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Expected Downside Risk-based Asset Pricing

Thesis book

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I. Introduction

Since the milestone paper of Harry Markowitz (1952) on Modern Portfolio Theory, literature on the pricing of capital assets has motivated a large number of research papers and is still one of the main research direction. However, the initial framework of Markowitz's paper has gone through an extensive evolution since. Various branches originating from the mean-variance setting have been proposed in the subsequent decades, all of which aiming to better capture the expected return of capital assets. Researchers in the topic followed one of two, fundamentally separate directions. In particular, one subgroup has devoted its research potential to better understand the fundamentals behind the prices of assets, while the other has made an effort to discover robust factors relevant in the dynamics of prices. The former is called equilibrium asset pricing that derives the value of goods in normative economics, whereas the latter is commonly referred to as empirical finance constituting a branch of positive economics.

Although, the mean-variance model of Markowitz provided a coherent framework describing the choice of individuals under risk, it had no practical use as a tool for pricing risky assets. Nevertheless, its findings boosted a great amount of research in the topic, and in a decade, economists of the first aforementioned subgroup have made success in creating a coherent pricing setting that was finally able to provide more or less reasonable estimates for asset prices, which could yield a model that can be used in everyday practice. These findings together have been indexed in literature under the name of Capital Asset Pricing Model or CAPM (Lintner, 1965; Mossin, 1966; Sharpe, 1964 and Treynor, 1962).

This latter model was based on the idea of diversification, the fact that investors hold portfolios in order to decrease the riskiness of their portfolio. Moreover, the authors have concluded that, if investors are rational, the market is perfect and there is an infinite limit for borrowing at the risk-free rate, each market participant holds the same combination of risky assets; only the share of the risk-free asset in their portfolio differs according to their preferences. This finding also yields that the one risky portfolio held by investors is the capital market itself; therefore, individual asset prices behave according to their relationship to this market portfolio. The authors called this latter relationship as the sensitivity to the market returns, or the CAPM Beta.

However, over the subsequent years, a great amount of evidence has accumulated on the poor performance of predictions and estimations of expected return based the CAPM. The detection of anomalistic patterns, such as seasonalities of the January effect (Rozeff and Kinney, 1976), the weekend (Cross, 1973) or the holiday effect (Ariel, 1985), and the findings on novel factors playing a significant role in driving asset prices, such as the price-to-earnings ratio (Basu, 1977) or the dividend yield (Keim, 1985) have all lead to the emergence of a new approach to asset pricing, the empirical finance. Since the first detections of such anomalies, a great amount of empirical research has focused on finding and documenting such patterns. The whole efficient market hypothesis (EMH) (Fama, 1970) is formed around these anomalistic findings, and tries to implement them in asset pricing. In particular, the weak form of efficiency, which states that prices include all the information derived from time series of financial and economic variables, denies the existence of such patterns. This market efficiency, however, is a dual hypothesis; it measures the abnormal returns or anomalies with respect to expected return derived from an equilibrium asset pricing model. Therefore, the existence of such patterns might be simply the cause of a false choice of the applied asset pricing model.

This question was first addressed in the theoretical discussion of Stephen Ross (1976) on the use of multifactor models. Since then, a vast number of papers have been published with the aim of obtaining better predictions of expected returns through the inclusion of novel risk measures, without deriving the principles of investors' preferences. One of the best-known models implementing the predictive ability of such factors was presented by Eugene Fama and Kenneth French (1993), in which the authors included cross-sectional return differences based on the market capitalization and price-to-book value ratio of equities in addition to the market premium proposed by the CAPM. The relevance of this approach is well reflected by the fact that studies aiming to discover new, relevant factors are still getting published on the topic. For example, some control for autocorrelation between returns in the momentum factor (Carhart, 1997) and some include the effect of the liquidity on asset prices (Amihud and Mendelson, 1986; Pastor and Stambaugh, 2003).

Nonetheless, during the last three decades, researchers aiming to provide fundamental models based on the preferences of investors have also contributed to the literature on asset pricing. One subgroup of these latter models has been focusing on relating the lifetime utility of investors through capturing the negative relationship between expected return of a capital asset and its sensitivity to changes in consumption (Merton, 1973). The other subgroup emerged from the novel findings related to individual preferences; these models either included additional elements to the standard expected utility theory introduced by Neumann and Morgenstern (2007), such as the Epstein and Zin recursive utility (1989) in Campbell et al. (2003), or implemented findings from behavioural finance such as prospect theory (Kahneman and Tversky, 1979) in asset pricing models (Barberis et al., 2001).

In this dissertation, I follow this latter approach by allowing for investors who behave according to prospect theory and are subject to heuristic biases in decision making and mental framing. Apart from the extensive amount of experimental evidence, the importance of implementing these findings from behavioural finance has been highlighted by results of recently emerged interdisciplinary studies as well. In particular, the findings of a very recent field between economics, psychology and neuro-science, the neuroeconomics, as well as results in non-human physiology (Chen et al, 2006; Lakshminarayanan et al., 2011), have confirmed the experimental evidence accumulated in the past decades on heuristics (Kuhnen and Knutson, 2005), reference dependence (de Martino et al., 2009) and prospect theory altogether (Glimcher and Fehr, 2013). Therefore, I aim to cover and implement as much of these biases as possible in the asset pricing framework presented in this dissertation.

In the current set of studies, however, I start from the origins of modern asset pricing, the Modern Portfolio Theory. As mentioned above, recent literature on the fundamental principles behind asset prices either implements behavioural findings in the mean-variance framework and under the standard equilibrium assumptions, such as infinite borrowing and a unique risk-free rate, or approach the modelling from the empirical side by searching for factors relevant in price dynamics. The key point is that practically all of these models are still based on the same assumptions defined by the CAPM fifty years ago.

Most of these standard assumptions, however, are unrealistic and have been shown to contradict the actual characteristics of financial markets. Nevertheless, in this thesis I present that relaxing the most contradictory assumptions, one can still apply the main conclusions of standard asset pricing models. In particular, by switching from the mean-variance framework to modelling based on Expected Downside Risk (EDR), the finite borrowing, non-unique risk-free interest rate, risk-seeking and price-maker investors, and non-normal distributions can be handled in one coherent model derived from the principles of utility maximisation. This latter risk measure is defined as the expectation of the returns below the expected return, that is, the expected bad outcome. As it captures the risk in terms of outcomes, instead of the usual positive relationship between risk and required return, we find a negative relationship between EDR and expected return in general.

This thesis book is structured as follows. Part II is based on the papers of Ormos and Timotity (2013a, 2013b, 2013c, 2013d, 2014a, 2016a) and presents the main modelling framework in the EDR - expected return system. In this section, I present the first two theses of the dissertation.

Thesis 1: The inclusion of Expected Downside Risk in asset pricing allows for relaxing one of the most unrealistic, yet crucial restrictions of commonly used equilibrium models, the assumption risk-averse investors.

I show that by extending the definition of market participants to investors who behave in line with prospect theory and become risk-seeking in the domain of losses, this behaviour can be implemented in the standard asset pricing framework as well. Moreover, in line with the second thesis, the use of EDR yields further benefits in addition to the aforementioned one.

Thesis 2: With the shift in risk measure to Expected Downside Risk, the assumptions of price-taker investors and unlimited leverage opportunity for a unique interest rate can be relaxed.

The proposed model derives that neglecting the effect of leverage margins and liquidation or not taking into account the cross-sectional dynamics of the borrowing rate may lead to biased results in standard asset pricing models. However, with the use of EDR, one considers the tail risks as well, which latter is the driving factor of the effect of leverage margin on risk and expected return. Furthermore, EDR can also be used as a proxy for leverage limits and investor-specific interest rate; therefore, it describes individual choice subject to realistic constraints. In Part II an aggregation of these individual choices is provided as well, in which each participant behaves as a price-maker investor contributing to the dynamics of the unique, aggregate expected return. Hence, the price is not anymore taken as exogenous but individual investors themselves play an important role in its formation; that is, the assumption of price-taker investors can be relaxed.

Part III discusses the implications of the EDR risk measure in asset pricing and its relationship to anomalistic findings in experimental economics. The third thesis is related to the studies of Ormos and Timotity (2016a, 2016c), which discusses the rare, yet possible case of a negative relationship between risk and expected return mentioned in Part II.

Thesis 3: By using the Expected Downside Risk as risk measure, both a positive and a negative relationship between expected return and risk can be derived under standard conditions of equilibrium asset pricing models, such as the expected utility theory and positive risk-aversion.

Using this framework no alternative psychological explanation or additional boundary condition on utility theory is required to explain the phenomenon often measured in experimental economics (Brooks et al, 2014; Kahneman and Tversky, 1979; 1992; Linville and Fischer, 1991; Post and Levy, 2005).

Finally, in Part IV that is based on the paper of Ormos and Timotity (2016b), empirical evidence for the superior performance of the proposed asset pricing model is presented in developed and emerging European markets. The fourth and fifth theses based on this latter study are as follows.

Thesis 4: The Expected Downside Risk-based asset pricing model captures the relationship between risk and expected return with superior performance in comparison with the volatility, variance, semi-variance, CAPM Beta, and Downside CAPM Beta on Central and Eastern European and Developed Western European markets.

Based on the empirical analysis of capital markets of the United States of America, the United Kingdom, Germany, France, Hungary, Poland, and the Czech Republic daily, weekly, monthly and yearly analysis provides evidence in favour of this latter point. Furthermore, by analysing local and dollar-denominated returns, the following pattern emerges.

Thesis 5: Dollar-denominated returns, in general, perform better than regressions in the local currency both in regressions based on EDR and alternative risk measures, which indicates that international capital inflow does play an important role in asset prices.

Moreover, this finding is particularly significant on Developed European capital markets, which is in contradiction with the belief of international investors having a greater influence on emerging markets compared to developed ones.

II. Generalized asset pricing: Expected Downside Risk-Based Equilibrium Modelling

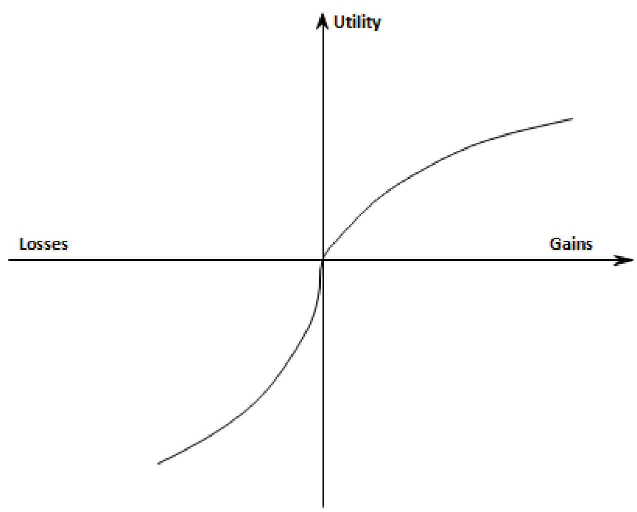
In this section I aim to review the main characteristics of the asset pricing framework based on Expected Downside Risk. First, I present briefly the Prospect Theory, the utility theory necessary to interpret the main results, then I turn to discussing the emergence of risk-seeking behaviour. Second, I show the definitions related to EDR. Third, I discuss the EDR-based asset pricing framework and implement the risk-seeking in an EDR-based environment. Fourth, the asset pricing implications of the limited leverage and non-unique interest rate are discussed. Finally, the formation of the expected return of capital assets is defined.

II.1. Risk aversion or loss aversion

Expected utility theory has been found to yield unrealistic implications in economics in many cases. Nonetheless, behavioural economists have found a way to handle most of these inconsistencies by proposing an alternative utility theory, the prospect theory. In this latter framework, utility does not depend on the total wealth but instead on the change of wealth. Furthermore, according to this theory, investors become risk-seeking in the domain of losses, where the utility function (as presented in Figure II/1) is convex.

The slope of the utility curve is much steeper for losses than for gains (hence, investors are loss-averse); therefore, investors prefer a fix outcome to a risky outcome with zero expected payoff. This is very similar to the risk-averse behaviour implied by the expected utility theory. However, when deciding between a certain loss and a risky loss with the same expected return, investors prefer the latter one due to the convexity of the utility function, which translates to risk-seeking behaviour.

Figure II/1: Utility curve in Prospect Theory



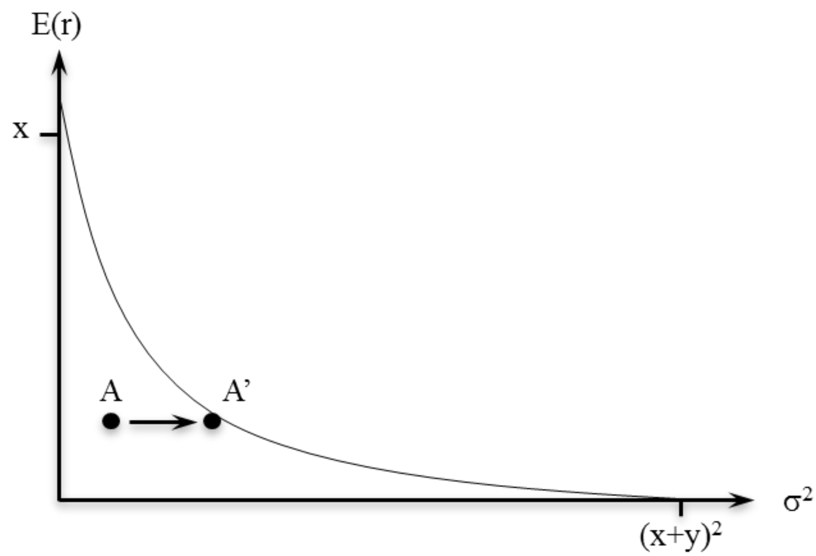
Source: Kahneman and Tversky (1979, p.279)

In a dynamic setting this risk-seeking behaviour may arise from a previous loss (*-x)*, which causes investors to create a negative reference point on the utility curve. In this case, they maximize utility by increasing risk until a given point, where they become risk-neutral. Given that they allocate their money to a portfolio with 50-50% of an (x+y) gain or loss, they become risk-neutral when the expected utility of the risky outcomes becomes equal to the status quo, that is

$$U(-x) - U(-2x - y) = U(y) - U(-x). \qquad \text{(II/1)}$$

Using the exact type of the utility function and its parameters one can thus define a risk-neutrality curve that collects all the risk-neutral states given as a function of the previous loss (-*x*) and the variance of the investment $(x+y)^2$. Investors having suffered losses in the past choose a portfolio on this curve. This function is always a downward sloping in a variance-based setting as presented in Figure II/2. Here, investors prefer portfolio A' to A, although, the former has higher variance with equal expected return.

Figure II/2: Risk-seeking until risk neutrality



Notes: Figure II/3 represents the optimization of risk-seeking investors. They maximize utility by increasing risk until they reach the risk neutral point A'. Depending on the initial portfolio choice alternatives of A' constitute the risk-neutral curve.

II.2. Expected downside risk (*EDR*) as a risk measure

Our definition of *EDR* is based on the popular risk measures widely used in practice of Value-at-Risk (VaR) (Holton, 2003) and Conditional Value-at-Risk (CVaR) (Rockafellar and Uryasev, 2000). Similar to Omega (Keating and Shadwick, 2002), semi-variance (Markowitz, 1968) and downside beta (Estrada, 2007), *EDR* does not apply any subjectively fixed α percentile to measure tail risk but is defined as a risk measure that covers the loss function on the whole domain, although, in contrast to Omega, we examine losses relative to the expected return *(E(r))* instead of zero. In other words, we define Expected Downside Risk as the negative Conditional Value-at-Risk for α

significance level, where *$VaR_\alpha(x)$* is the expected return. This is shown in eq. (II/2), where the *EDR* of investment *x* is described. Hence, EDR is defined as the expected negative outcome or the expectation of returns below the expected return.

$$EDR(x) = p(r_x \leq E(r_x))^{-1} \int_{r_x(y) \leq E(r_x)} r_x(y) p(y) dy, \qquad \text{(II/2)}$$

II.3. *EDR*-based asset pricing

By applying the same derivation as used in common asset pricing models, EDR-based asset pricing can be defined as follows. In the case of a risk aversion and F outcome with σ^2 variance, the approximation of expected utility could be used in our model as well.

$$U(F) \cong E(F) - 0.5a\sigma^2 \qquad \text{(II/3)}$$

Furthermore, we can define *EDR* as the function of expected return and variance for any distribution. For Normal distribution the variable is calculated as follows (it obtains a 0.8 coefficient).[1]

$$EDR(x) = E(r_x) - 0.8\sigma \qquad \text{(II/4)}$$

The framework obtained looks very similar to the one proposed by Markowitz: the efficiency frontier stays intact in the sense that there is a concave curve representing the set of efficient portfolios, and the indifference curves are convex. Therefore, optimal choice can be defined in a similar way at the tangency point of the curves. However, due to the fact that lower EDR means higher risk (in contrast to higher variance), the efficiency frontier becomes downward sloping as shown in Figure II/3.

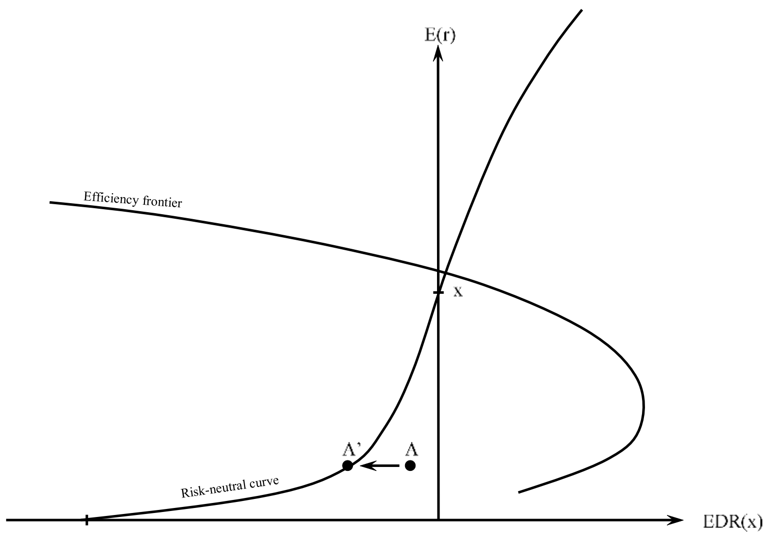
Adding the aforementioned risk-seeking behaviour to this setting, the risk-neutral curve also becomes upward sloping in the EDR-based environment. Considering that investors driven by previous losses hold portfolios from the risk-neutral curve, they maximize expected return on this latter curve. The highest reachable portfolio, however, will be at

[1]in the case of normal distribution EDR=$CVaR_{0.5}$= $\int^{E(r)} r \cdot \left(\frac{1}{\sigma\sqrt{2\pi}} e^{\frac{[r-E(r)]^2}{2\sigma^2}}\right) dr$

the cross-section of the risk-neutral curve and the efficiency frontier. Hence, even if risk-seeking investors are included in the framework, their behaviour can be modelled as a risk-neutral behaviour that yield an optimal portfolio from the efficiency frontier, hence the asset pricing model stays intact. Therefore, the first thesis can be defined as follows.

Thesis 1: The inclusion of Expected Downside Risk in asset pricing allows for relaxing one of the most unrealistic, yet crucial restrictions of commonly used equilibrium models, the assumption risk-averse investors.

Figure II/3: Risk-neutral curve and efficiency frontier



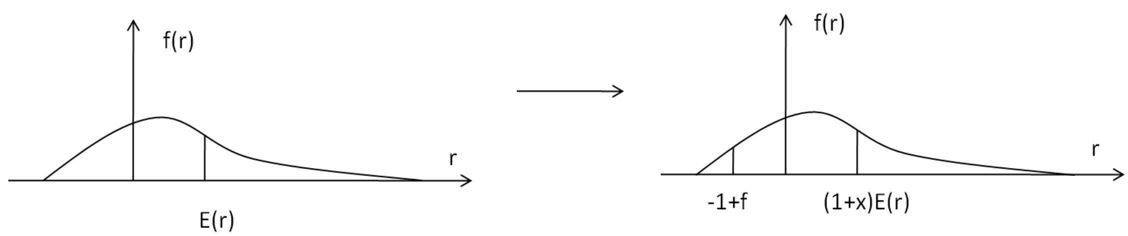
Notes: Figure II/11 shows the optimization of risk-seeking investors. They maximize utility by increasing risk (thus decreasing EDR) until they reach the risk neutral point A' then, as the only determinant of utility is the expected return on the risk-neutral curve, they pick the highest reachable portfolio, which turns out to be exactly the cross-section of the risk-neutral curve and the efficiency frontier.

II.4. The effect of limited borrowings

CAPM defines the capital market line (CML) as the set of efficient investment opportunities, including risk-free and risky assets, that goes to infinity. However, this assumption is fairly unrealistic (Holmes et al, 2015). In most of the cases, there is no opportunity to invest in such positions. Using realistic factors the expected return of portfolios is completely different from that of standard regressions. Here, finite borrowing constraint is used that is available at different interest rates. In order to create a leveraged model the following assumptions are defined: (i) for each investor borrowing is limited (as it is either investment credit or proceeds from short sales) – henceforth, this limit is measured by *(1+x)* (for example, in the case of 2:1 leverage *x=1*); (ii) every time investors use leverage, the lending institution defines a margin that involves the automatic closing of the position or liquidation if the value of the portfolio reaches its *f* percentage – that is, *r=(-1+f)* for returns lower than this value.

Due to these assumptions, investors gain other advantages in exchange for paying the interest rate. On the one hand, in the vast majority of contracts, they get insurance "for free" due to liquidation at the margin call. In this case, the investors cannot lose more than their own invested money; however, it would be possible through a leveraged portfolio without marginal requirements. This reduction of risk has no excess cost for them; however, they get some of the negative risk eliminated, and thus get a higher expected return, as is described in Figure II/4 and in the following analytics. This latter, however, has serious effect on the portfolio choice of investors with different leverage limits.

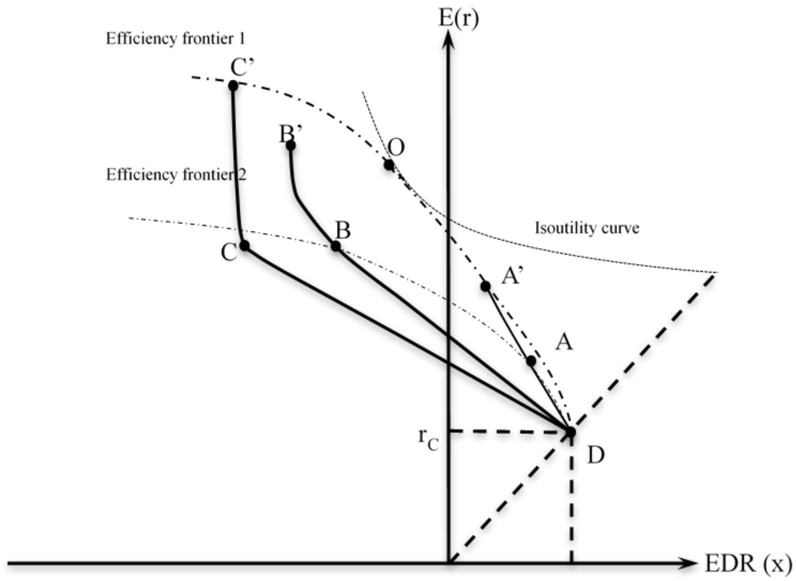
Figure II/4: Effect of leverage with margin requirements



Notes: The graphs represent the effect of leverage and margin call: as the leverage increases to (1+x) the expected return would increase with it, however, the margin call protects both the investor and the lender from losing more than the cutoff level (-1+f), therefore, further increasing the expected return.

The implications of this latter effect on portfolio choice are illustrated in Figure II/5, where *A, B* and *C* are unleveraged, *A', B'* and *C'* are leveraged positions, O is the optimal choice and D is the interest rate (which is risk-free, thus $EDR=E(r)=r_c$). For different leverage possibilities or interest rates, investors' preference may change. In this case, Efficiency frontier 2 included both *A* and *B* portfolios but not *C*; however, for an investor with Efficiency frontier 1, *A*' and *C'* are efficient and *B'* is not. This phenomenon implies that there is no such thing that a unique market portfolio that is optimal at every leverage.

Figure II/5: Individual optimization with leverage constraints

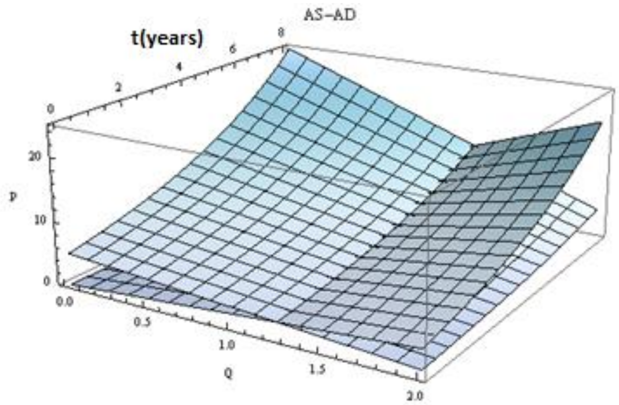


Notes: The graph represents three portfolios with different return distributions. As in Figure II/13, the efficiency frontier may change as the leverage differs. Furthermore, combining the frontier with the highest reachable indifference curve yields the optimal portfolio choice.

II.5. Formation of the expected return

So far the individual optimization has been shown to provide different optima for distinct types of investors, which would not yield a unique expected return and a market price. Nevertheless, by aggregating the individual optimal solutions, financial demand and supply functions can be defined, considering that every investor places an buy or sell offer at a given price. Through aggregating these individual demand and supply curves, a market clearing price is defined in their cross-section, which is shown in Figure II/6. Here, *P* and *Q* stand for the prices and quantities of the aggregate demand and supply curves of a given asset, which evolves exponentially as time goes by.

Figure II/6: The formation of the expected return



Notes: The simulated data represents the evolution of the price P as the function of aggregate demand and supply Q and time t. The increasing price shows the effect of the expected return over time.

Hence, taking each participants leverage limit and interest rate separately, their optimum can be defined, which will contribute to the aggregate demand and supply functions. Therefore, each investor – proportional to her invested money – plays a contributes to the formation of the expected return of a given asset, which means that price-maker investors are present. This implies the second thesis as follows.

Thesis 2: With the shift in risk measure to Expected Downside Risk, the assumptions of price-taker investors and unlimited leverage opportunity for a unique interest rate can also be relaxed.

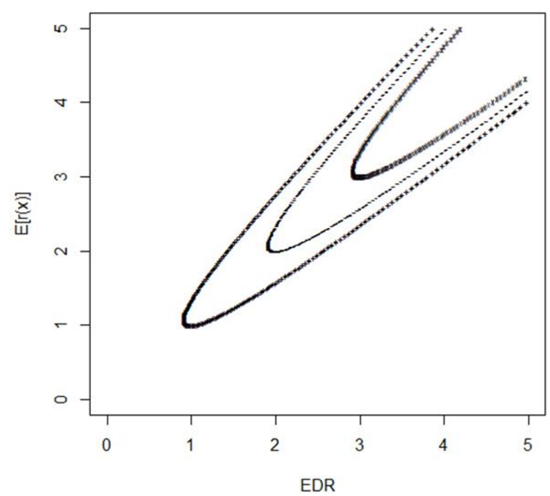
III. The case of "Less is more": Modelling risk-preference with Expected Downside Risk

The well-known linear pricing equations of CAPM and its extensions (e.g. Capital Asset Pricing Model by Lintner (1965); Mossin (1966); Sharpe (1964)) always suggest a positive relationship between expected return and volatility under standard circumstances (i.e. positive risk-aversion coefficient). However, contradicting empirical results (Brooks et al, 2014; Kahneman and Tversky, 1979; 1992; Linville and Fischer, 1991; Post and Levy, 2005) often indicate a negative relationship between the two parameters. I argue, however, that this behaviour deviating from that suggested by the EUT is not necessarily due to a flaw in the theory itself but the measurement of the risk perception. In line with Alonso and Prado (2015) we keep the expected utility framework while focusing on the factors driving utility; however, instead of including other types of randomness (e.g. ambiguity) the perception of risk is analysed.

The risk-return relationship is defined in the EDR-based framework as shown in equation III/1. Here, the squared function intuitively indicates that the relationship between this type of risk and the expected return is not necessarily positive – as suggested by alternative risk measures. Figure III/1 represents a couple of indifference curves for *a*=4 risk-aversion coefficient under the expected utility framework.

$$U = E(r_x) - \frac{0.5}{0.8^2} a[E(r_x) - EDR(x)]^2. \quad \text{(III/1)}$$

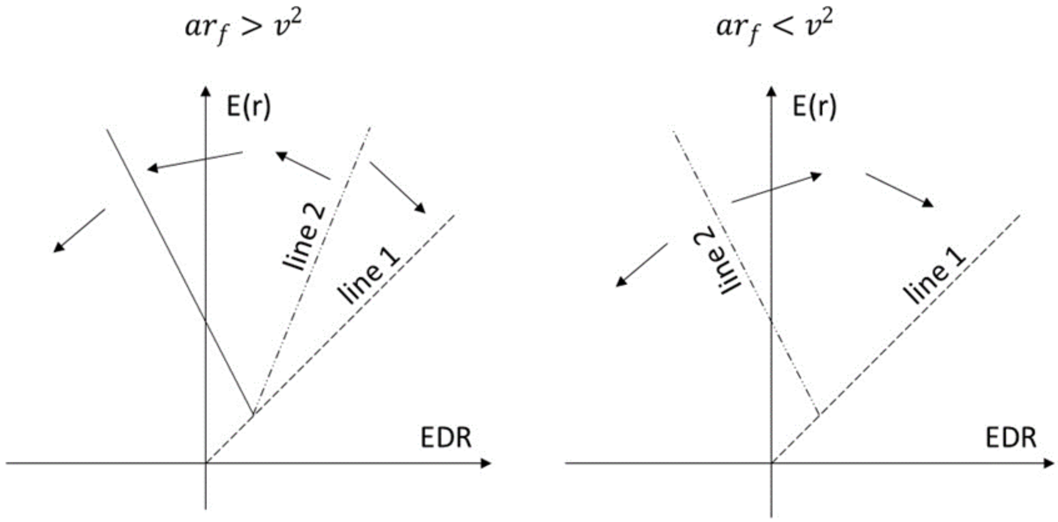
Figure III/1: Indifference curves in EDR-E(r) system given a=4



The inclusion of leveraged opportunities, the optimal leveraged portfolio can be derived within the framework; however, the solution does not always yield a positive relationship between risk and expected return. In particular, depending on the parameters of the risk-aversion coefficient *a,* the risk-free return *rf* and the distribution-dependent volatility coefficient *v*, the utility maximization can yield an optimal leverage both with negative and positive slopes in the EDR-E(r) framework. This is shown in Figure III/2, where line 1 stand for the upper limit of EDR (i.e. portfolio under this line cannot exist), and line 2 for the portfolios providing minimum utility. The figure reveals that if either no portfolios can be reached to the right of line 2 or their utility is smaller than the ones reachable on the left side of line 2, the optimal choice will be provided in a negative relationship between risk and return; however, a positive relationship will hold otherwise. Hence, I define here the third thesis of the dissertation.

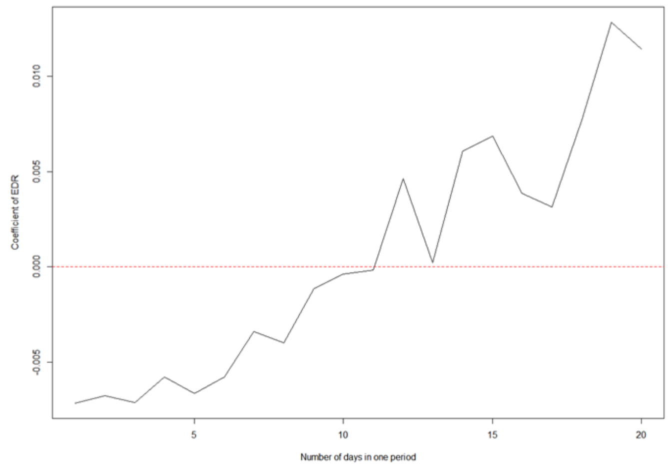
Thesis 3: By using the Expected Downside Risk as risk measure, both a positive and a negative relationship between expected return and risk can be derived under standard conditions of equilibrium asset pricing models, such as the expected utility theory and positive risk-aversion.

Figure III/2: Leveraged portfolio optimization



The existence of this theoretical consideration is well-reflected by empirical analysis as well. In Figure III/3 relationship between risk and return is plotted against the time-horizon of investors, that is, the coefficient between EDR and E(r) is shown as the period length increases. Since the increasing horizon raises the risk-free return as well, the optimization changes over time in line with the aforementioned findings. Therefore, one can clearly see an initially negative relationship that gradually turn into a positive one.

Figure III/3: Relationship between time, risk, and return



IV. Expected Downside Risk and Asset Prices: Characteristics of Emerging and Developed European Markets

Finally, in order to present the relevance in practice of the theoretical framework discussed above, in this section, I present a brief empirical validation of the model. The methodology applied consists of testing the goodness-of-fit of the top ten publicly traded companies based on market capitalisation and of the stock index of six European countries and the USA. The markets analysed are chosen to fit developed and emerging markets: the Developed European markets are represented by the United Kingdom, Germany, and France, the Emerging Eastern European market group includes Poland, Hungary and Czech Republic, and numbers for the United States are tested as well as a proxy for non-European developed markets. Due to limited time-series data of the top ten stocks in emerging markets the analysed period covers the five years from 12/08/2010 to 12/08/2015. The statistics are run for daily, weekly, monthly and yearly returns as well.
When aggregating the individual country results, standardized errors are taken in order to avoid assigning too much weight to countries that have poor goodness-of-fit for expected returns. In Table IV/1 the R-squared values are presented for EDR and its mainstream alternatives, such as volatility, variance, CAPM Beta, semi-variance and downside beta. The results are presented for the no intercept case (**α=0**) and for both local and foreign currencies.

Table IV/1: Separate R-squared results for monthly return

	US	UK	Germany	France	Hungary	Poland	Czech Rep.
α=0, returns in local currency							
vol	0.94	0.08	0.87	0.51	0.02	0.13	0.52
var	0.91	0.02	0.80	0.41	0.03	0.14	0.68
edr	0.86	0.01	0.78	0.32	0.10	0.22	0.77
beta	0.77	0.11	0.83	0.46	0.16	0.13	0.48
svar	0.77	0.03	0.68	0.27	0.10	0.15	0.78
dbeta	0.90	0.11	0.81	0.46	0.08	0.14	0.70
α=0, dollar-denominated returns							
	US	**UK**	**Germany**	**France**	**Hungary**	**Poland**	**Czech Rep.**
vol	0.94	0.01	0.81	0.30	0.03	0.01	0.57
var	0.91	0.02	0.77	0.22	0.01	0.02	0.81
edr	0.86	0.01	0.73	0.18	0.01	0.04	0.78
beta	0.77	0.00	0.78	0.27	0.00	0.00	0.40
svar	0.77	0.01	0.77	0.22	0.00	0.01	0.76
dbeta	0.90	0.01	0.81	0.31	0.02	0.00	0.65
α≠0, returns in local currency							
	US	**UK**	**Germany**	**France**	**Hungary**	**Poland**	**Czech Rep.**
vol	0.60	0.55	0.01	0.00	0.06	0.00	0.62
var	0.63	0.59	0.02	0.00	0.05	0.02	0.66
edr	0.09	0.88	0.09	0.24	0.58	0.14	0.87
beta	0.02	0.06	0.00	0.01	0.36	0.00	0.43
svar	0.34	0.37	0.00	0.02	0.48	0.05	0.75
dbeta	0.39	0.16	0.00	0.01	0.40	0.01	0.74
α≠0, dollar-denominated returns							
	US	**UK**	**Germany**	**France**	**Hungary**	**Poland**	**Czech Rep.**
vol	0.60	0.66	0.00	0.06	0.12	0.00	0.70
var	0.63	0.66	0.01	0.06	0.11	0.01	0.82
edr	0.09	0.87	0.12	0.44	0.87	0.11	0.91
beta	0.02	0.66	0.01	0.08	0.27	0.05	0.32
svar	0.34	0.66	0.01	0.01	0.18	0.00	0.69
dbeta	0.39	0.64	0.00	0.02	0.18	0.00	0.65

It is clearly shown that EDR, in general, outperforms its alternatives; however, in order to provide a robust test for significance, the error terms are aggregated and the significance of difference is analysed in F-tests comparing the variance ratios. These results are shown in Table IV/2 in local currency and in Table IV/3 in US dollars.

Table IV/2: F-test results of residuals against EDR in local currency

		in local currency					
		total sample		developed markets		emerging markets	
	Variable	ratio	p-value	ratio	p-value	ratio	p-value
Without alpha	volatility	1.6478	0.0000	2.6426	0.0000	1.5549	0.0167
	variance	1.1781	0.1717	3.2219	0.0000	0.8829	0.4981
	beta	3.9338	0.0000	3.1473	0.0000	3.8649	0.0000
	semi-variance	2.3110	0.0000	2.7137	0.0000	2.2749	0.0000
	downside beta	2.3945	0.0000	2.4422	0.0000	2.4442	0.0000
With alpha	volatility	2.8998	0.0000	3.4820	0.0000	2.7573	0.0000
	variance	2.4539	0.0000	3.4262	0.0000	2.2280	0.0000
	beta	6.9201	0.0000	3.4929	0.0000	7.5777	0.0000
	semi-variance	5.7105	0.0000	3.4328	0.0000	6.1194	0.0000
	downside beta	5.5178	0.0000	3.2356	0.0000	5.9264	0.0000

Table IV/3: F-test results of residuals against EDR in US dollars

		in USD					
		total sample		developed markets		emerging markets	
	Variable	ratio	p-value	ratio	p-value	ratio	p-value
Without alpha	volatility	1.2650	0.0501	1.5536	0.0169	1.2619	0.2060
	variance	0.9055	0.4075	1.5746	0.0139	0.7700	0.1555
	beta	3.5241	0.0000	1.5408	0.0191	3.7365	0.0000
	semi-variance	1.1291	0.3113	1.5240	0.0223	1.0530	0.7786
	downside beta	1.7704	0.0000	1.5164	0.0239	1.8593	0.0008
With alpha	volatility	2.5773	0.0000	1.7179	0.0034	2.7549	0.0000
	variance	2.2289	0.0000	1.6726	0.0054	2.3261	0.0000
	beta	8.1801	0.0000	1.6577	0.0062	9.7878	0.0000
	semi-variance	2.7523	0.0000	1.9919	0.0002	2.8624	0.0000
	downside beta	3.5648	0.0000	2.1846	0.0000	3.8398	0.0000

As implied by the high R-squared values, EDR significantly outperforms the alternative risk measures: except for the some regressions in the no intercept case – where the difference from the latter risk measures is insignificant –, all p-values are extremely low indicating a much better fit. Hence, the fourth thesis of the dissertation can be defined as follows.

Thesis 4: The Expected Downside Risk-based asset pricing model captures the relationship between risk and expected return with superior performance in comparison with the volatility, variance, semi-variance, CAPM Beta, and Downside CAPM Beta on Central and Eastern European and Developed Western European markets.

However, local currency and US dollar denominated results also suggest another interesting pattern: there is a great difference between the performances of these models. Hence, Table IV/4 provides an aggregated F-test by summing up the squared, standardized error terms of individual countries and risk measures.

Table IV/4: Aggregated F-test results of local currency residuals against US dollar

	total sample		developed markets		emerging markets	
	ratio	p-value	ratio	p-value	ratio	p-value
Without alpha	1.1038	0.0431	1.5252	0.0000	1.0420	0.5812
With alpha	1.0178	0.7181	1.5157	0.0000	0.9637	0.6199

Based on these findings, in each case where the difference is significant, regressions on US dollar denominated returns yield lower error variance (as local over foreign variance ratios are above one), and in particular, this pattern is extremely relevant in the case of developed markets. Therefore, the fifth thesis of the dissertation can be defined as follows.

Thesis 5: Dollar-denominated returns, in general, perform better than regressions in the local currency both in regressions based on EDR and alternative risk measures, which indicates that international capital inflow does play an important role in asset prices.

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