A Note on Euler Allocation for Performance Measurement

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Abstract

It is a well-known result that when an Euler allocation is used to allocate capital by line the overall expected return on capital can be increased by writing more business in lines where the expected return on allocated capital is greater than the overall companywide expected return. If the cost of equity capital varies by line, however, writing more business in these lines may not be the best choice for the company. In this paper we give a simple example that highlights why using an Euler allocation to allocate capital by line for the purpose of performance measurement is not always appropriate if the cost of equity capital varies by line.

Keywords. Capital allocation; Euler allocation; performance measurement; cost of equity capital.

1. INTRODUCTION

If a property and casualty insurer would like to allocate its capital for the purpose of performance measurement, the literature suggests numerous ways to do so.

One particularly appealing option is the Euler allocation. This method is the only one that guarantees that if a company writes more business in lines where the expected return on allocated capital is greater (less) than the overall company expected return on capital, then the overall company expected return on capital will increase (decrease). In the standard application of this approach, there is an underlying assumption that the risk of a line is reflected solely by the amount of capital allocated to it. In particular, the cost of equity capital is assumed to be the same for all lines of business.

There is, however, empirical evidence that the cost of equity capital may vary by line of business. In this case, we show that using an Euler allocation to allocate capital by line for performance measurement is not always appropriate.

1.1 Research Context

Venter [5] surveys capital allocation methods in the literature.

Tasche [4] defines the Euler allocation method for allocating capital and discusses some important properties of this method. Tasche [3] derives the key result regarding the use of Euler allocation for performance measurement. In Tasche's approach, the risk of a line is reflected by the amount of capital allocated to it. There is an implicit assumption that the cost of equity capital does not vary by line of business.

Cummins and Phillips [2] provide empirical evidence that the cost of equity capital may vary by line of business. Their analysis suggests "significant differences in the cost of equity capital across lines".

1.2 Objective

We give a simple example that highlights why using an Euler allocation to allocate capital for the purpose of performance measurement is not always appropriate if the cost of equity capital varies by line. In particular, our example shows how writing more business in a line that (based on an Euler allocation) is performing worse than average can actually improve the results of the company overall.

1.3 Outline

The remainder of the paper proceeds as follows. Section 2 will discuss Tasche's result regarding the use of Euler allocation for performance measurement. In Sections 3 we consider the case when the cost of equity capital varies by line of business and give a simple example that illustrates why an Euler allocation is not always appropriate for performance measurement in this context. Section 4 continues the discussion from Section 3. Section 5 concludes.

2. BACKGROUND: EULER ALLOCATION AND RORAC

Insurance companies charge premiums to cover the cost of expected claims. Actual claims costs may end up being much higher than expected, for example due to a catastrophic event, and so an insurance company must have additional funds – economic capital – available to ensure it can meet its obligations in this case. The amount of capital a firm will hold is typically determined by (or at least guided by) a risk measure such a Value at Risk, Tail Value at Risk or Standard Deviation as well as by regulatory requirements. Once the total amount of capital has been determined, the firm might want to allocate this capital by line of business and/or geographic region. This may be helpful for reasons such as risk management - for example to understand which lines/regions are driving the need to hold capital - and performance measurement (which will be discussed in more detail below). An Euler allocation is a particular method of allocating capital which is often considered very suitable for performance management purposes. If the risk measure being used to determine the overall capital requirement satisfies certain properties, we will see later in Section 2 that an Euler allocation will exist for that risk measure.

The notation, definitions and wording in the remainder of Section 2 are largely based on Tasche [3] and Tasche [4]. The wording has been modified slightly to reflect a focus on an insurance (rather than investment) context. The main result in Section 2 (Proposition 2.2) is based on Theorem 4.4 in Tasche [3] and Proposition 2.1 in Tasche [4].

Suppose that real-valued variables $X_1,\ldots,X_n$ are given and represent the profits and losses of the various lines of business written by an insurance company. Let X denote the companywide portfolio profit/loss, ie

$$X=\sum_{i=1}^{n} X_i.$$

It is useful to allow for some dynamics in this model by introducing variables $u=(u_1,\ldots u_n)$:

$$X(u)=X(u_1,\ldots u_n)=\sum_{i=1}^{n} u_i X_i.$$

Then we have obviously $X=X(1,\ldots 1)$. For the purposes of this paper we assume that the probability distribution of the random variable $(X_1,\ldots,X_n)$ is fixed and that the u_i only take on values close to 1 (ie the company's current mix of business will not be changing drastically).

Definition 2.1

- A non-empty set U in R^n is homogeneous if for each u in U and t>0, t*u is in U.
- A function $h:U \rightarrow R$ is homogeneous if U is homogeneous and for each u in U and t>0, h(t*u)=t*h(u).

Proposition 2.1 tells us that differentiable homogeneous functions can be represented as a weighted sum of their derivatives in a canonical manner. This result is stated (in a more general form) in Tasche [3] and follows from Euler's theorem on homogeneous functions.

Proposition 2.1 Let U be a non-empty open set in R^n and $h:U \rightarrow R$ be a real-valued function. If h is totally differentiable, then it is homogeneous if and only if for all u in U,

$$h(u)=\sum_{i=1}^{n} u_i\left(\frac{\partial h}{\partial u_i}\right)(u).$$

We define a risk measure ϱ to be a function from U to R. We assume that the economic capital (EC) required by the company (ie capital as a buffer against high losses) is determined by a homogeneous and totally differentiable risk measure ϱ, ie:

$$EC(X(u)) = \varrho(X(u)).$$

Proposition 2.1 tells us that

$$\varrho(X(u)) = \sum_{i=1}^{n} u_i\left(\frac{\partial\varrho}{\partial u_i}\right)(X(u)).$$

Definition 2.2 Let $\varrho(X_i|X)$ be the capital allocated to line i. Then

- The total portfolio Return on Risk Adjusted Capital is defined by

$$\mathrm{RORAC}(X(u)) = E[X(u)]/\varrho(X(u)).$$

- The portfolio-related RORAC of the i-th line is defined by

$$\mathrm{RORAC}((X_i|X)(u)) = (u_i E[X_i])/\varrho((X_i|X)(u)).$$

Definition 2.3 Let X denote the portfolio-wide profit/loss.

- A capital allocation $\varrho(X_1|X),\ldots,\varrho(X_n|X)$ of the total economic capital $\varrho(X)$ satisfies the full allocation property if

$$\sum_{i=1}^{n} \varrho(X_i|X) = \varrho(X).$$

- A capital allocation $\varrho(X_1|X),\ldots,\varrho(X_n|X)$ is RORAC compatible if there exist $\varepsilon_i>0$ such that

$$\mathrm{RORAC}(X_i|X) > \mathrm{RORAC}(X) \Rightarrow \mathrm{RORAC}(X+hX_i) > \mathrm{RORAC}(X)$$

for all $0 < h < \varepsilon_i$.

Proposition 2.2 Let ϱ be a risk measure. Assume that ϱ is homogeneous and totally differentiable. If there is a capital allocation $\varrho(X_1|X),\ldots,\varrho(X_n|X)$ that is RORAC compatible in the sense of Definition 2.3 for arbitrary expected values $m_1,\ldots,m_n$ of $X_1,\ldots X_n$, then $\varrho(X_i|X)$ is uniquely determined as

$$\varrho((X_i|X)(u)) = \varrho_{\mathrm{Euler}}((X_i|X)(u)) = u_i\left(\frac{\partial\varrho}{\partial u_i}\right)(X(u)).$$

In this case, there also exist $\varepsilon_i>0$ such that

$$\mathrm{RORAC}(X_i|X) < \mathrm{RORAC}(X) \Rightarrow \mathrm{RORAC}(X+hX_i) < \mathrm{RORAC}(X)$$

for all $0 < h < \varepsilon_i$.

Proposition 2.2 is the key result regarding the use of Euler allocation for performance measurement. It tells us that if an Euler allocation exists, then it is the unique RORAC compatible allocation that satisfies the full allocation property. In particular, with an Euler allocation if a company writes more business in lines where the expected return on allocated capital is greater (less) than the overall company expected return on capital, then the overall company expected return on capital will increase (decrease).

3. MAIN RESULT: EULER ALLOCATION AND EXCESS RORAC

Proposition 2.2 underlines the suitability of using an Euler allocation for performance measurement when RORAC is the performance metric. However if the cost of equity capital varies by line a RORAC compatible capital allocation may not be the best choice for the company. Cummins and Phillips [2] suggest that the variation in the cost of equity capital by line may be quite significant.

The overall company cost of equity capital is a weighted average of the by line costs of equity capital, weighted by the capital allocated to each line. If the cost of equity capital is the same for all lines of business, then clearly the overall company cost of capital will not change if there are small changes in the volume of business written in each line. In this case, an increase in the overall company RORAC due to these small changes is always beneficial to the company.

If the cost of equity capital varies by line of business, however, it may not always be the case that an increase in the company RORAC due to small changes in the volume of business written in each line is beneficial to the company. In this case, we must also consider any possible impact to the overall company cost of equity capital due to these small changes. This observation motivates Definition 3.1.

Definition 3.1 Let $\varrho(X_1|X),\ldots,\varrho(X_n|X)$ be an allocation of the total economic capital $\varrho(X)$ that satisfies the full allocation property. Let t_i be the cost of equity capital for line i, and t be the overall cost of equity capital for the company. Then

- The total portfolio Excess Return on Risk Adjusted Capital is defined by

$$\text{Excess RORAC}(X) = \text{RORAC}(X) - t.$$

- The portfolio-related Excess RORAC of the i-th line is defined by

$$\text{Excess RORAC}(X_i|X) = \text{RORAC}(X_i|X) - t_i.$$

The definition of Excess RORAC for a line i is basically the same as the definition of Economic Value Added on Capital (EVAOC) for a line i in Cummins [1] except that we require the capital allocation to satisfy the full allocation property and we do not specify any constraints on how to define the profit/loss of a line.

For the remainder of Section 3, we consider an increase in the overall company Excess RORAC ("XS RORAC") as being beneficial to the company. In other words. Excess RORAC (rather than RORAC) is our performance metric.

This means that, for example, we consider a situation where the RORAC is 22% and the cost of equity capital is 20% to be preferable to a situation where the RORAC is 11.5% and the cost of equity capital is 10% since an Excess RORAC of 2% is considered preferable to an Excess RORAC of 1.5%.

Note that if the cost of equity capital is the same for all lines of business, then small changes in the volume of business written in each line will result in an increase in the overall company Excess RORAC if and only if it will result in an increase in the overall company RORAC.

We now consider whether using an Euler allocation to allocate capital by line for the purpose of performance measurement is appropriate in this context. In particular, for all i, does there exist $\varepsilon_i>0$ such that

$$\text{XS RORAC}(X_i|X) > \text{XS RORAC}(X) \Rightarrow \text{XS RORAC}(X+hX_i) > \text{XS RORAC}(X) \text{ and}$$

$$\text{XS RORAC}(X_i|X) < \text{XS RORAC}(X) \Rightarrow \text{XS RORAC}(X+hX_i) < \text{XS RORAC}(X)$$

for all $0 < h < \varepsilon_i$?

The following result suggests that this is not the case in general.

Proposition 3.1 Let ϱ be a risk measure. Assume that ϱ is homogeneous and totally differentiable. Let $\varrho(X_i|X) = \varrho_{\text{Euler}}(X_i|X)$ be the Euler allocation of the total economic capital $\varrho(X)$, and R=XS RORAC(X) be the total portfolio Excess RORAC. Then for each i,

$$\frac{\partial \mathrm{R}}{\partial \mathrm{u_i}} = \frac{\left[\rho \mathrm{m_i} - \mathrm{E[X]}\left(\frac{\partial \rho}{\partial \mathrm{u_i}}\right)\right]}{\rho^2} - \partial t/\partial u_i$$

Proof: Let R= XS RORAC(X) = E[X] - t. Note that $\mathrm{E[X]} = \sum_{i=1}^{n} \mathrm{m_i u_i}$. The result follows from the Quotient Rule.

We assume for the two notes below that n=2 and XS RORAC(X_1|X) > XS RORAC(X).

Note that:

- If $t_1=t_2$ (ie the cost of equity capital doesn't vary by line), then $t=t_1=t_2$ (ie t is a constant and does not depend on u_1 or u_2) so that $\frac{\partial t}{\partial u_1} = 0$, and so our assumption that XS RORAC(X_1|X) > XS RORAC(X) implies that $\frac{\partial R}{\partial u_1} > 0$, ie R is an increasing function of u_1. This implies that there exists some ε_i>0 such that XS RORAC(X+hX1) > XS RORAC(X) for all 0 < h < ε_i, so that an Euler allocation is appropriate for the purpose of performance measurement.

- In general, to ensure that $\frac{\partial R}{\partial u_1} > 0$, we need $\frac{\partial(\text{RAROC(X)})}{\partial u_1} > \frac{\partial t}{\partial u_1}$ which is not always the case.

The following simple example highlights why an Euler allocation is not always appropriate for the purpose of performance measurement if the cost of equity capital varies by line and Excess RORAC is the performance metric.

Suppose a company writes two lines of business and capital is allocated to the two lines based on an Euler allocation.

We assume that $\rho(X) = 2\sqrt{\text{Var (X)}}$ and that the overall capital required by the company is 100.

We further assume that X_1 and X_2 are independent so that Cov(X1,X2)=0, and also assume that Var(X_1)=Var(X_2)=1250=Var(X)/2 and that u_1=u_2=1.

Note that ϱ(X) is homogeneous and totally differentiable and that

$$\frac{\partial \rho}{\partial u_i} = \frac{2\,u_i \text{Var}(X_i)}{\sqrt{\text{Var}(X)}}.$$

Note also that

$$t = \sum_{i=1}^{2} \frac{t_i u_i^2 \text{Var}(X_i)}{\text{Var}(Z)}$$

and so

$$\frac{\partial t}{\partial u_i} = \frac{\text{Var}(Z)\left(2u_i t_i \text{Var}(X_1)) - (\sum_{j=1}^{2} t_j u_j^2 \,\text{Var}(X_j)\right)(2u_i \text{Var}(X_1))}{(\text{Var Z})^2}$$

The expected profit, allocated capital, RORAC, cost of equity capital and Excess RORAC for each line and for the company overall are shown in Table 1.

Table 1: Simple Example

	Profit	Capital	RORAC	Cost	XS RORAC
Line 1	3	50	6.0%	6.0%	0.0%
Line 2	4	50	8.0%	7.5%	0.5%
Total	7	100	7.0%	6.75%	0.25%

Using the approach of Proposition 2.2, Line 1 would be considered the worse performing line since its RORAC is lower than that of the company overall (6% vs 7%). Proposition 2.2 tells us that writing more business in Line 1 would lower the overall company RORAC.

The approach of Section 3 would also suggest that Line 1 is the worse performing line since its Excess RORAC is lower than that of the company overall (0.0% vs 0.25%). This means that for the Euler allocation to be suitable for performance measurement, writing more business in Line 1 should result in a lower overall company Excess RORAC.

However, applying the Quotient Rule, and using the fact that $Var(X) = 2Var(X_1)$, $Var(X_2) = Var(X_1)$ and $u_1=u_2=1$, we have:

$$\frac{\partial R}{\partial u_1} = \sqrt{2\,Var(X_1)}\,\frac{(2m_1 - (m_1 + m_2))}{8\,Var(X_1)} - \frac{2t_1 - (t_1 + t_2)}{2} = -0.005 + 0.0075 > 0$$

This means that the overall company Excess RORAC will increase if we increase the volume in Line 1. So the Euler allocation is not suitable for performance measurement in this case where the cost of equity capital is not the same for the two lines of business and Excess RORAC is the performance metric. Note that if the cost of equity capital was the same for both lines, we would have $t_1 = t_2$, and so $\frac{\partial R}{\partial u_1} < 0$, which would be consistent with a capital allocation that is suitable for performance measurement (which is what we would expect due to Proposition 2.2).

4. ADDITIONAL RESULT: EULER ALLOCATION AND RELATIVE RORAC

As well as the Excess RORAC, a company may also be interested in the Relative RORAC, ie the RORAC divided by the cost of equity capital. For example, if a company has a choice between two options with the same expected Excess RORAC (say, 2%) but different costs of equity capital (say, 10% and 20%), it may prefer the option with the lower cost of equity capital as this may be considered less risky. This option will also have a higher Relative RORAC (since, for example, 12%/10% = 1.2 is greater than 22%/20% = 1.1).

With this in mind, we give the following definitions:

Definition 4.1 Let $\varrho(X_1|X),\ldots,\varrho(X_n|X)$ be an allocation of the total economic capital $\varrho(X)$ that satisfies the full allocation property. Let t_i be the cost of equity capital for line i, and t be the overall cost of equity capital for the company. Then

- The total portfolio Relative Return on Risk Adjusted Capital is defined by

  Relative RORAC(X) = RORAC(X)/t.

- The portfolio-related Relative RORAC of the i-th line is defined by

$$\text{Relative RORAC}(X_i|X) = \text{RORAC}(X_i|X)/t_i.$$

Although the Relative RORAC will likely be of less interest to the company than the Excess RORAC, in this section we will examine it in much the same way that we examined the Excess RORAC in the previous section.

So in Section 4, Relative RORAC ("Rel RORAC") is our performance metric.

This means that, for example, we consider a situation where the RORAC is 11.5% and the cost of equity capital is 10% to be preferable to a situation where the RORAC is 22% and the cost of equity capital is 20% since a Relative RORAC of 1.15 is considered preferable to a Relative RORAC of 1.1.

Note that if the cost of equity capital is the same for all lines of business, then small changes in the volume of business written in each line will result in an increase in the overall company Relative RORAC if and only if it will result in an increase in the overall company RORAC.

We now consider whether using an Euler allocation to allocate capital by line for the purpose of performance measurement is appropriate in this context. In particular, for all i, does there exist $\varepsilon_i>0$ such that

$$\text{Rel RORAC}(X_i|X) > \text{Rel RORAC}(X) \Rightarrow \text{Rel RORAC}(X+hX_i) > \text{Rel RORAC}(X) \text{ and}$$

$$\text{Rel RORAC}(X_i|X) < \text{Rel RORAC}(X) \Rightarrow \text{Rel RORAC}(X+hX_i) < \text{Rel RORAC}(X)$$

for all $0 < h < \varepsilon_i$?

The following result suggests that this is not the case in general.

Proposition 4.1 Let ϱ be a risk measure. Assume that ϱ is homogeneous and totally differentiable. Let $\varrho(X_i|X) = \varrho_{Euler}(X_i|X)$ be the Euler allocation of the total economic capital $\varrho(X)$, and R=Rel RORAC(X) be the total portfolio Relative RORAC. Then for each i,

$$\frac{\partial R}{\partial u_i} = \frac{\left[(t\,\rho)m_i - E[X]\left(\frac{\partial(t\,\rho)}{\partial u_i}\right)\right]}{(t\,\rho)^2}$$

Proof: Let R= Rel RORAC(X) = $E[X]/(t\,\varrho(X))$. Note that $E[X] = \sum_{i=1}^{n} m_i u_i$. The result follows from the Quotient Rule.

We assume for the two notes below that n=2 and Rel RORAC($X_1|X$) > Rel RORAC(X).

Note that:

- If $t_1=t_2$ (ie the cost of equity capital doesn't vary by line), then $t=t_1=t_2$ (ie t is a constant and does not depend on u_1 or u_2), and so our assumption that Rel RORAC(X_1|X) > Rel RORAC(X) implies that $\frac{\partial R}{\partial u_1} > 0$, ie R is an increasing function of u_1. This implies that there exists some ε_i>0 such that Rel RORAC(X+hX1) > Rel RORAC(X) for all 0 < h < ε_i, so that an Euler allocation is appropriate for the purpose of performance measurement.

- In general, to ensure that $\frac{\partial R}{\partial u_1} > 0$, we need $\frac{m_1}{\frac{\partial (t\,\rho)}{\partial u_1}} > \frac{E[X]}{t\,\rho}$ which is not always the case.

We now return to the simple example from Section 3 but with Relative RORAC (instead of Excess RORAC) as the performance metric.

Suppose a company writes two lines of business and capital is allocated to the two lines based on an Euler allocation.

We assume that $\rho(X) = 2\sqrt{\mathrm{Var}\,(X)}$ and that the overall capital required by the company is 100.

We further assume that X_1 and X_2 are independent so that Cov(X1,X2)=0, and also assume that $\mathrm{Var}(X_1)=\mathrm{Var}(X_2)=1250=\mathrm{Var}(X)/2$ and that $u_1=u_2=1$.

Note that $\varrho(X)$ is homogeneous and totally differentiable and that

$$\frac{\partial \rho}{\partial u_i} = \frac{2\,u_i \mathrm{Var}(X_i)}{\sqrt{\mathrm{Var}(X)}}.$$

Note also that

$$t\,\rho = \frac{t_1 u_1 \left(2\,u_1 \mathrm{Var}(X_1)\right)}{\sqrt{\mathrm{Var}(X)}} + \frac{t_2 u_2 \left(2\,u_2 \mathrm{Var}(X_2)\right)}{\sqrt{\mathrm{Var}(X)}}$$

and so

$$\frac{\partial (t\,\rho)}{\partial u_1} = \frac{4 t_1 u_1 \mathrm{Var}(X_1)}{\sqrt{\mathrm{Var}(X)}} - 2\frac{u_1 \mathrm{Var}(X_1)\left(t_1 u_1^2\,\mathrm{Var}(X_1) + t_2 u_2^2 \mathrm{Var}(X_2)\right)}{\mathrm{Var}(X)^{\frac{3}{2}}}$$

The expected profit, allocated capital, RORAC, cost of equity capital and Relative RORAC for each line and for the company overall are shown in Table 2.

Table 2: Simple Example - Continued

	Profit	Capital	RORAC	Cost	Rel RORAC
Line 1	3	50	6.0%	6.0%	1.00
Line 2	4	50	8.0%	7.5%	1.07
Total	7	100	7.0%	6.75%	1.04

Using the approach of Proposition 2.2, Line 1 would be considered the worse performing line since its RORAC is lower than that of the company overall (6% vs 7%). Proposition 2.2 tells us that writing more business in Line 1 would lower the overall company RORAC.

The approach of Section 4 would also suggest that Line 1 is the worse performing line since its Relative RORAC is lower than that of the company overall (1.00 vs 1.04). This means that for the Euler allocation to be suitable for performance measurement, writing more business in Line 1 should result in a lower overall company Relative RORAC.

However, applying the Quotient Rule, and using the fact that $Var(X) = 2Var(X_1)$, $Var(X_2) = Var(X_1)$ and $u_1=u_2=1$, we have:

$$\frac{\partial R}{\partial u_1} = \sqrt{2\,Var(X_1)}\,\frac{6.5t_2 - 7.5t_1}{(t\,\rho)^2} = \frac{50(0.0375)}{(0.0675 \text{ x } 100)^2} = \frac{1.875}{(6.75)^2} > 0$$

This means that the overall company Relative RORAC will increase if we increase the volume in Line 1. So the Euler allocation is not suitable for performance measurement in this case where the cost of equity capital is not the same for the two lines of business and Relative RORAC is the performance metric. Note that if the cost of equity capital was the same for both lines, we would have $t_1 = t_2$, and so $\frac{\partial R}{\partial u_1} < 0$, which would be consistent with a capital allocation that is suitable for performance measurement (which is what we would expect due to Proposition 2.2).

5. CONCLUSIONS

Performance measurement is an important application of capital allocation and Proposition 2.2 highlights why an Euler allocation is particularly appropriate for this purpose when the cost of equity capital does not vary by line. In particular, with an Euler allocation if a company writes more business in lines where the expected return on allocated capital is greater (less) than the overall company expected return on capital, then the overall company expected return on capital will increase (decrease).

The example presented in this paper illustrates that the equivalent result in not always true if the cost of equity capital varies by line of business.

So although an Euler allocation (if it exists) will always be suitable for performance measurement when RORAC is the performance metric, it may not be suitable for performance measurement if the cost of equity capital varies by line and Excess RORAC or Relative RORAC is the performance metric. This means that care must be taken when using an Euler allocation to allocate capital by line for the purpose of performance measurement when the cost of equity capital varies by line.

5. REFERENCES

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