959) and others. In other words, *IO* research has revealed the relevance of resource margins to performance at the level of industries. The valuation framework proposed

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[4] See Grant, R.M., (1992), *Contemporary Strategy Analysis: Concepts, Techniques, Applications*, Oxford: Blackwell.

[5] For instance see Porter (1980,1985)

[6] This is a simplification insofar as we overlook the need to achieve a competitive level of raw material and purchase prices through effective purchasing.

[7] For example: Fairburn J., Geroski P., (1993) The Empirical Analysis of Market Structure and Performance in Kay J., Bishop M., *European Mergers and Merger Policy*, Oxford: OUP.

extends this *IO* approach (which relates structure to levels of performance) to the level of individual companies.

Furthermore, growth and profitability in relation to resources accommodate two approaches to business strategy which, while complementary, are often considered to represent opposing views: the resource-based view of the firm as developed by Prahalad and Hamel (1990), and portfolio-based strategy popularised by General Electric, McKinsey and the Boston Consulting Group. The performance of a firm depends both upon the structural context in which all competing firms find themselves, and the individual firm's ability to establish a competitive advantage relative to its competitors in that context. The context will determine the magnitude of resources over which firms compete, the growth of those resources, and typical levels of profit that may be sustained in relation to those resources. Competitive advantage, on the other hand, will determine the profitability and development of resources for the individual firm relative to its competitors.

In other words, the level of *RM* achieved by a firm will depend upon how well it uses it resources relative to competitors (the resource-based view), as well as the attractiveness of the segments it operates in (the portfolio-based view), and the structure of the industry surrounding these segments (Porter Five Forces). Similarly, the ability to generate superior returns in a segment, and the attractiveness of segments for new business development will be strongly influenced by the growth of resources. The resource margins approach incorporates the two prevailing perspectives on strategy.

One may inquire as to the nature of the linkages between resource margins and investor rates of return. Resource margin captures the relative magnitude of the economic rents in relation to the economic resources consumed.

One can visualise this on a one-year basis. Imagine that investors provide funding sufficient to cover the cost of the business' net output for one year. This means that the business can cover all its value-adding activities, but raw material and bought-in purchase costs are billed direct to the customer. If the business operates competitively, the return it achieves on the economic resources it consumes will be just sufficient to reward investors for the risk they have borne. This may be stated mathematically as

$$RM = r$$

The resource margin equals the required rate of return of investors. This normative result is a general prerequisite for financial and physical markets to be in equilibrium i.e. Tobin's Q = 1. In practice shareholder value will be created or destroyed according to whether $RM >< r$ (and hence $Q >< 1$): hence residual margins $RM-r$ will directly determine the value of the business. This immediately suggests that if we can determine the likely future pattern of the return on resources, we will be able to determine the future value of the business. How can we develop a view of likely future returns on resources?

The author believes that the past pattern of resources offers a good guide. Unlike many other financial measures, such as return on sales, or return on assets, return on resources is fundamentally embedded in the structural competitive context that surrounds a firm. It is determined by the microeconomics of the business. Different structural circumstances, combined with particular competitive advantages will determine the level of economic rents available in relation to the economic resources committed to the business, as has been seen at the industry level in the work of Bain and others. This relationship between rents and resources is exactly what is expressed by a resource margin. In this way, we may make an explicit link at the level of a firm between the microeconomic context, the strategy pursued and levels of return, that is robust, explanatory and well grounded. Accounting and financial theory then allows us to integrate the resource margin series into a numerical value. Because of its grounding in strategy and microeconomics, we can place good confidence n using resource margin patterns as a predictor of likely future resource margins over a short-to-medium term window (just as we do with good c.v.'s).

The theoretical underpinning of resource margins in microeconomics and strategy should, in principle, allow us to use historic patterns of returns to shape reliably our view of likely future returns in a way that avoids much of the arbitrariness of typical DCF projections.

RM also allows interesting and meaningful comparisons between businesses which have markedly different capital requirements: contrast for example a hotel business, a contract catering business and a restaurant business. Traditional measures of performance such as return on capital employed or return on sales do not produce meaningful comparisons between these businesses. Hotel businesses show low returns on capital because capital growth through property appreciation is not usually included in profits; restaurants make income on moderate levels of assets; contract catering has paper-thin sales margins, but excellent cash characteristics. The use of resource margins can allow meaningful comparisons to be made. [8]

	Capital employed	**Return on sales**	**Return on capital**	**RM**
Hotels	High	High	Low	Satisfactory
Restaurants	Moderate	Moderate	Good	Satisfactory
Contract catering	Negative	Very small	Non-sensical	Satisfactory

[8] *EVA* fares no better, because (i) the hotel business is in fact a combination of an investment business and an accommodation renting business, (the former warrants a capital charge derived from the market value of the hotel property, whereas the latter does not); (ii) the capital employed in contract catering is often negative because payables exceed the combined value of debtors, stocks and fixed assets. As we shall see later, separation of the operational and funding aspects of a business, allows us to develop a comparative measure which reflects the efficiency with which businesses use resources, capturing in a much sounder way the opportunity costs associated with the consumption of resources by particular businesses.

While the resource-oriented nature of *RM* may meet with approval, it will perhaps be objected that we have failed to take account of the need to provide adequate returns to capital. This is traditionally done by deducting a charge for book capital from earnings to yield residual earnings, more popularly known as Economic Value Added (*EVA*):

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

where x_t^a are residual earnings in period *t*, x_t are earnings in period t , *R* is 1 plus the cost of capital *r*, and y_{t-1} is the closing book value of the previous period. It can then be shown (Peasnell 1982) that

$$P_t \quad = \quad y_t \quad + \quad \sum_{\tau=1}^{\infty} E_t\left[x_{t+\tau}^a \; R^{-\tau}\right]$$

where P_t is the market value of a company at time *t*. $E_t[Q]$ represents the expected value at time *t* of variable Q. (In general going forward $E_t[\;]$ will not be specified for the sake of clarity, unless expressly required). This expression states that the value of the company is equal to its book value plus the sum of discounted future residual earnings. The second sum on the right-hand side may also be considered to be unrecorded goodwill.

O'Hanlon (1996) has modified this approach by developing valuation models that incorporate residual returns scaled by the book capital in the company. He introduces the Rate of Residual Income (*RRI*), denoted by χ^a, which is defined as

$$\chi_t^a \quad = \quad \frac{x_t^a}{y_{t-1}} \quad = \quad \frac{x_t - (R-1)y_{t-1}}{y_{t-1}} \quad = \quad A_t - (R-1)$$

where A_t is the accounting rate of return on capital (*ARR*).

The difficulty with the *EVA* approach is that it conflates questions of economic efficiency with questions of funding. Criticism along these lines has been voiced by Kwong, Munro and Peasnell (1994). Part of the capital y_t is required to fund working capital because of the operating cycle of the business. This need for capital has nothing to do with the efficiency of the use of resources by the firm in competitive markets.[9]

Consider the case of a business which is newly established and where invoices are settled instantaneously, where all equipment is efficiently rented at a cost equal to the economic rate of depreciation of the assets involved, and where all profits are immediately paid over to the owners. In these circumstances, the

[9]A specific difficulty for *EVA* as traditionally formulated, is that a capital charge is made against fixed operating capital and inventories, with no account taken of the other elements of working capital.

question of the economic use of resources by the business still arises, but the book value of the company is zero. *EVA* and residual earnings, in the case of this very fast turning business, are equal to earnings, but it is not possible to assess whether the use of resources by the business amounts to an opportunity (utility) gain or loss.

A similar situation arises if we contemplate an extremely lengthy accounting period for a business where what are customarily the unexpired costs of capital assets are treated as period expenses. Again, starting and ending book values would be zero. Hence, *EVA* assessments of performance would appear to be subject to accounting conventions with regard to periods, and strongly influenced by the operating cycles of the business.

As an alternative, we may separate conceptually the operational funding of a business from the contribution to the value of the firm that arises from the efficient or inefficient use of resources. This separation is similar to the separation of tax and financing effects from an all-equity valuation that arises in Adjusted Present Value approaches to discounted cash flow.[10] Let us set aside the question of the funding of the operational cycle of the business: any capital which exists and is recorded on the balance sheet should be regarded, under this approach, as equivalent to cash or marketable investments, which do not feature in the valuation of the business as a going economic concern.[11]

In other words, we may consider the value of the firm to be comprised of two elements: an investment component and an operational component. The investment component not only includes cash and marketable securities, but also working capital viewed as a largely involuntary or passive investment in the company. It would also include any holding gain expected to arise from the retention of physical assets in excess of the purchase price of the asset. A risk-adjusted rate of return would be required on the investment component.

The operational component of valuation would be determined by the level and development of resource margins, and would be independent of the book values of physical assets employed, once account had been taken of any expected holding gains. The value of the physical assets deployed would be entirely captured in the future economic rents in the business. No charge for book capital would be made in the evaluation of the operational component, but the question would remain as to how to gauge whether the returns quantified in the operational component are adequate to satisfy investors. This will be considered in due course. Note that in drawing a distinction between investment and operational components of value, the intention is not to diminish the practical importance of tight control of inventories and working capital, but to focus upon the microeconomic linkages that support the *RM* performance measures which have been introduced.

[10] Brearley and Myers (1981) or Luehrman (1997)

[11] Assets other than cash should be valued by discounting their associated flows at a risk-adjusted rate *r*. If the rate of depreciation is equal to the economic rate of depreciation no bargain or loss will occur in relation to book asset values.

One immediate corollary of this approach is that, if assets are depreciated according to their true economic returns and these returns are capitalised in the balance sheet i.e. the assets are efficiently priced, the value of the firm will be independent of starting book value, putting the realities of working capital and the payments cycle aside. The value of the firm would be entirely captured by the flows which occur as a result of its operations, and would not include stock variables. This makes sense because we do not want the economic value of the company to be affected by accounting conventions which determine how balance sheet assets are fixed.

Consider the case of a new firm operating on an instantaneous payment cycle which has purchased or leased assets for its business on an efficient basis. Assume instantaneous full pay-out of dividends Since there was no prior period operation, the value of the firm P_t is given by:

$$
\begin{aligned}
P_t &= \sum_{\tau=1}^{\infty} x_{t+\tau} R^{-\tau} \\
&= \sum_{\tau=1}^{\infty} RM_{t+\tau} . \upsilon_{t+\tau} R^{-\tau}
\end{aligned}
$$

where $RM_{t+\tau}$ and $\upsilon_{t+\tau}$ are respectively the resource margin and the level of resources in period $t+\tau$. If resources grows at a compound rate g, P_t is equal to:

$$
\begin{aligned}
P_t &= \sum_{\tau=1}^{\infty} RM_{t+\tau} . \upsilon_{t+1} R^{-\tau} (1+g)^{\tau-1} \\
&= \sum_{\tau=1}^{\infty} (RM_{t+\tau} - \quad r) . \upsilon_{t+1} R^{-\tau} (1+g)^{\tau-1} + \sum_{\tau=1}^{\infty} r . \upsilon_{t+1} R^{-\tau} (1+g)^{\tau-1} \\
&= \upsilon_{t+1} \sum_{\tau=1}^{\infty} \gamma^{-\tau} (RM_{t+\tau} - \quad r) \quad + \quad \frac{r\,\upsilon_{t+1}}{r-g}
\end{aligned}
$$

where $\gamma^{-\tau} = \dfrac{(1+g)^{\tau-1}}{R^{\tau}}$.

The second term on the right-hand side is equal to the capitalised normal returns expected on the resources flows of the company. (The first term discounts resource margins which exceed investors required rate of return, r i.e. residual or surplus resource margins). In an ideal accounting system these normal flows, which result from contracts with employees, customers and suppliers, would be recorded as assets and liabilities in the balance sheet, and their sum would represent the book value of the firm and equal the replacement cost of the firm's resources. These assets and liabilities are distinct from the investments historically made to fund the company which have already been discussed. The assets and liabilities recorded are the yet-to-be-incurred costs and yet-to-be-recovered revenues of the firm which together give rise to the stream of normal profits arising on the resources $\upsilon_{\tau+1}$ which grows at rate *g*. If we then divide the left-hand side of the above expression by this book value, we obtain:

$$Q = 1 + \frac{r-g}{r} \sum_{\tau=1}^{\infty} \gamma^{-\tau} \left(RM_{\tau} - r\right)$$

In the case of $g = 0$, this simplifies to:

$$Q = 1 + \sum_{\tau=1}^{\infty} R^{-\tau} \left(RM_{\tau} - r\right)$$

This equation states that for the idealised firm, the ratio of the market to book value of the firm is given by one plus the sum of the discounted marginal revenue products of the firm i.e. Tobin's Q. The magnitude of Q is determined by $RM_{\tau} - r$ and g making explicit the importance of excess resource margins and the growth in resources in the creation of shareholder wealth through competitive advantage.

It may be objected that the importance of residual resource margins $RM_{\tau} - r$ has been overstated since we may create pseudo-residual returns for other measures of profitability, which are not of strategic relevance to valuation. Consider for instance returns on sales, ROS_{τ}, where σ_{τ} represents the corresponding level of sales and g' is the compound growth in sales:[12]

$$\begin{aligned}
P_t &= \sum_{\tau=1}^{\infty} x_{t+\tau} R^{-\tau} \\
&= \sum_{\tau=1}^{\infty} ROS_{t+\tau}.\sigma_{t+\tau} R^{-\tau} \\
&= \sum_{\tau=1}^{\infty} ROS_{t+\tau}.\sigma_{t+1} R^{-\tau} (1+g')^{\tau-1} \\
&= \sum_{\tau=1}^{\infty} \left(ROS_{t+\tau} - r\right).\sigma_{t+1} R^{-\tau} (1+g')^{\tau-1} + \sum_{\tau=1}^{\infty} r.\sigma_{t+1} R^{-\tau} (1+g')^{\tau-1}
\end{aligned}$$

[12] We are not assuming here that materials and purchases are billed direct to the customer i.e. sales are not equal to value-added.

$$= \sigma_{t+1} \sum_{\tau=1}^{\infty} \gamma^{-\tau} \left(ROS_{t+\tau} - r \right) + \frac{r\sigma_{t+1}}{r-g'}$$

Thus the value of the firm is equal to the discounted sum of residual returns on sales plus a capitalised normal return on sales.

This result does not undermine the significance of the corresponding equations for RM. The key difference is that in the case of RM the resources in each period equal the net cash flow of the firm upon which the required rate of return r must be earned.[13] This is not the case with the ROS returns, which do not equate to the stream of cash flows of the firm in each year. One may visualise this situation by considering the history of the firm to comprise a series of one period share offerings and liquidations. The amount of investment required in each period is equal to the resources of that period, assuming materials are billed direct to customers; shareholders require a return of r during the period.[14] Any returns on the resources used up by the firm in the period beyond this rate create unexpected additional wealth for shareholders.

Use of residual RM returns is not inconsistent with the fundamental notions that support EVA, and may be held to be a logical improvement. In EVA, a charge is made against the book capital of the business, and we obtain the familiar:

$$P_t = y_t + \sum_{\tau=1}^{\infty} E_t \left[\left(x_{t+\tau} - (R-1) \; y_{t+\tau-1} \right) R^{-\tau} \right]$$

It is later shown that if this equation is modified to accommodate RM measures of profitability, we obtain:

$$P_t = \upsilon_{t+1} \sum_{\tau=1}^{\infty} \gamma^{-\tau} \left(RM_{t+\tau} - r \right) + \frac{r\upsilon_{t+1}}{r-g} - \frac{g_B}{r-g_B} y_t$$

where g_B is the growth in book value y_t which reflects the historic funding of the firm, not the replacement cost of resources contracted by the firm. This equation is similar to the equation derived for the value of a firm which does not require subsequent injections of capital, and where assets are efficiently priced, but an extra term is introduced which represents the capitalised stream of additional investment absorbed by the business to fund assets and working capital. Hence

Value	=	abnormal returns on resources i.e. value-added	+	normal returns on resources	-	additional capital to support application of resources

[13] Assuming economic depreciation of assets.

[14] Any holding gains or timing differences from using depreciation schedules different from economic depreciation are assumed to be captured in the investment component of valuation discussed above.

Note, in particular, that if there is no growth in book value, the value of the firm is independent of the value of starting capital y_t as conjectured. The associated Q ratio is given by:

$$Q' = 1 + \frac{r-g}{r}\left(\sum_{\tau=1}^{\infty}\gamma^{-\tau}\left(RM_{\tau}-r\right) - \frac{g_B}{r-g_B}\alpha\right)$$

where α is the ratio of book value y_t to initial resources υ_1.

In order to complete the account of the relationship between *EVA* and *RM*, a reconciliation of these two measures for an idealised company is required. If the replacement value of the resources to be consumed by the company is efficiently priced and recorded on the balance sheet, then the opening asset value y_t (equal to the initial book value of the company) will be $r\upsilon_1/(r-g)$ as detailed above. It remains to show that for this company $Q'(EVA)=Q(RMA)$, i.e. that $g_B=0$. Let us assume initially that the company pays out dividends equal to ry_t, consistent with *EVA* methods. Let us consider the development of the book value of the firm B_{t+1}, which we know was initially equal to the replacement value of the resources contracted i.e. $B_t = y_t$. From accounting identities we know

$$B_{t+1} = B_t + \upsilon_1 RM_1 - \left(y_t - y_{t+1}\right) - rB_t$$

If we substitute known identities and assume assets are subject to economic depreciation, we obtain:

$$B_{t+1} = \frac{r\upsilon_1}{r-g} + \upsilon_1 RM_1 - \left(\frac{r\upsilon_1}{r-g} - \frac{r\upsilon_2}{r-g}\right) - r.\frac{r\upsilon_1}{r-g}$$

Substituting $\upsilon_2 = (1+g)\,\upsilon_1$ yields

$$B_{t+1} = \frac{r\upsilon_1}{r-g} + \upsilon_1 RM_1 + g.\frac{r\upsilon_1}{r-g} - r.\frac{r\upsilon_1}{r-g}$$

$$= \frac{r\upsilon_1}{r-g} + \upsilon_1\left(RM_1 - r\right)$$

$$= B_t + \upsilon_1\left(RM_1 - r\right)$$

Thus book value will increase by the level of abnormal returns in the period if these abnormal returns are retained. The assumption of retention is not consistent, however, with the assumptions used to determine the replacement value of the resources contracted. In attributing a replacement value of

$r\upsilon_1/(r-g)$, it was assumed that the replacement value was equal to the discounted marginal products of the growing stream of resources of the firm. If abnormal earnings are retained, additional return will be earned on the retentions and the replacement values for future periods ($r\upsilon_2/(r-g)$etc.) will require adjustment.[15] The replacement values adopted reflect full pay-out of abnormal returns, in which case $B_{t+1} = B_t$ and $g_B = 0$.

For an idealised firm, the book value of equity will be constant if dividends are paid equal to a normal return upon the replacement value of resources contracted to the firm plus any abnormal returns earned on those resources. Under these conditions $Q' = Q$ and the use of *RM* as a value-creating measure of performance is entirely reconciled with the more familiar *EVA* approach.

4. Advantages of *RMA* relative to *EVA*

Consider again the Peasnell (1982) identity:

$$P_t \;=\; y_t \;+\; \sum_{\tau=1}^{\infty} E_t\left[x^a_{t+\tau}\, R^{-\tau}\right]$$

where P_t is the market value of a company at time *t*, y_t is the book value of the company at time *t*, x^a_t are residual earnings in period *t*, *R* is 1 plus the cost of capital *r*. $E_t[Q]$ represents the expected value at time *t* of variable Q. Residual earnings are given by:

$$x^a_t \;=\; x_t \;-\; (R-1)\; y_{t-1}$$

where x^a_t are residual earnings in period *t*, x_t are earnings in period *t*, *R* is 1 plus the cost of capital *r*, and y_{t-1} is the closing book value of the previous period.

The first equation says that the market value of the company is equal to its book value plus a goodwill item, which Stern Stewart call Market Value Added (*MVA*). This *MVA* term is made up of the sum of earnings in excess of what the market requires on the book value of capital in the business discounted at the investor cost of capital. Stern Stewart call these residual earnings terms, *when calculated using Stern Stewart's accounting conventions*, Economic Value Added. The second equation describes how these terms are defined.

This approach is very intuitively appealing. It says the value consists of what's in the books plus the goodwill that arises when we make more than investors require on the firm's assets. Because Stern Stewart's approach makes managers

[15] This is discussed in Ohlson (1995) p.673.

account for capital in their business on a risk-adjusted basis, and because of its simplicity, it has won a large measure of acceptance as a single-period operating measure. Nonetheless, it has problems.

The first is that a single-period residual return (*EVA*) measure is not necessarily reliable when it comes to maximising value. If a company always chooses the course of action which maximises the residual return in the next period, this may lead to the rejection of a strategy which maximises value over a number of periods. Remember, the first equation involved a summation of residual earnings over (theoretically) an infinite number of periods, not just one. In going from a horizon of ten or more years, to a single year, we seem to have gone too far.

Second, the *EVA* in any given period is unlikely to equal the total return to shareholders in that period. As Peasnell and O'Hanlon (1998) have shown:

$$\text{Shareholder abnormal return in period } t \quad = \quad x_t^a + \left(\Delta GW_t - rGW_{t-1}\right)$$

where GW_t is unrecorded goodwill at time *t* and ΔGW_t is the single-period change in goodwill. The term in brackets is not generally zero, so shareholder abnormal return will not normally equal *EVA*.

Another problem is that companies systematically generate too many positive residuals. Investors are well informed, so if nearly all companies earned positive residual returns, investor expectations would change and result in different required rates. One might also ask why, when residual returns are nearly always positive, do a large number of companies have a market-to book ratio of less than one. Asset valuation is only one of a number of accounting problems which each lead to modifications and revisions of accounting data. Other issues relate to the treatment of unrecorded intangibles, fluctuating cycles of working capital, and the extent to which we should look at gross rather than net assets.

As discussed above, the *EVA* approach like historical cost accounting in general, conflates questions of economic efficiency with questions of funding. Part of the capital y_t is required to fund working capital because of the operating cycle of the business. This need for capital has nothing to do with the efficiency of the use of resources by the firm in competitive markets.

In the same way that *EVA* mixes up resources and funding, it might be argued that *EVA* illogically mixes up past and present economic performance. *EVA* combines stock variables (assets and balance sheet items) and flows (P&L items) into a return measure of economic performance rather than relying entirely upon flows so as to produce an economic margin (or spread). For instance, the book value of equity includes not only the money spent in the past buying assets, but also reflects residual earnings elements from superior performance in the past, which have not been paid out as dividends. The result for *EVA* is a measure which tries to convey whether a business is using resources efficiently *now* by reference to the resources the business consumed *previously*. Some managers will rightly protest that they do not care about how the business performed in the past; what they want to understand is whether the business is making good economic use of resources it is consuming currently.

Given these difficulties, it makes sense to reflect on how they arose. Much of the damage is caused by the infinite discounting formulae used as the basis of valuation. We are encouraged to think that the value of a company should be equal to the endless stream of dividends we would receive from a share, discounted at appropriate opportunity costs of capital. Is this valid given that no one has ever held a share for an infinite period? If we hold a share for a finite period, then sell it, we might think of its value today as the dividends we receive plus the value we sell the share for (appropriately discounted). But what is the value of the share at the end of the holding period? Traditional financial theorists, will say that a person buying the share at the end of the initial holding period will carry out the same sort of analysis, thinking about interim dividends and the value of the shares at the end of the second period. So the value for the original purchaser will equal the dividends received in the first two holding periods plus the value of the share at the end of the second holding period. Clearly we can continue this analysis for all the subsequent periods. If we follow this logic, we will be led to conclude that the value today is, indeed, the discounted sum of an infinite series of dividends. Although this reasoning might satisfy the financiers, philosophers would regard it as question-begging, rather like justifying induction as a principle on the grounds that this principle has always worked. The assumption that values in the future are determined by an infinitely discounted series of (then) future cash flows cannot be used as an argument when this very assumption of infinite discounting is in question.

It is perfectly possible that the value of the share at the end of the holding period might not reflect the underlying performance of the company over the holding period. But, the traditionalists will say, this can only be a temporary aberration because arbitrage between physical and financial markets will require that ultimately the market value of the company will coincide with its economic value, which is set by the expected infinite stream of remaining dividends. This is not a winning counter-argument to the hold-and-dispose model of valuation: for significant periods physical and financial markets may be decoupled (witness dot.com speculation). Nonetheless, financial markets may remain efficient in the sense that prices correspond accurately to investor expectations, even though these expectations are collectively considered unrealistic by experts. If we adopt the hold-and-dispose model, and search empirically for performance measures which explain how expectations are set, we will be able to develop a valuation method that restricts itself to an horizon that corresponds to management and investor holding periods, without running into the problems that arise from the traditional dividend-discounting paradigm. This paper proposes that as a robust performance measure resource margins can play a significant part in setting expectations, which is not surprising given their role in industrial organisation and micro-economics.

5. Time-series ARIMA Processes

Having provided a theoretical grounding for the use of *RM* measures, we may turn to the modelling of residual *RM* returns using time series analysis to investigate the response of these returns to transitory and permanent shocks. Such methods allow us to address explicitly the significant auto-correlation that exists in a series of annual resource margins.

Define *residual earnings on resources*, f_t^a, *residual resource margins*, ϕ_t^a, and *resource margins*, RM_t, as follows:

$$f_t^a = x_t - (R-1)\,\upsilon_t$$

$$\phi_t^a = \frac{f_t^a}{\upsilon_t} = \frac{x_t}{\upsilon_t} - (R-1) = RM_t - r$$

$$RM_t = \frac{x_t}{\upsilon_t}$$

Then we may substitute residual earnings on resources for customary residual earnings[16]

$$\begin{aligned} x_t^a &= x_t - (R-1)\,y_{t-1} \\ &= f_t^a + (R-1)(\upsilon_t - y_{t-1}) \end{aligned}$$

and apply this expression to the standard formula for firm value to obtain:

$$P_t = y_t + \sum_{\tau=1}^{\infty} f_{t+\tau}^a R^{-\tau} + (R-1)\sum_{\tau=1}^{\infty} \upsilon_{t+\tau} R^{-\tau} - (R-1)\sum_{\tau=1}^{\infty} y_{t+\tau-1} R^{-\tau}$$

If resources grows at a compound rate of g and book value at g_B, then

$$\begin{aligned} P_t = y_t + \sum_{\tau=1}^{\infty} f_{t+\tau}^a R^{-\tau} + (R-1)\left[\frac{\upsilon_{t+1}}{R} + \frac{(1+g)\upsilon_{t+1}}{R^2} + \frac{(1+g)^2\upsilon_{t+1}}{R^3} + \ldots\right] \\ - (R-1)\left[\frac{y_t}{R} + \frac{(1+g_B)y_t}{R^2} + \frac{(1+g_B)^2 y_t}{R^3} + \ldots\right] \end{aligned}$$

Summing the series yields:

$$P_t = y_t + \sum_{\tau=1}^{\infty} f_{t+\tau}^a R^{-\tau} + \frac{(R-1)\,\upsilon_{t+1}}{(r-g)} - \frac{(R-1)\,y_t}{(r-g_B)}$$

---

[16] Note that in all cases we use clean surplus earnings

Substituting ϕ_t^a for f_t^a yields

$$P_t \;=\; y_t\left(\frac{-g_B}{r-g_B}\right) \;+\; \upsilon_{t+1}\left(\frac{r}{r-g}\right) \;+\; \sum_{\tau=1}^{\infty}\upsilon_{t+\tau}\phi_{t+\tau}^a R^{-\tau}$$

and since $\upsilon_{t+\tau} = \upsilon_{t+1}(1+g)^{\tau-1}$

$$P_t \;=\; y_t\left(\frac{-g_B}{r-g_B}\right) \;+\; \upsilon_{t+1}\left(\frac{r}{r-g}\right) \;+\; \upsilon_{t+1}\sum_{\tau=1}^{\infty}\gamma^{-\tau}\,\phi_{t+\tau}^a$$

$$=\; y_t\left(\frac{-g_B}{r-g_B}\right) \;+\; \upsilon_{t+1}\left(\frac{r}{r-g}\right) \;+\; \upsilon_{t+1}\sum_{\tau=1}^{\infty}\gamma^{-\tau}\,(RM_{t+\tau}-r)$$

which is the result cited in Section 3, page 10 above.

Next consider the case of the evolution of ϕ_t^a according to a generalised auto-regressive, integrated, moving-average process ARIMA (*p*,*d*,*q*):

$$\Delta^d\phi_t^a \;-\; \overline{\Delta}^d\phi^a \;=\; \sum_{c=1}^{c=p}\omega_c\left(\Delta^d\phi_{(t-c)}^a - \overline{\Delta}^d\phi^a\right) \;-\; \sum_{j=1}^{j=q}\theta_j e_{(t-j)} \;+\; e_t$$

where ω_c is an auto-regressive coefficient of order c, θ_j is a moving-average coefficient of order j, and e_t is a zero mean, randomly distributed error term. *p*, *d*, *q* are the orders of the auto-regressive, differencing and moving-average processes respectively.

Adapting the results of O'Hanlon (1994), it is possible to obtain a generalised expression for the impact of ϕ_t^a on the value of P_t:

$$P_t = \upsilon_t \left[\frac{r(1+g)}{r-g} - \frac{\alpha g_B}{r-g} + \left[\begin{array}{l} \overline{\Delta}^d \phi^a \left(\frac{\gamma^d}{(\gamma-1)^{d+1}} \right) + \left(\sum_{z=0}^{z=d-1,d>0} \Delta^z \phi_t^a \left(\frac{\gamma^z}{(\gamma-1)^{z+1}} \right) \right) + \\ \left(\frac{1}{\left(\frac{\gamma-1}{\gamma}\right)^d \left(1-\sum_{c=1}^{c=p} \frac{\omega_c}{\gamma^c}\right)} - \left(\frac{\gamma}{\gamma-1}\right)^d \right) \left(\Delta^d \phi_t^a - \overline{\Delta}^d \phi^a \right) + \\ \frac{1}{\left(\frac{\gamma-1}{\gamma}\right)^d \left(1-\sum_{c=1}^{c=p} \frac{\omega_c}{\gamma^c}\right)} \left(\sum_{c=2}^{c=p} \sum_{s=1}^{s=c-1} \omega_c \left(\frac{\Delta^d \phi_{t-s}^a - \overline{\Delta}^d \phi^a}{\gamma^{c-s}} \right) \right) - \\ \frac{1}{\left(\frac{\gamma-1}{\gamma}\right)^d \left(1-\sum_{c=1}^{c=p} \frac{\omega_c}{\gamma^c}\right)} \left(\sum_{j=1}^{j=q} \sum_{k=0}^{k=j-1} \frac{\theta_j e_{t-k}}{\gamma^{j-k}} \right) \end{array} \right] \right]$$

where three small changes have been made to simplify the result: $\gamma^\tau = (1+r)^\tau / (1+g)^\tau$, incorporating an extra factor of $(1+g)$ in relation to the expression for gamma used previously; υ_t has replaced υ_{t+1} ; and accordingly $\alpha = y_t / \upsilon_t$.

The general expression may be summed for the simplest ARIMA processes to yield the following specific models.

ARIMA (1, 0, 0)

$$P_t = \upsilon_t \left[\frac{-\alpha g_B}{r-g_B} + \frac{\overline{RM}}{(\gamma-1)} \left(\frac{\gamma(1-\omega)}{\gamma-\omega} \right) + \frac{RM_t}{\gamma-1} \left(1 - \left(\frac{\gamma(1-\omega)}{\gamma-\omega} \right) \right) \right]$$

This is a weight-average of the current level of RM and the mean level of RM.

ARIMA (0, 0, 1)

$$\begin{aligned} P_t &= \upsilon_t \left[\frac{-\alpha\, g_B}{r-g_B} + \frac{\overline{RM}}{\gamma-1} - \frac{\theta}{\gamma} \left[\phi_t^a - \overline{\phi}^a + \gamma \left[\frac{-\alpha\, g_B}{r-g_B} . \frac{G_V}{G_B} + \frac{\overline{RM}}{\gamma-1} - \frac{P_{t-1}}{\upsilon_{t-1}} \right] \right] \right] \\ &= \upsilon_t \left[\frac{-\alpha\, g_B}{r-g_B} \left(1 - \frac{\theta\, G_v}{G_B} \right) + \frac{\overline{RM}}{\gamma-1} (1-\theta) + \theta \left[\mu_{t-1} - \frac{\left(RM_t - \overline{RM}\right)}{\gamma} \right] \right] \end{aligned}$$

where $\mu_t = P_t / \upsilon_t$. Thus the market value is a weight average of mean margins and a term involving the deviation from average margins and the market to resources ratio in the previous period.

ARIMA (1, 1, 0)

$$P_t \;=\; \upsilon_t \left[\frac{-\alpha\, g_B}{r - g_B} + \frac{RM_t}{\gamma - 1} + \left(\frac{\omega\gamma}{(\gamma-\omega)(\gamma-1)} \right). \,\Delta RM_t \right]$$

This expression results from another weight-average expression (see Section 7) and combines current and first difference terms.

ARIMA (0, 1, 1)

$$P_t \;=\; \upsilon_t \left[\frac{-\alpha\, g_B}{r - g_B} \left(1 - \frac{\theta\, G_v}{G_B} \right) + \left(\frac{RM_t}{\gamma - 1} \right) (1-\theta) + \theta\, \mu_{t-1} \right]$$

The formula is a weight-average of the current level of *RM* and the prior period ratio of market value to resources.

The models correspond to (i) a simple auto-regressive process on levels of resource margin; (ii) a moving-average process on levels of resource margin; (iii) a simple auto-regressive process on first differences in levels of resource margin; and (iv) a moving-average process for first differences. The models generally involve a weight average of terms which relate to average and current levels of resource margin. They are similar to those in O'Hanlon (1994, 1996), Ohlsen (1995) and Ramakrishnan and Thomas (1992). In Section 7 individual derivations are given for each of these results.

In the second paper, these simple models are tested longitudinally against US corporate and market data extracted from the Compustat Research Insight company and market databases.

6. Conclusions

In this paper a theoretical framework has been developed to substantiate the value-relavance of clean surplus resource margins in a "c.v." valuation framework. It has been shown that resource margins have a good pedigree arising from research in industrial organisation, that they can be embedded in traditional microeconomic, accounting and finance frameworks, and are consistent with but avoid some of the drawbacks of *EVA*. Specific models have also been developed to examine the time-series behaviour of residual resource margins which are empirically testable.

An initial analysis will undertaken to test the strength of the linkages between market-to-resources and market-to-book ratios and (i) clean surplus resource margins, (ii) average clean surplus resource margins, (iii) residual returns, (iv) growth in resources for all years for the companies in the sample.

A second module of analysis will be undertaken in which companies are allocated to one of four basic ARIMA models. The models of resource margin development for each family of companies will then be used to compare actual and predicted values of market-to-resources and market-to-book ratios for individual companies.

If empirical evidence supports such an approach, there are good prospects for the development of a robust retrospective valuation method that avoids many of the deficiencies long associated with discounted cash-flow methods.

7 Derivations

7.1 ARIMA (1, 0, 0)

As a first order autoregressive process it follows that

$$
\begin{aligned}
\phi_t^a - \bar{\phi}^a &= \omega \left(\phi_{t-1}^a - \bar{\phi}^a\right) \\
\phi_{t+1}^a - \bar{\phi}^a &= \omega \left(\phi_t^a - \bar{\phi}^a\right) \\
\phi_{t+2}^a - \bar{\phi}^a &= \omega \left(\phi_{t+1}^a - \bar{\phi}^a\right) = \omega^2 \left(\phi_t^a - \bar{\phi}^a\right) \quad \textit{etc.}
\end{aligned}
$$

If we then sum the discounted series $\phi_{t+\tau}^a$ we obtain

$$
\begin{aligned}
\sum \phi_{t+\tau}^a \gamma^{-\tau} &= \frac{\omega\left(\phi_t^a - \bar{\phi}^a\right) + \bar{\phi}^a}{\gamma} + \frac{\omega^2\left(\phi_t^a - \bar{\phi}^a\right) + \bar{\phi}^a}{\gamma^2} + \ldots \\
&= \left(\phi_t^a - \bar{\phi}^a\right)\left[\frac{\omega}{\gamma} + \frac{\omega^2}{\gamma^2} + \frac{\omega^3}{\gamma^3} + \ldots\right] + \bar{\phi}^a\left[\frac{1}{\gamma} + \frac{1}{\gamma^2} + \frac{1}{\gamma^3} + \ldots\right] \\
&= \left(\phi_t^a - \bar{\phi}^a\right)\left(\frac{\omega}{\gamma - \omega}\right) + \frac{\bar{\phi}^a}{\gamma - 1}
\end{aligned}
$$

If we substitute this formula into the expression for P_t on page 16 we obtain

$$
\begin{aligned}
P_t &= \upsilon_t \left[\frac{-\alpha g_B}{r - g_B} + \frac{(R-1)G}{(R-G)} + \frac{\bar{\phi}^a}{\gamma - 1} + \frac{\omega}{\gamma - \omega}\left(\phi_t^a - \bar{\phi}^a\right)\right] \\
&= \upsilon_t \left[\frac{-\alpha g_B}{r - g_B} + \frac{(R-1)}{(\gamma-1)} + \frac{\bar{\phi}^a}{\gamma - 1} + \frac{\omega}{\gamma - \omega}\left(\phi_t^a - \bar{\phi}^a\right)\right] \\
&= \upsilon_t \left[\frac{-\alpha g_B}{r - g_B} + \frac{\overline{RM}}{(\gamma-1)} + \frac{\omega}{\gamma - \omega}\left(RM_t - \overline{RM}\right)\right] \\
&= \upsilon_t \left[\frac{-\alpha g_B}{r - g_B} + \frac{\overline{RM}}{(\gamma-1)}\left(\frac{\gamma(1-\omega)}{\gamma - \omega}\right) + \frac{RM_t}{\gamma - 1}\left(1 - \left(\frac{\gamma(1-\omega)}{\gamma - \omega}\right)\right)\right]
\end{aligned}
$$

where $G = \left(1 + g_{VA}\right)$ and $R = (1 + r)$. This is a weight-average of the current level of RM and the mean level of RM.

7.2 ARIMA (0, 0, 1)

For this process we know

$$\begin{aligned}
\phi_t^a - \bar{\phi}^a &= -\theta\, e_{t-1} + e_t \\
\phi_{t+1}^a - \bar{\phi}^a &= -\theta\, e_t + e_{t+1} \\
\phi_{t+2}^a - \bar{\phi}^a &= -\theta\, e_{t+1} + e_{t+2} \quad etc.
\end{aligned}$$

Since the error terms e_{t+1} and onwards are randomly distributed about a zero mean, their expected value is zero. If we sum the discounted series of residual returns we obtain

$$\begin{aligned}
\sum \phi_{t+\tau}^a \gamma^{-\tau} &= -\frac{\theta\, e_t}{\gamma} + \frac{\bar{\phi}^a}{\gamma} + \frac{\bar{\phi}^a}{\gamma^2} + \frac{\bar{\phi}^a}{\gamma^3} + \ldots \\
&= -\frac{\theta\, e_t}{\gamma} + \frac{\bar{\phi}^a}{\gamma - 1}
\end{aligned}$$

Substituting into the expression for P_t

$$\begin{aligned}
P_t &= \upsilon_t \left[\frac{-\alpha g_B}{r - g_B} + \frac{(R-1)G}{(R-G)} + \left[\frac{\bar{\phi}^a}{\gamma - 1} - \frac{\theta\, e_t}{\gamma} \right] \right] \\
&= \upsilon_t \left[\frac{-\alpha g_B}{r - g_B} + \frac{(R-1)}{(\gamma-1)} + \frac{\bar{\phi}^a}{\gamma - 1} - \frac{\theta\, e_t}{\gamma} \right] \\
&= \upsilon_t \left[\frac{-\alpha g_B}{r - g_B} + \frac{\overline{RM}}{(\gamma-1)} - \frac{\theta\, e_t}{\gamma} \right]
\end{aligned}$$

Rearranging

$$e_t = \frac{\gamma}{\theta} \left[\frac{-\alpha g_B}{r - g_B} + \frac{\overline{RM}}{\gamma - 1} - \frac{P_t}{\upsilon_t} \right]$$

Hence

$$e_{t-1} = \frac{\gamma}{\theta} \left[\frac{-\alpha g_B}{r - g_B} . \frac{G_{VA}}{G_B} + \frac{\overline{RM}}{\gamma - 1} - \frac{P_{t-1}}{\upsilon_{t-1}} \right]$$

Since

$$e_t = \phi_t^a - \bar{\phi}^a + \theta\, e_{t-1}$$

we obtain

$$
\begin{aligned}
P_t &= \upsilon_t \left[\frac{-\alpha\, g_B}{r-g_B} + \frac{\overline{RM}}{\gamma-1} - \frac{\theta}{\gamma}\left[\phi_t^a - \bar{\phi}^a + \gamma \left[\frac{-\alpha\, g_B}{r-g_B} . \frac{G_V}{G_B} + \frac{\overline{RM}}{\gamma-1} - \frac{P_{t-1}}{\upsilon_{t-1}} \right]\right]\right] \\
&= \upsilon_t \left[\frac{-\alpha\, g_B}{r-g_B}\left(1-\frac{\theta\, G_v}{G_B}\right) + \frac{\overline{RM}}{\gamma-1}(1-\theta) + \theta \left[\mu_{t-1} - \frac{\left(RM_t - \overline{RM}\right)}{\gamma} \right]\right]
\end{aligned}
$$

where $\mu_t = P_t / \upsilon_t$. Thus the market value is a weight average of mean resource margins and a term involving the deviation from average resource maaargins and the market to resources ratio in the previous period.

7.3 ARIMA (1, 1, 0)

For this process

$$
\begin{aligned}
\left(\phi_{t+1}^a - \phi_t^a\right) - \overline{\Delta}\phi^a &= \omega\left[\left(\phi_t^a - \phi_{t-1}^a\right) - \overline{\Delta}\phi^a\right] \\
\left(\phi_{t+n-1}^a - \phi_{t+n-2}^a\right) - \overline{\Delta}\phi^a &= \omega\left[\left(\phi_{t+n-2}^a - \phi_{t+n-3}^a\right) - \overline{\Delta}\phi^a\right] \\
\left(\phi_{t+n}^a - \phi_{t+n-1}^a\right) - \overline{\Delta}\phi^a &= \omega^n \left(\phi_t^a - \phi_{t-1}^a - \overline{\Delta}\phi^a\right) \\
\phi_{t+n}^a - \phi_t^a - n\,\overline{\Delta}\phi^a &= \left[\omega^n + \omega^{n-1} + \omega^{n-2} + \ldots + \omega\right]\left(\phi_t^a - \phi_{t-1}^a - \overline{\Delta}\phi^a\right) \\
\phi_{t+n}^a &= \left[\omega^n + \omega^{n-1} + \omega^{n-2} + \ldots + \omega\right]\left(\phi_t^a - \phi_{t-1}^a - \overline{\Delta}\phi^a\right) - \phi_t^a - n\,\overline{\Delta}\phi^a
\end{aligned}
$$

The last term on the right-hand side generates a series of perpetuities which when discounted as a series S gives

$$
\begin{aligned}
S &= \frac{\overline{\Delta}\phi^a}{\gamma-1}\left[1 + \frac{1}{\gamma} + \frac{1}{\gamma^2} + \frac{1}{\gamma^3} + \ldots\right] \\
&= \frac{\overline{\Delta}\phi^a\,\gamma}{(\gamma-1)^2}
\end{aligned}
$$

Using similar methods one can show the polynomial in ω sums to S' where

$$
S' = \frac{\omega\left(\omega^n - 1\right)}{\omega - 1}
$$

Thus if we discount the series of residual returns we obtain

$$\sum \phi_{t+\tau}^{a} \gamma^{-\tau} = \sum \left[\frac{\omega(\omega^{\tau}-1)}{\omega-1} . \left(\phi_t^a - \phi_{t-1}^a - \overline{\Delta}\phi^a\right) + \phi_t^a \right] \gamma^{-\tau} + \frac{\overline{\Delta}\phi^a \, \gamma}{(\gamma-1)^2}$$

$$= \frac{\omega}{\omega-1} . \left(\phi_t^a - \phi_{t-1}^a - \overline{\Delta}\phi^a\right) \sum \frac{\omega^{\tau}-1}{\gamma^{\tau}} + \frac{\phi_t^a}{\gamma-1} + \frac{\overline{\Delta}\phi^a \, \gamma}{(\gamma-1)^2}$$

$$= \frac{\omega}{\omega-1} . \left(\phi_t^a - \phi_{t-1}^a - \overline{\Delta}\phi^a\right) \left(\frac{\omega}{\gamma-\omega} - \frac{1}{\gamma-1} \right) + \frac{\phi_t^a}{\gamma-1} + \frac{\overline{\Delta}\phi^a \, \gamma}{(\gamma-1)^2}$$

$$= \frac{\omega \gamma}{(\omega-1)(\gamma-1)} . \left(\phi_t^a - \phi_{t-1}^a - \overline{\Delta}\phi^a\right) + \frac{\phi_t^a}{\gamma-1} + \frac{\overline{\Delta}\phi^a \, \gamma}{(\gamma-1)^2}$$

The corresponding market price is given by

$$P_t = \upsilon_t \left[\frac{-\alpha \, g_B}{r-g_B} + \frac{(R-1)}{\gamma-1} + \frac{\omega \gamma}{(\omega-1)(\gamma-1)} . \left(\phi_t^a - \phi_{t-1}^a - \overline{\Delta}\phi^a\right) + \frac{\phi_t^a}{\gamma-1} + \frac{\overline{\Delta}\phi^a \, \gamma}{(\gamma-1)^2} \right]$$

$$= \upsilon_t \left[\frac{-\alpha \, g_B}{r-g_B} + \frac{(R-1)}{\gamma-1} + \frac{\phi_t^a}{\gamma-1} + \frac{\overline{\Delta}\phi^a \, \gamma}{(\gamma-1)^2} + \frac{\omega \gamma}{(\omega-1)(\gamma-1)} . \left(\phi_t^a - \phi_{t-1}^a - \overline{\Delta}\phi^a\right) \right]$$

$$= \upsilon_t \left[\frac{-\alpha \, g_B}{r-g_B} + \frac{RM_t}{\gamma-1} + \frac{\overline{\Delta}\phi^a \, \gamma}{(\gamma-1)^2} \left[\frac{1}{\gamma-1} - \frac{\omega}{\gamma-\omega} \right] + \frac{\omega \gamma}{(\omega-1)(\gamma-1)} . \Delta RM_t \right]$$

$$= \upsilon_t \left[\frac{-\alpha \, g_B}{r-g_B} + \frac{RM_t}{\gamma-1} + \frac{\omega \gamma}{(\omega-1)(\gamma-1)} . \Delta RM_t + \frac{\overline{\Delta}RM \, \gamma}{(\gamma-1)^2} \left[\frac{\gamma(1-\omega)}{\gamma-\omega} \right] \right]$$

$$= \upsilon_t \left[\frac{-\alpha \, g_B}{r-g_B} + \frac{RM_t}{\gamma-1} + \left[\left(1 - \left[\frac{\gamma(1-\omega)}{\gamma-\omega} \right] \right) \Delta RM_t + \overline{\Delta}RM \left[\frac{\gamma(1-\omega)}{\gamma-\omega} \right] \right] \frac{\gamma}{(\gamma-1)^2} \right]$$

This is a weight-average of the current first difference and average first difference plus current level of resource margins. In the current case the average of the first difference is zero, so we obtain

$$P_t = \upsilon_t \left[\frac{-\alpha \, g_B}{r-g_B} + \frac{RM_t}{\gamma-1} + \left(\frac{\omega\gamma}{(\gamma-\omega)(\gamma-1)} \right) . \Delta RM_t \right]$$

7.4 ARIMA (0, 1, 1)

For this process on an expected value basis we may derive

$$
\begin{aligned}
\left(\phi^a_{t+1} - \phi^a_t\right) - \overline{\Delta}\phi^a &= -\theta\, e_{t-1} + e_t \\
\left(\phi^a_{t+n-1} - \phi^a_{t+n-2}\right) - \overline{\Delta}\phi^a &= 0 \\
\left(\phi^a_{t+n} - \phi^a_{t+n-1}\right) - \overline{\Delta}\phi^a &= 0 \\
\phi^a_{t+n} - \phi^a_t - n\,\overline{\Delta}\phi^a &= -\theta\, e_{t-1} \\
\phi^a_{t+n} &= -\theta\, e_{t-1} - \phi^a_t - n\,\overline{\Delta}\phi^a
\end{aligned}
$$

If we discount the residual returns we obtain

$$
\begin{aligned}
\sum \phi^a_{t+\tau}\,\gamma^{-\tau} &= -\theta\, e_t \left[\frac{1}{\gamma} + \frac{1}{\gamma^2} + \frac{1}{\gamma^3} + \ldots\right] + \frac{\phi^a_t}{\gamma - 1} + \frac{\overline{\Delta}\phi^a\,\gamma}{(\gamma-1)^2} \\
&= \frac{-\theta\, e_t}{\gamma - 1} + \frac{\phi^a_t}{\gamma - 1} + \frac{\overline{\Delta}\phi^a\,\gamma}{(\gamma-1)^2}
\end{aligned}
$$

This gives rise to the following price equation:

$$
\begin{aligned}
P_t &= \upsilon_t \left[\frac{-\alpha g_B}{r - g_B} + \frac{(R-1)G}{(R-G)} + \frac{-\theta\, e_t}{\gamma - 1} + \frac{\phi^a_t}{\gamma - 1} + \frac{\overline{\Delta}\phi^a\,\gamma}{(\gamma-1)^2}\right] \\
&= \upsilon_t \left[\frac{-\alpha g_B}{r - g_B} + \frac{RM_t}{(\gamma-1)} + \frac{\overline{\Delta}RM\,\gamma}{(\gamma-1)^2} - \frac{\theta\, e_t}{\gamma - 1}\right]
\end{aligned}
$$

Rearranging

$$
e_t = \frac{\gamma - 1}{\theta}\left[\frac{-\alpha g_B}{r - g_B} + \frac{RM_t}{\gamma - 1} + \frac{\overline{\Delta}RM\,\gamma}{(\gamma-1)^2} - \frac{P_t}{\upsilon_t}\right]
$$

Hence

$$
e_{t-1} = \frac{\gamma - 1}{\theta}\left[\frac{-\alpha g_B}{r - g_B}.\frac{G_{VA}}{G_B} + \frac{RM_{t-1}}{\gamma - 1} + \frac{\overline{\Delta}RM\,\gamma}{(\gamma-1)^2} - \frac{P_{t-1}}{\upsilon_{t-1}}\right]
$$

Since

$$
\begin{aligned}
e_t &= \phi^a_t - \phi^a_{t-1} - \overline{\Delta}\phi^a + \theta\, e_{t-1} \\
&= \Delta RM_t - \overline{\Delta}RM + \theta\, e_{t-1}
\end{aligned}
$$

we obtain

$$P_t = \upsilon_t \left[\begin{array}{l} \dfrac{-\alpha\, g_B}{r-g_B} + \dfrac{RM_t}{\gamma-1} + \dfrac{\overline{\Delta}RM\ \gamma}{(\gamma-1)^2} \\ -\dfrac{\theta}{\gamma-1}\left[\Delta RM_t - \overline{\Delta}RM + (\gamma-1)\left[\dfrac{-\alpha\, g_B}{r-g_B}.\dfrac{G_V}{G_B} + \dfrac{RM_{t-1}}{\gamma-1} + \dfrac{\overline{\Delta}RM\ \gamma}{(\gamma-1)^2} - \dfrac{P_{t-1}}{\upsilon_{t-1}}\right]\right] \end{array} \right]$$

$$= \upsilon_t \left[\begin{array}{l} \dfrac{-\alpha\, g_B}{r-g_B}\left(1-\dfrac{\theta\, G_v}{G_B}\right) + \dfrac{RM_t}{\gamma-1} + \dfrac{\overline{\Delta}RM\ \gamma}{(\gamma-1)^2}(1-\theta) \\ -\dfrac{\theta}{\gamma-1}\left[RM_t - \overline{\Delta}RM - (\gamma-1)\dfrac{P_{t-1}}{\upsilon_{t-1}}\right] \end{array} \right]$$

$$= \upsilon_t \left[\dfrac{-\alpha\, g_B}{r-g_B}\left(1-\dfrac{\theta\, G_v}{G_B}\right) + \left(\dfrac{RM_t}{\gamma-1} + \dfrac{\overline{\Delta}RM\ \gamma}{(\gamma-1)^2}\right)(1-\theta) + \theta\left[M_{t-1} + \dfrac{\overline{\Delta}RM}{\gamma-1}\right]\right]$$

In the current case the average of the first difference is zero, so we obtain

$$P_t \quad = \quad \upsilon_t \left[\dfrac{-\alpha\, g_B}{r-g_B}\left(1-\dfrac{\theta\, G_v}{G_B}\right) + \left(\dfrac{RM_t}{\gamma-1}\right)(1-\theta) + \theta\,\mu_{t-1}\right]$$

The formula is a weight-average of the current level of *RM* and the prior period ratio of market value to resources.

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