Resource Margin Accounting: Empirical Results for US Manufacturing Companies 1983-1998

Peter Johnson
Said Business School
Exeter College
Oxford
OX1 3DP

Abstract: in this paper empirical results are presented concerning Resource Margin valuation models previously developed by the author. The research tests the strength of the general linkages between resource margins and valuation measures for a sample of approximately 300 US manufacturing companies between 1983 and 1998. Good explanatory support is found for the use of resource margins. In particular, the resource model developed has greater explanatory power than traditional market-to-book models. In a separate body of analysis, specific time-series valuation models for individual companies are tested, for which the results are poor. For both analyses, supplementary investigations have been carried out into multi-collinearity, and heteroskedasticity for the ordinary least squares models developed. Altogether the results are encouraging, but further work is required to extend the sample of companies, and to develop improved general model specifications to cope with problems of auto-correlation amongst the data for individual companies.

1. Introduction

The objective of the research[1] presented in this paper is to test the resource margin valuation models previously developed by the author (Johnson 1999a, 2000) on a good US data set of companies. This follows earlier work carried out in the UK, where empirical testing was hampered by the limitations and quality of the available data set.

Section 2 provides a short introduction to resource margin valuation methods to those who are not familiar with this approach. In Section 3, the construction of the data-set of US companies is described. The next section of the paper examines the links between resource margin performance and traditional measures of value using ordinary least squares (OLS) techniques. A comparison with the traditional ROE: M/B model of valuation (Wilcox (1984)) on both a normal and residual basis is made. Dummy variables are introduced for year, companies and industry codes, and results are discussed in Section 5. In Section 6, empirical results for 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. Issues of multi-collinearity and heteroskedasticity for the models developed are discussed in the following section. The paper concludes with a summary and a description of the remaining issues to be researched.

2. Resource Margins

Value-added, often called net output by economists, is an important factor in the determination of competitive success. Normally, value-added is defined as firm revenues minus the cost of raw materials and purchases.[2] The structure of an industry and how it evolves can be well captured by the analysis of the distribution of value-added between different industry participants and how it shifts over time. This is what consultants and businesspeople more loosely describe as the evolution of the value chain. Similarly, within what strategy consultants call a strategic segment of an industry[3], 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.[4] Within the firm, value-added

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[2] 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.

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

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

corresponds to the resource base which managers control and which they use to implement strategies.[5] 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 of 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*.

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

Many studies in industrial organisation (*IO*) have examined the relationship between profitability and resources in different structural contexts.[6] 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 *RMA* valuation framework proposed extends this approach to the level of individual companies.

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:

$$P_t \quad = \quad \sum_{\tau=1}^{\infty} x_{t+\tau} R^{-\tau}$$

$$= \quad \sum_{\tau=1}^{\infty} RM_{t+\tau} . \upsilon_{t+\tau} R^{-\tau}$$

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

[6] 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.

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

The first term discounts resource margins which exceed the investors' required rate of return, r , i.e. residual or surplus resource margin. The second term on the right-hand side is equal to the capitalised normal returns expected on the resources flows of the company. 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 elsewhere, (Johnson, 2000), have previously 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 grow at rate g. If we then divide the left-hand side of the above expression by this book value, we obtain:

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

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

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

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.

Use of residual RM returns is not inconsistent with the fundamental notions that support Economic Value Added (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 may be shown, (Johnson,1999), 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

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.

If the responsiveness of resource margins to shocks, evident in the auto-correlation of resource margin series, is modelled by ARIMA processes, it is possible to derive expressions for the value of a company in terms of the resources it commands, the growth in these resources and a combination of terms typically involving resource margins, their average, their deviations from their trend, and excess resource margins above the resource margin required by investors:

$$V_t = f \left(RM_t, \overline{RM_t}, RM_t - r, g \right)$$

This general relationship is subject to empirical testing via ordinary least-squares regression in Section 4.

In the case of individual companies, it is possible to analyse which of the simplest ARIMA model best fits the resource margin series of the company, and hence to derive a specific valuation model for that company. These company-specific models are analysed and tested in Sections 5 and 6.

3. Construction of the US Data Set

3.1 Data on Resource Margins

The primary source of corporate data for this programme of research was Compustat Research Insight, amongst the most comprehensive databases available for the United States. This particular database was chosen because it was held to contain salary and payroll information, which would provide the means to calculate resource margins for a large number of companies, (initially expected to be several thousand), over many years (initially expected to be twenty years). In the event, it turned out that this information was only available for a very small number of companies over the expected time period, which was chosen to provide a suitable base for time-series methods.

The first step was to define clean surplus and resource margin in terms of the elements of the database. Three definitions of resource margin were employed as a result of the emergent paucity of data. All three definitions shared a common numerator: clean surplus, but each employed a slightly different estimate of resources. The first added to the difference between sales and the cost-of-goods-sold a salary element which represented the proportionate allocation of known labour and related costs to the share of the cost structure represented by cost-of-goods-sold as opposed to total cost. The second definition adopted the definition often taken by economists: resources equal labour plus economic profit, which was estimated by clean surplus plus labour and related costs. The third definition extracted raw materials as a percentage of overall sales. None of these measures are entirely satisfactory, but the choice of definition was strongly influenced by considerations of tractability. In terms of the Compustat codes, these variables are defined as follows:

Table 1 : Definitions

Concept	Monic	Formula
Clean Surplus	CX	(CEQ – CEQ[-1]) +DV – SSTK + PRSTKC
Resources #1	VA1	SALE – COGS + [(XLR * COGS) / (SALE – OIADP)]
Resources #2	VA2	CX + XLR
Resources #3	VA3	SALE – (PRAWM * SALE)
Resource Margin #1	RM1	CX / VA1
Resource Margin #2	RM2	CX / VA2
Resource Margin #3	RM3	CX / VA3

Excess RM #1	XSRM1	RM1 – [GOVNOTES + CALCBETA*0.09]
Excess RM #2	XSRM2	RM2 – [GOVNOTES + CALCBETA*0.09]
Excess RM #3	XSRM3	RM3 – [GOVNOTES + CALCBETA*0.09]
Residual Income	RI	Net Income / Book Value
Residual Return On Equity	RESROE	Residual Income / Book Value

Screens were constructed in order to identify for which companies twenty years of data were available for the different resource margin definitions. The relevant companies were then selected and data were compiled. At the same time excess resource margins were calculated using carefully matched beta and risk-free values, adjusting for the timing of fiscal year-ends. Five-year Treasury notes were used to determine the risk-free rate, but the results are not significantly sensitive to this assumption (as opposed to Treasury bills, for example). The use of clean surpluses over the twenty-year period also had the effect of reducing the number of years of available data to nineteen given the way it is calculated. Average resource margins and growth in resources were also calculated on a five-year basis where possible. For a consistent data set averaging reduced the time series to fifteen years in length.

The data sets produced for the data screens were inadequate for all resource margin definitions except the third, which did not rely upon Compustat for its primary data. The original definitions or resource margin only produced complete data for 23 companies from the universe of some 9000 companies, increasing to 30 when all inactive companies were added.

The subsequent analysis derives almost entirely from the third definition of resource margin, which relies upon the extraction of raw materials from output using manufacturing census data. In the rest of the paper, where we speak of the values of resource margins in an empirical context, we will mean resource margins computed according to this third definition.

Table 2 : Data Availability

Data Item / Concept	Number of companies for which it is available
Clean surplus	525
Resource margin 1	43
Resource margin 2	44
Excess resource margin 1	23
Excess resource margin 2	23
Raw materials percentage of sales	789
Resource margin 3	321
Excess resource margin 3	266

Included in this sample are a small number of companies with unusual resource margins that arise because of bookkeeping anomalies. These companies were eventually excluded from the analysis.

The eventual series of excess resource margins extracted were predominantly negative. Substituting Treasury bill rates for note rates had little impact, giving 55 companies out of 266 instead of 44 whose resource margins over nineteen years summed to a positive value. It may simply be the case that these sectors of manufacturing were not producing sufficient returns for investors over this period.

3.2 NBER / Census Bureau Productivity Database.

This database is available on the National Bureau of Economic Research website and gathers together data on 450 companies from 1958 to 1994, gathered from the Census Bureau's Annual Survey of Manufacturers (ASM).

This database provides, time series for raw materials expenditure and value of shipments, by four-digit SIC code, for manufacturing companies. (Codes 2011 to 2999). Materials cost was divided by value of shipments to get the percentage spent on raw materials for different SIC codes. The data were transposed to get horizontal time series and the years up to and including 1978 were removed. Values for the years from 1995 to 1998 inclusive were calculated using a five-year moving average. This gave the required timeframe for a twenty-year series of raw material ratios by SIC code that matches up with Compustat company information. This series was imported into the Research Insight database, allowing the appropriate raw material ratio to be allocated to individual companies depending upon their predominant SIC coding. This in turn allowed resource margins and excess margins to be calculated for these companies. These resource margin data, together with averages, excess margin data, and data on the growth of resources were then extracted for analysis in SPSS in order to carry out time-series modelling and regression analysis.

3.3 Allocation of best-fit ARIMA models to individual companies

The excess resource margin series for the 266 companies were transferred from Research Insight into SPSS to that the time-series behaviour of the excess resource margins of the companies could be analysed. The excess resource margins exhibited strong auto-correlation effects.

Table 3 : Distribution of Absolute Auto-correlation in Residual Resource Margins

Lag	1	2	3	4	5
Mean	.3882	.2430	.1906	.1513	.1565
Median	.3720	.2020	.1565	.1390	.1535
25th Centile	.1758	.0837	.0787	.0517	.0597
50th Centile	.3720	.2020	.1565	.1390	.1535
75th Centile	.5938	.3915	.2803	.2380	.2173

For the purposes of this research, it was decided to look only at first order ARIMA processes, given the complexity of higher orders processes, and given that the reliability of even simple models was untested. For each company output was produced to test the fit of six basic ARIMA models: (1, 0, 0) with and without a constant, (0, 0, 1) with and without a constant, (0, 1, 1) and (1, 1, 0) without a constant (a constant at the level of first differences would create constantly increasing excess resource margins). These models correspond to first-order auto-regressive and moving-average processes on levels and first differences. Because the testing of the fit for each ARIMA model for each company generates five extra data series per company (7980 extra series in total), the companies were split into four sub-files to allow SPSS to cope with this large amount of data. The files were then combined.

The process of modelling had to be automated due to the number of companies: each of the ARIMA models was tested for fit for each of the 266 companies amounting to 1596 tests of fit. Manually each test requires approximately twenty minutes to carry out so the automation saved a large amount of time. The automation instructions were specified as scripts in SPSS, a type of macro. Each iteration of the script produced an output file containing the results of the test of fit for each ARIMA model for a given company. A second script extracted the relevant measures of fit for each company-model combination. These measures were then fed into an allocation model, where the results of the six ARIMA models for each company were compared and ranked so as to produce the best fitting model for that company, and the associated auto-regressive or moving-average coefficient for the best ARIMA model selected.

The allocation model eliminated models for which the auto-correlation and partial-correlation errors lay outside 95% confidence limits for any of the first five lags (i.e. auto-correlations up to the fifth order). Beyond the fifth lag, where auto-correlation effects are less significant, the breaching of error confidence limits was not taken to be a sufficient cause for rejecting the model. For three companies, this procedure excluded all of the six available ARIMA models: these companies were eliminated from the sample. Where SPSS recorded that the t statistics for the auto-regressive or moving-average coefficient were suspect for an individual ARIMA model for a particular company, the influence of the t statistic on the relative ranking of the available models for that particular company was excluded.

The evaluation procedure for unproblematic models took into account the Aikike Information Criterion, the Schwartz Bayesian Coefficient, residual variance, and the t statistic for the relevant auto-regressive or moving-average coefficient. These factors were scaled and normalised over the available models for each company as follows:

(i) AIC numbers were normalised by dividing by the average AIC value across the available ARIMA models for a given company. The reciprocal was then taken of each.

(ii) SBC numbers were normalised by dividing by the average SBC value across the available ARIMA models for a given company. The reciprocal was then taken of each.

(iii) Residual variance numbers were normalised by dividing by the average RV value across the available ARIMA models for a given company. The reciprocal was then taken of each.

(iv) T Ratios were normalised by taking the log to base 2 of each of the absolute values.

(v) Weightings of 1, 1, 2, 1 were then applied to the numbers resulting from (i) to (iv) and the score calculated for each model, with the highest score being chosen.

The weights were chosen to balance the influence of the three types of fit measure: AIC type measures, residual variance and t statistics. The final allocation method was the result of a certain amount of trial and error with other procedures in order to produce allocations which agreed with manual selections on six companies. The summary allocation results are shown in Table 4.

Table 4 : Distribution of Auto-regressive and Moving-average Absolute Coefficients

Model	(1,0,0)	(0,0,1)	(1,1,0)	(0,1,1)
Number	140	21	33	57
Mean	.7678	-.4486	-.5864	.7108
Median	.8299	-.5635	-.5855	.7307
Std. Dev.	.2027	.4836	.1391	.1977

Table 5 compares the allocation of companies to the four basic ARIMA models in the US sample with that found by Ramakrishnan and Thomas (1992), and with the author's UK results (Johnson 1999).

Table 5 : Allocation of Companies to Models

	US	%	R&T	%	Datastream	%
100 model	140	54.90	308	60.27	8	12.69
001 model	21	8.23	0	0.00	23	36.50
110 model	33	12.94	47	9.19	12	19.04
011 model	57	22.35	156	30.52	20	31.74

3.4 Company Valuation Predictions

Once the best-fit ARIMA process for residual resource margins had been identified for each company, a further script extracted the parameters necessary to compute predicted values of the ratio of market value to resources (i.e. value-added) for each company, using the valuation models appropriate to each ARIMA process, which are described in Section 5. For each of the four families of valuation model ((1, 0, 0), (0, 0, 1), (1, 1, 0), and (0, 1, 1)), predictions for fifteen years of the ratio of market value to resources were made for the companies that shared that type of valuation model. The quality of the predictions of the ratio of market value to resources was assessed for each of these families of valuation model.

One of the parameters in the valuation models is the growth in book value. Where growth is negative, the valuation models produce unsatisfactory results, and this led to the elimination of twelve companies from the sample of companies, leaving predictions for 251 companies.

4. The Linkages between Resource Margins and Value

Ordinary least squares regressions were used to investigate the linkages between market value variables and measures of resource margin and growth. Table 6 records the descriptive statistics of the variables investigated.

Table 6 : Descriptive Statistics for Value Relevant Factors

	No.	Range	Minimum	Maximum	Mean	Std. Dev.
5yr av RM	3945	40.85	-39.62	1.23	0.0362	1.2647
5yr Growth in resources	3945	366.83	-42.15	324.69	8.3076	14.5373
M/B	3945	865.93	-37.41	828.53	2.4315	13.3451
M/Resources	3945	23943.5	0.000	23943.50	15.5546	509.140
RM	3945	116.14	-108.75	7.39	0.0454	1.8610
XSRM	3945	116.03	-108.81	7.22	-0.0995	1.8595
RI/B	3945	180.97	-89.22	91.75	-0.4164	4.2825
NI/B	3945	155.40	-55.22	100.18	0.1065	1.9056

where RM, M, B, XSRM, RI and NI denote resource margin, market value, book value, excess resource margins, residual income after deducting a rent for book capital and net income respectively.

Because the variables contain a number of outliers, likely to adversely affect the results of the regressions, the sample was filtered in order to ensure that all variables lay within reasonable bounds. The following criteria were used:

Table 7 : Filtering Criteria

Data Item	Criteria Required to Pass
Market Value	>$10M
Book Value	>$10M
Resources (Value Added)	>$2M

Market Value / Resources	0.1 < M/Resources < 30
Market Value / Book Value	0.1 < M/B < 30
Resource margins	-2 < RM < 2
Average resource margins	-2 < 5 yr av RM < 2
Excess resource margins	-2 < XSRM < 2
Return On Equity (NI/B)	-2 < ROE < 2
Residual Return On Equity (RI/B)	-2 < ResROE < 2

The new statistics are:

Table 8 : Descriptive Statistics for Value Relevant Factors (Filtered Data)

	No	Range	Minimum	Maximum	Mean	Std. Dev.
5yr av RM	3357	2.24	-1.01	1.23	0.1086	0.1108
5yr Growth in resources	3357	352.37	-27.69	324.69	8.8133	11.2002
M/B	3357	20.27	0.35	20.62	2.2945	1.7715
M/Resources	3357	28.31	0.12	28.43	2.0768	1.9141
RM	3357	2.71	-1.10	1.61	0.1119	0.1411
XSRM	3357	2.79	-1.24	1.55	-0.0385	0.1495
RI/B	3357	3.57	-1.96	1.61	-0.0308	0.2381
NI/B	3357	3.19	-1.55	1.65	0.1189	0.1387

As a first step, market to book and market to resources ratios were regressed against individual regressors to determine their value relevance. Growth refers to growth in resources. The results are shown in Table 9.

Table 9 : Regressions of Value – Relevant Factors (Filtered Data)

Dep / Indep Variables	Adj R Squared	F statistic	T statistic	Significance	Coefficient	Durbin Watson
M/B vs RM	0.110	413.832	20.343	0.000	4.160	0.572
M/B vs XSRM	0.092	343.063	18.522	0.000	3.609	0.542
M/B vs5yr av RM	0.108	409.181	20.228	0.000	5.274	0.509
M/B vs 5yr Growth	0.028	98.934	9.947	0.000	0.0267	0.469
M/B vs ROE	0.288	1356.564	36.832	0.000	6.854	0.814
M/B vs Residual ROE	0.155	614.894	24.797	0.000	2.928	0.536

M/ Resources vs RM	0.295	1404.699	37.479	0.000	7.370	0.811
M/ Resources vs XSRM	0.219	944.360	30.730	0.000	6.001	0.677
M/ Resources vs 5yr avRM	0.300	1440.857	37.959	0.000	9.473	0.690
M/ Resources vs 5yr Growth	0.020	67.991	8.246	0.000	0.0240	0.475
M/ Resources vs ROE	0.080	294.304	17.155	0.000	3.920	0.509
M/ Resources vs Residual ROE	0.058	208.498	14.439	0.000	1.945	0.457

If the normative assumptions that underpin ordinary least squares regression hold good, the analysis shows that resource margin, and resource growth are value-relevant factors not only for market to resource ratios, but also for market to book ratios. In fact the explanatory power, measured by R-squared is better for the model comprising [market to resource ratio; resource margin], than for the traditional model [market to book ratio; return on equity]. We call these two models the M/R and the M/B models. It is also noteworthy that resource margins are more relevant to the M/B model than ROE is to the M/R model. The t statistics are of limited significance because of large sample effects. It also noteworthy that the Durbin-Watson statistics do indicate a high level of auto-correlation in the data sample.

Stepwise multivariate regressions were then undertaken first for the market value to resource ratio model, then the traditional market to book value model. The results for the resource margin model were of considerable significance.

Table 10 : Regression of Value Relevant Factors against M/R (Filtered Data)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.614	.377	.376	1.5119	.797

ANOVA Results

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4639.099	6	773.183	338.269	.000
	Residual	7657.111	3350	2.286		
	Total	12296.211	3356			

Coefficients of Stepwise Regression

Model		Unstandardized Coefficients	Std. Error	Standardized Coefficients	t	Sig.
1	(Constant)	.971	.070		13.830	.000
	RM	5.300	.458	.391	11.561	.000
	XSRM	-.165	.385	-.013	-.430	.667
	Av RM	5.927	.299	.343	19.825	.000

	5yrGrowth	0.007	.002	.043	3.047	.002
	ROE	-1.611	.285	-.117	-5.652	.000
	RESROE	.341	.147	.042	2.316	.021

These results show that the resource margin model has high explanatory power if we assume that the conditions for reliable OLS regressions obtain. The t statistics are less significant than might first appear because of problems of large numbers and auto-correlation. Average and current resource margins have good explanatory power, whereas residual resource margins add little extra information, as is explicitly reflected in the families of simple ARIMA valuation models discussed in Section 6. Surprisingly growth of resources is a less valuable regressor: in spite of some significance as measured by the t statistic, the coefficient is relatively small. ROE and residual equity returns have a small influence on the regression results for market to resource ratios. The negative coefficient for equity returns suggest it operates as a corrective factor to the basic resource margin model.

By way of comparison, results were determined for the traditional market to book ratio model.

Table 11 : Regression of Value Relevant Factors against M/B (Filtered Data)

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.567	.321	.320	1.4605	.796

ANOVA Results

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3385.728	6	564.288	264.534	.000
	Residual	7146.020	3350	2.133		
	Total	10531.748	3356			

Coefficients of Stepwise Regression

Model		Unstandardized Coefficients	Std. Error	Standardized Coefficients	t	Sig.
1	(Constant)	1.358	.068		20.012	.000
	RM	-2.121	.443	-.169	-4.789	.000
	XSRM	.489	.372	.041	1.316	.188
	Av RM	3.128	.289	.196	10.832	.000
	5yr Growth	0.013	.002	.084	5.712	.000
	ROE	6.302	.275	.493	22.889	.000
	RESROE	.407	.142	.055	2.865	.004

First, using OLS, the market value to resource model has greater explanatory power then the traditional market to book value model for this set of companies: the difference in adjusted r-squared (0.376 versus 0.321) is highly significant. Average resource margins contribute to the explanatory power of the traditional model, while current resource margins introduce a corrective element to the model. As a minimum this suggests including resource margins in standard M/B models.

While the OLS regressions lend general support to the resource margin approach, and suggest superiority to the traditional market to book model, further analysis is required to validate the assumptions upon which the OLS regressions rest. It also remains to ask whether the models can be improved by introducing company and year specific effects in fixed effect and variable slope models. These aspects are covered in Sections 5.

5. Company and Year Specific Effects

In order to improve the explanatory power of the M/R multi-variate regression, dummy variables were introduced first for years, second for companies, and then finally for industry groupings using a variable slope approach, (all fixed effects).

The choice of fixed effects makes the results conditional on the data set (random effects would be appropriate if the results were to be generalised to all companies). Random effects would increase the degrees of freedom and would allow EGLS (estimated generalised least-squares) modelling which incorporated heteroskedastic errors. On the other hand this would require a larger sample of companies and might introduce further correlation effects between general resource margin residuals and company specific errors. Further discussion of GLS occurs in Section 8.

5.1 Base case

As shown in Table 9, ROE and residual equity returns contribute little explanatory power to the M/R model. Consequently the following analysis only includes the resource margin measures in this model. Similarly, regressions of the traditional market to book value ratios will only include ROE and residual equity returns. Table 12 shows the base case M/R results against which company- and year-specific models are evaluated.

Table 12 : Stepwise Regression of Resource Margin Factors against M/R

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.548	.300	.300	1.6012	
2	.608	.370	.369	1.5203	
3	.609	.371	.371	1.5186	.782

Model 1 Predictors: (Constant), Av RM
Model 2 Predictors: (Constant), Av RM, RM
Model 3 Predictors: (Constant), Av RM, RM, 5yr Growth Resources

Dependent Variable: M/R

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3694.248	1	3694.248	1440.857	.000
	Residual	8601.963	3355	2.564		
	Total	12296.211	3356			
2	Regression	4543.773	2	2271.887	982.905	.000
	Residual	7752.438	3354	2.311		
	Total	12296.211	3356			
3	Regression	4564.016	3	1521.339	659.715	.000
	Residual	7732.195	3353	2.306		
	Total	12296.211	3356			

Coefficients

Model		Unstandard.	Coeffs	Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	1.048	.039		27.073	.000
	Av RM	9.473	.250	.548	37.959	.000
2	(Constant)	.925	.037		24.792	.000
	Av RM	5.960	.300	.345	19.895	.000
	RM	4.508	.235	.332	19.171	.000
3	(Constant)	.875	.041		21.370	.000
	Av RM	5.945	.299	.344	19.867	.000
	RM	4.416	.237	.325	18.636	.000
	5yr Growth	0.007	.002	.041	2.963	.003

Comparison of these results with those in Table 10 indicates that residual resource margins have little significance in the regression (R squared for the two regressions are almost identical). Exclusion of residual resource margins will introduce a small bias in the beta estimates, but given the high degree of collinearity between resource margins and residual resource margins (differing only by a constant if the required rate of return is stable), there will be a significant improvement in efficiency (reduced variance) as reflected in the increased t statistics. Interestingly growth became more significant, suggesting a correlation between growth and excess returns in line with expectations.

5.2 Fixed Effects Dummy Variable Regressions

Fifteen new dummy variables were defined: Year 1984, Year 1985, Year 1986 and so on up to Year 1998. Stepwise multivariate regressions were performed involving M/R against these new dummy variables, along with the resource margin variables. The results show that the dummy variables do not contribute significantly to the explanatory power of the model. Inclusion of all the dummies increases the adjusted R squared by 10%. This implies that seasonal effects, and anomalous years are less important than resource margins in explaining market values in relation to resources. Only the models for the first five dummy years of significance are displayed.

Table 13: Stepwise Regression of Resource Margin Factors, plus Dummy Variables Years vs. M/R

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.548	.300	.300	1.6012	
2	.608	.370	.369	1.5203	
3	.612	.375	.374	1.5145	
4	.615	.379	.378	1.5096	
5	.618	.381	.380	1.5067	
6	.620	.384	.383	1.5036	
7	.621	.386	.385	1.5015	
8	.623	.388	.386	1.4995	

Model 1 Predictors: (Constant), AV RM
Model 2 Predictors: (Constant), AV RM, RM
Model 3 Predictors: (Constant), AV RM, RM, IS1997
Model 4 Predictors: (Constant), AV RM, RM, IS1997, IS1993
Model 5 Predictors: (Constant), AV RM, RM, IS1997, IS1993, IS1991
Model 6 Predictors: (Constant), AV RM, RM, IS1997, IS1993, IS1991, IS1992
Model 7 Predictors: (Constant), AV RM, RM, IS1997, IS1993, IS1991, IS1992, 5YRGResources
Model 8 Predictors: (Constant), AV RM, RM, IS1997, IS1993, IS1991, IS1992, 5YRGResources, IS1984
Dependent Variable: M/R

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3694.248	1	3694.248	1440.857	.000
	Residual	8601.963	3355	2.564		
	Total	12296.211	3356			
2	Regression	4543.773	2	2271.887	982.905	.000
	Residual	7752.438	3354	2.311		
	Total	12296.211	3356			
3	Regression	4605.604	3	1535.201	669.327	.000
	Residual	7690.606	3353	2.294		
	Total	12296.211	3356			
4	Regression	4657.671	4	1164.418	510.978	.000
	Residual	7638.539	3352	2.279		
	Total	12296.211	3356			
5	Regression	4688.700	5	937.740	413.061	.000
	Residual	7607.511	3351	2.270		
	Total	12296.211	3356			
6	Regression	4722.544	6	787.091	348.148	.000
	Residual	7573.667	3350	2.261		

	Total	12296.211	3356			
7	Regression	4746.015	7	678.002	300.738	.000
	Residual	7550.196	3349	2.254		
	Total	12296.211	3356			

An initial regression involving dummy variables for each specific company was undertaken. This showed significant company effects, but also revealed that one company gave rise to very curious values. Inspection of the financial results of this company (Arabian Shield) showed that this company was a type of holding company, with an atypical financial structure, and it was excluded from the analysis. The results, excluding Arabian Shield are shown in Table 14.

Table 14 : Stepwise Regression of Resource Margin Factors, plus Dummy Variables for Companies vs. M/R

Model Summary

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.618	.382	.381	1.4386	
2	.656	.430	.430	1.3815	
3	.682	.465	.464	1.3390	
4	.693	.481	.480	1.3192	
5	.701	.491	.490	1.3061	
6	.708	.502	.501	1.2926	
7	.716	.512	.511	1.2786	
8	.723	.523	.522	1.2647	
9	.730	.533	.532	1.2511	
80	.808	.653	.644	1.0907	1.047

Model 1 Predictors: (Constant), AV RM
Model 2 Predictors: (Constant), AV RM, RM
Model 3 Predictors: (Constant), AV RM, RM, FTO
Model 4 Predictors: (Constant), AV RM, RM, FTO, OEA
Model 5 Predictors: (Constant), AV RM, RM, FTO, OEA, STJ
Model 6 Predictors: (Constant), AV RM, RM, FTO, OEA, STJ, IFF
Model 7 Predictors: (Constant), AV RM, RM, FTO, OEA, STJ, IFF, WWY
Model 8 Predictors: (Constant), AV RM, RM, FTO, OEA, STJ, IFF, WWY, LAW
Model 9 Predictors: (Constant), AV RM, RM, FTO, OEA, STJ, IFF, WWY, LAW, TR
Model 80 Predictors: (Constant), AV RM, RM, FTO, OEA, STJ, IFF, WWY, LAW, TR, PFE, BW, WDFC, K, ABT, GLK, ANEN, UST, MAS, CKP, SCP, NPK, HRL, BRID, MIL, JNJ, WLA, SYMM, AZZ, FSS, ION, NUE, 5YRGVA, PEP, ATPC, AMP, NEWP, ATX, HEI, UTR, DJ, HSY, BDG, MCDY, ITW, RYC, GEN, AHAA, ROHN, DBD, SUP, KMB, TER, ATSN, HWP, DLX, LPX, SMSC, JH, GBCOA, HPC, FSCR, JOS, CIS, TNB, SNA, ESP, CLC, CMC, CRRC, CUB, OLGR, LIQB, SRR, RAY, PATK, BCR, WMO, HMF, CUO, WEYS
Dependent Variable: M/R

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	4242.690	1	4242.690	2049.967	.000
	Residual	6875.340	3322	2.070		
	Total	11118.030	3323			
2	Regression	4779.970	2	2389.985	1252.298	.000

	Residual	6338.060	3321	1.908		
	Total	11118.030	3323			
3	Regression	5165.267	3	1721.756	960.265	.000
	Residual	5952.763	3320	1.793		
	Total	11118.030	3323			
4	Regression	5342.403	4	1335.601	767.511	.000
	Residual	5775.627	3319	1.740		
	Total	11118.030	3323			
5	Regression	5458.192	5	1091.638	639.957	.000
	Residual	5659.838	3318	1.706		
	Total	11118.030	3323			
6	Regression	5576.039	6	929.340	556.230	.000
	Residual	5541.991	3317	1.671		
	Total	11118.030	3323			
7	Regression	5696.791	7	813.827	497.792	.000
	Residual	5421.239	3316	1.635		
	Total	11118.030	3323			
8	Regression	5815.708	8	726.963	454.496	.000
	Residual	5302.322	3315	1.599		
	Total	11118.030	3323			
9	Regression	5930.912	9	658.990	421.022	.000
	Residual	5187.118	3314	1.565		
	Total	11118.030	3323			

The results show that company-specific effects contribute a 26% improvement in adjusted R squared over the first eighty companies which are included in the stepwise regression at a 5% *p* threshold level for the associated F test. This compares with the 38% of variance explained by the RM concepts. These company-specific effects support the introduction of specific company parameters such as those produced from ARIMA modelling of residual resource margins. Before moving to this level of analysis, it was appropriate to examine whether there were industry group effects.

In the initial fixed effects dummy variable model, each company has a different intercept in the linear regression model. It is also possible to define slope dummy variables where each group defined by the dummy variable has a different slope. Due to the large number of companies, it was decided to use groups defined by the SIC code of the company. The variables take the form of variables A though T, where the variable takes the value of the RM for that particular case when the SIC code of that company lies within the relevant interval, and 0 otherwise. The variable A corresponds to SIC codes between 2000 and 2100, B corresponds to codes between 2100 and 2200 and so on up to T which corresponds to codes between 3900 and 4000. The results obtained showed no significance for these new variables, even when relaxing the entry criteria, and removing the company specific dummy variables.

The value-relevance of resource margins in general, and the significant company specific effects prompts an investigation into the predictive ability of company-specific ARIMA models which take explicit account of the auto-correlation of residual resource margins.

6. Empirical testing of company-specific valuation models

It may be shown (Johnson 1999) that the simplest ARIMA processes for excess resource margin development yield the following specific valuation 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 resource 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 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.

Note that none of these models contain any terms involving excess resource margins. Required rates of return are specific to individual companies in individual years. For the precise definition of terms consult the derivation in the Appendix.

Using the version of these models appropriate to a given company, and inserting company specific parameters (resource margins, growth, auto-regressive coefficients etc.), it is possible to derive predicted theoretical values of the market value to resources ratios for the data set to compare with actual values. The predicted results highlighted two general problems.

First, in a large number of instances the growth rate of resources, or the growth rate of book value exceeded the market-derived required rate of return. This resulted in negative values for the ratio of market value to resources. In basic financial theory, firms are assumed to be self-funding, which constrains the rate of growth of book value and resources. It was not possible to adjust the data to reflect changes in capital structure, or for acquisitions, and an argument may be made to disregard these non-sensical results.

Second, the rates of growth were often similar to the levels of required rates of return. Given that the difference between these two factors frequently appears in the denominator of the valuation models, the results amplify the data uncertainties associated with the estimates of growth factors.

Besides analysing the raw results, two stages of data enhancement were also carried out. First, predictions resulting in growth rates in excess of required rates were excluded, and then as a further step any additional negative values were excluded. Table 15 shows the results obtained for the pooled predictions and for the individual families of models.

Table 15 : Regression of Predicted against Actual Ratios of Market Value to Resources for Families of ARIMA Models (Filtered Data)

Model	Version	Adj. R Squared	Beta t Statistic	df	Durbin Watson
(1, 0, 0)	All	0.001	-1.955	1910	1.996
	r>g	0.004	-2.418	1342	1.388
	r>g & +ve	-0.001	0.554	651	2.004
(0, 0, 1)	All	0.078	-5.002	284	1.854
	r>g	0.030	-2.684	203	1.986
	r>g & +ve	-0.003	-0.893	65	2.048
(1, 1, 0)	All	0.048	4.937	466	1.248
	r>g	0.011	2.216	349	2.090
	r>g & +ve	0.047	3.225	190	1.542
(0, 1, 1)	All	0.032	5.244	798	2.048
	r>g	0.015	3.045	529	1.790
	r>g & +ve	0.177	8.347	319	2.013
All	All	0.000	-1.163	3008	1.992
	r>g	0.000	-1.034	2426	1.996
	r,g +ve	0.000	0.851	1228	2.001

Regressions conducted on the full set of predicted values for the pooled and ARIMA family predictions lacked explanatory power (low or negative adjusted R squared), with the exception of (0, 1, 1), where the particular strength of the moving-average model may in part due to the inclusion of the prior period ratio of market value to resources. While the relatively small samples relative to each company may account for some of the poor performance of the models, given the value relevance of resource margins in general, and the importance of company-specific adjustments, these results are disappointing, reflecting either model mis-specification, data inadequacies (the difficulty of determining the correct rate of growth of resources, book-values, required rates of return etc), or significant violation of OLS assumptions. Note also that twenty years of data may not be sufficient to develop reasonable estimates of auto-correlation coefficients These aspects will be discussed further in Section 8.

Given the failure of these particular ARIMA model families, it is appropriate to investigate whether there have been other company-specific parameters which have not been captured by these particular ARIMA models. The results for regressions of actual and predicted M/R values when company dummies are introduced are shown in Table 16.

Table 16 : Regression of Predicted against Actual Ratios of M/R for Families of ARIMA Models (Company dummies)

Model	Version	Adj. R Squared	Beta t Statistic	df	Durbin Watson
(1, 0, 0)	All	0.655	-1.870	1910	0.822
	r>g	0.762	-3.781	1342	1.196
	r>g & +ve	0.826	-0.826	651	1.425
(0, 0, 1)	All	0.235	-3.602	284	1.216
	r>g	0.167	-1.095	203	2.242
	r>g & +ve	0.582	-1.241	65	1.637
(1, 1, 0)	All	0.567	5.285	466	0.978
	r>g	0.602	0.666	349	1.005
	r>g & +ve	0.680	1.164	190	1.441
(0, 1, 1)	All	0.422	4.071	791	0.992
	r>g	0.656	-1.411	529	1.072
	r>g & +ve	0.654	0.906	319	1.264

Explanatory power (measured as adjusted R squared) has improved markedly, but generally at the expense of predictive value (t statistics, associated beta variances, and auto-correlation). This was largely to be expected, given the loss of information available for determining individual beta coefficients that results from including the dummies in the regression, (the information is still available for the calculation of R squared). These results generally suggest there is scope for a re-specification of the individual company ARIMA models. Given that the ARIMA models are mis-specified, one may consider which aspects of the data set undermine the assumptions upon which the models were constructed.

7. Multi-collinearity and Heteroskedasticity

In Section 5.1, the collinearity of residual resource margins and resource margins was discussed. In the subsequent regressions, residual resource margins were excluded as a regressor, resulting in an improvement in efficiency of the regression, at the expense of a small bias in the expected mean value of M/R. Additionally multi-collinearity effects were investigated for the remaining regressors. The following results were obtained from performing a stepwise multivariate regression of the resource margin measures against M/R.

Table 17 : Multi-collinearity Diagnostics.

Coefficient Correlations

Model			AV RM	RM	5YRGRes
1	Correlations	AV RM	1.000		
	Covariances	AV RM	.06228		
2	Correlations	AV RM	1.000	-.612	
		RM	-.612	1.000	
	Covariances	AV RM	.08973	-.04309	
		RM	-.04309	.05529	
3	Correlations	AV RM	1.000	-.604	-.016
		RM	-.604	1.000	-.132
		5YRGRes	-.016	-.132	1.000
	Covariances	AV RM	.08955	-.04284	-.0000117
		RM	-.04284	.05614	-.0000742
		5YRGRes	-.00001170	-.00007425	.0000056

Dependent Variable: M/R

Average and current resource margins are correlated, but growth in resources is not. This collinearity will not effect the value of R squared or introduce biases for the OLS regressions, but will result in poor predictions (higher variances), as though the size of the data set had been reduced. Given the explanatory power of both measures of resource margins, it is not clear that either measure should be omitted, even though this would improve variances while introducing some bias. One approach would be to extend the data set. Alternatively, a lagged equation could be used to make the linkage between the regressors explicit.

One other problem with time series data is the possible presence of heteroskedasticity. Plots of the residuals against the dependent variables showed an asymmetric distribution of errors: relatively few of the residuals had negative values (which might be anticipated given the orientation of management to positive returns). A more formal analysis of heteroskedasticity (Goldfeld-Quandt), involved splitting the sample into two halves, ordered with respect to the resource margins, and carrying out a regression of M/R against the resource margin measures and comparing the sums of the squared residuals in each case.

Table 18 : Stepwise Regressions carried out Half Data Sets

Model Summary First Half

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.184	.034	.033	.9835	
2	.258	.067	.066	.9669	1.891

Model 1 Predictors: (Constant), AV RM
Model 2 Predictors: (Constant), AV RM, RM
Dependent Variable: M/R

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	56.646	1	56.646	58.565	.000
	Residual	1620.121	1675	.967		
	Total	1676.768	1676			
2	Regression	111.883	2	55.942	59.842	.000
	Residual	1564.884	1674	.935		
	Total	1676.768	1676			

Model Summary Second Half

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.615	.379	.378	1.7333	
2	.643	.414	.413	1.6841	
3	.652	.426	.425	1.6673	1.986

Model 1 Predictors: (Constant), RM
Model 2 Predictors: (Constant), RM, AV RM
Model 3 Predictors: (Constant), RM, AV RM, 5YRGRes
Dependent Variable: M/R

ANOVA

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	3070.583	1	3070.583	1022.028	.000
	Residual	5041.385	1678	3.004		
	Total	8111.968	1679			
2	Regression	3355.401	2	1677.701	591.499	.000
	Residual	4756.567	1677	2.836		
	Total	8111.968	1679			
3	Regression	3452.628	3	1150.876	413.979	.000
	Residual	4659.339	1676	2.780		
	Total	8111.968	1679			

The associated F test of the squares of the residual errors for the two halves, is significant at more than the 99% level, confirming the conclusions drawn from visual inspection.

Heteroskedasticity will not affect the R squared or the bias of the OLS regressions, but will make the regressions less efficient. Of much greater significance, however, is the fact that the derivation of the company-specific ARIMA model families explicitly assumed that error terms were normal and homoskedastic. Violation of this assumption requires the models to be re-specified.

8. Summary and Conclusions

The combination of Compustat and US Census data has allowed the creation of a good data set of 266 US manufacturing companies for which resource margins may be determined over a fifteen year period.

OLS regressions on this data set, supported strongly the general linkages between resource margins and market values, and the M/R model compares favourably with M/B alternatives.

Dummy variable investigations show that yearly and SIC coding effects are not material, but company-specific effects increase the power of the basic model. An investigation of a particular set of ARIMA models, designed to address explicitly the auto-correlation of resource margins, performed poorly. This lack of performance may in part be explained either by the size of the data set, given the presence of collinearity amongst some of the principal regressors, or by the difficulty obtaining robust and accurate values for the company parameters including auto-correlation coefficients. On balance, however, it is held to be more likely that the violations of OLS assumptions concerning multi-collinearity, heteroskedasticity and auto-correlation have not been adequately captured by the current ARIMA model specifications, which only specifically address auto-correlation, and assume homoskedastic errors and orthogonal variables.

In further work, an explicit formulation of collinear variables will be addressed, heteroskedastic assumptions will be made, and new ARIMA heteroskedastic models will be developed allowing further regressions to be carried out on the data set in an estimated generalised least-squares (EGLS) framework.

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10. Appendix

ARIMA (1, 0, 0)

As a first order auto-regressive process it follows that

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

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 immediately below we obtain

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

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

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

ARIMA (0, 0, 1)

For this process we know

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

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

$$\sum \phi^a_{t+\tau}\gamma^{-\tau} = -\frac{\theta\, e_t}{\gamma} + \frac{\bar{\phi}^a}{\gamma} + \frac{\bar{\phi}^a}{\gamma^2} + \frac{\bar{\phi}^a}{\gamma^3} + \ldots$$

$$= -\frac{\theta\, e_t}{\gamma} + \frac{\bar{\phi}^a}{\gamma - 1}$$

Substituting into the expression for P_t

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

$$= \upsilon_t \left[\frac{-\alpha g_B}{r - g_B} + \frac{(R-1)}{(\gamma-1)} + \frac{\bar{\phi}^a}{\gamma-1} - \frac{\theta\, e_t}{\gamma} \right]$$

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

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

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

we obtain

$$P_t = \upsilon_t \left[\frac{-\alpha\, g_B}{r - g_B} + \frac{\overline{RM}}{\gamma-1} - \frac{\theta}{\gamma} \left[\phi^a_t - \bar{\phi}^a + \gamma \left[\frac{-\alpha\, g_B}{r - g_B} . \frac{G_V}{G_B} + \frac{\overline{RM}}{\gamma - 1} - \frac{P_{t-1}}{\upsilon_{t-1}} \right] \right] \right]$$

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

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

ARIMA (1, 1, 0)

For this process

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

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

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

The corresponding market price is given by

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

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

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

ARIMA (0, 1, 1)

For this process on an expected value basis we may derive

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

If we discount the residual returns we obtain

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

This gives rise to the following price equation:

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

Rearranging

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

Hence

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

Since

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

we obtain

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

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

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

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