ISSN 2392-1641

Economics and Business Review

Volume 2 (16) Number 3 2016

CONTENTS

A word from the Editor

ARTICLES

From duration analysis to GARCH models – An approach to systematization of quantitative methods in risk measurement
Krzysztof Jajuga

Credit markets and bubbles: is the benign credit cycle over?
Edward I. Altman, Brenda J. Kuehne

Bipolar growth model with investment flows
Katarzyna Filipowicz, Tomasz Misiak, Tomasz Tokarski

Twitter and the US stock market: The influence of micro-bloggers on share prices
Karl Shutes, Karen McGrath, Piotr Lis, Robert Riegler

Can we invest on the basis of equity risk premia and risk factors from multi-factor models?
Paweł Sakowski, Robert Ślepaczuk, Mateusz Wywiał

Quantifying wage effects of offshoring: import- ***versus*** **export-based measures of production fragmentation**
Joanna Wolszczak-Derlacz, Aleksandra Parteka

Simple four-step procedure of parabolic B curve determination for OECD countries in 1990Q1–2015Q4
Dariusz J. Błaszczuk

BOOK REVIEW

Jerzy Witold Wiśniewski, *Microeconometrics in Business Management*, John Wiley & Sons, United Kingdom 2016 (*Dorota Appenzeller*)

Poznań University of Economics and Business Press

Paper based publication

ISSN 2392-1641

POZNAŃ UNIVERSITY OF ECONOMICS AND BUSINESS PRESS
ul. Powstańców Wielkopolskich 16, 61-895 Poznań, Poland
phone +48 61 854 31 54, +48 61 854 31 55, fax +48 61 854 31 59
www.wydawnictwo-ue.pl, e-mail: wydawnictwo@ue.poznan.pl
postal address: al. Niepodległości 10, 61-875 Poznań, Poland

Printed and bound in Poland by:
Poznań University of Economics and Business Print Shop

Circulation: 230 copies

Economics and Business Review, Vol. 2 (16), No. 3, 2016: 78–98
DOI: 10.18559/ebr.2016.3.6

Can we invest on the basis of equity risk premia and risk factors from multi-factor models[1]?

Paweł Sakowski[2], Robert Ślepaczuk[3], Mateusz Wywiał[4]

Abstract: We examine two investment algorithms built on the weekly data of world equity indices for emerging and developed countries in the period 2000–2015. We create seven risk factors using additional data about market capitalization, book value, country GDP and betas of equity indices. The first strategy utilizes the theoretical value of equity risk premium from the seven-factor Markov-switching model with exogenous variables. We compare theoretical with the realized equity risk premium for a given index to undertake the buy/sell decisions. The second algorithm works only on eight risk factors and applies them as input variables to Markowitz models with alternative optimization criteria. Finally we note that the impact of risk factors on the final results of investment strategy is much more important than the selection of a particular econometric model in order to correctly evaluate the equity risk premium.

Keywords: investment algorithms, multi-factor models, Markov switching model, asset pricing models, equity risk premia, risk factors, Markowitz model.

JFL codes: C15, G11, F30, G12, G13, G14, G15.

Introduction

The idea of this article comes from an analysis of various multi-factor models with and without regime switching mechanism. After detailed analysis of many approaches focusing on the proper evaluation of equity risk premium [Sakowski, Ślepaczuk, and Wywiał 2016] we decided to turn from theoretical

[1] Article received 17 May 2016, accepted 8 August 2016. The support of NCN grant number 2014/13/B/HS4/03209 is gratefully acknowledged. The views presented in this text are those of the authors and do not necessarily represent those of Union Investment TFI S.A. or Quedex Derivatives.

[2] Warsaw University, Faculty of Economic Sciences, ul. Długa 44/5, 00-241, Warsaw, Poland.

[3] Warsaw University, Faculty of Economic Sciences, ul. Długa 44/5, 00-241 Warsaw, Poland; Union Investment TFI S.A, corresponding author: rslepaczuk@wne.uw.edu.pl.

[4] Warsaw University, Faculty of Economic Sciences, ul. Długa 44/5, 00-241, Warsaw, Poland; Quedex Derivatives Exchange.

modelling to a practical one. Our main objective is to construct investment algorithms based on the information coming from multi-factor models and factors themselves.

We decided to accomplish this aim in two separate steps. The first will focus on direct extraction of equity risk premia. The investment decision will be based on simple comparison of actual and theoretical equity risk premium for a given index. In the second step we propose an entirely new approach. We incorporate Markowitz' methodology [Markowitz 1952] to risk factors from multi-factor models which are treated as single investment assets and then we allocate funds into these risk factors.

The literature describing the first approach in a direct way is rather limited. We hardly find any studies that focus on the second idea. However as far as the first part is concerned we can find several examples where authors, having introduced a new multi-factor model, try to turn to the practical world and show how their new methodology could work in real financial markets. Examples of such attempts can be summarized as follows:

- creating new factors for multi-factor models [Asness, Frazzini, and Pedersen 2013; Arshanapalli, Coggin, and Doukas 1998; Fama and French 2012; Jegadeesh and Titman 1993; Rahim and Noor 2006; Asness 1995; Chen, Novy-Marx, and Zhang 2011; Hou, Karolyi, and Kho 2011; Foye, Mramor, and Pahor 2013; Griffin 2002];
- introducing new model functional forms [Tan 2013; Ammann and Verhofen 2006; Angelidis and Tessaromatis 2014; Hammerschmid and Lohre 2014];
- new approaches to extract information from risk factors [Fama and French 2012];
- application of an existing model in a different geographical setting [Connor and Sehgal 2001; Griffin 2002; Cakici, Fabozzi, and Tan 2013];
- developing a model tailored to specific markets and countries [Hou, Karolyi, and Kho 2011; Lieksnis 2010];
- application of the multi-factor models to economic forecasting [Liew and Vassalou 2000; Vassalou 2000];
- using model-derived forecasts in capital budgeting [Hu 2003].

It is also important to mention Mulvey [2010] who describes an investment approach similar to some extent to our first strategy. Constructing long/short US equity portfolios the authors employ a set of risk factors, including market index, treasury yields, implied volatility changes, US dollar index and credit spread. The authors augment it with the Markov regime switching model. However, unlike our approach, instead of predicting equity risk premium for a single asset they jointly estimate the portfolio weights and portfolio covariance matrix. They find that the selected portfolio produces significantly higher risk-adjusted returns with lower risk compared to popular US equity indices.

Regarding our second strategy, employing the multi-factor models and risk factors themselves is not a completely new idea. However setting them in a Markowitz framework adds value. The interest in investing directly in the market portfolio instead of selecting individual stocks has surged since the publication of Sharpe's [1964] paper. In 1971 the Wells Fargo/Nikko first "market" index fund appeared and five years later the first mutual fund targeting market portfolio was set up by Vanguard. Seminal papers of Fama and French [1992] and Carhart [1997] sparked interest in what was later called "smart beta". Investing directly in the risk factors themselves became feasible not only for the largest financial institutions but also for the wider spectrum of indices when first "fundamentally-weighted" Exchange-Traded Funds appeared. Since then risk factors have been used either directly as investable asset classes or as a proxy to evaluate exposure of the portfolio consisting of individual equities as documented in Ang [2014]. The robustness of treating factors as investable indices, presented as a reasonable alternative to cap-weighted indices has been evaluated by e.g. Amenc et al. [2015].

Cazalet, Grison and Roncalli [2013] evaluated construction of "smart beta" indices based on risk factors. They find that factor-based indices and portfolios of these indices exhibit generally higher returns and lower volatility than capitalization-weighted indices such as market portfolio. However the authors point out that the source of this supposed outperformance may lie in the greater difficulty of the passive execution of the strategy, namely higher tracking error. Other attempts to incorporate dynamic factor portfolio selection have been made by Komatsu and Makimoto [2011] where the authors search for an optimal algorithm for choosing factor portfolios. However the article contained no empirical analysis and a numerical simulation was applied as the sole means to experimentally verify the model. Ma and Maclean [2011] evaluated a dynamic portfolio selection algorithm based on regime switches, applied to 9 ETFs, with the equally-weighted portfolio as a benchmark. They found that applying dynamic selection to generalized asset classes embodied by ETFs outperforms the naive equally-weighted portfolio.

To sum up, what is novel in our approach is incorporating the risk factors into the Markowitz portfolio selection framework. We choose a simpler but hopefully more robust approach to selecting factor portfolios. The structure of this paper is as follows. After an introduction we carefully describe the methodology of investment strategies used in this paper i.e. equity risk premium approach and the Markowitz model based on risk factors. Data are described in the Section 2. The Section 3 contains our results and shortly addresses sensitivity analysis. The last section explains our results and concludes.

1. Methodology

The methodological section of this paper is divided into two subsections. First, we delineate a strategy directly based on equity risk premium disequilibrium with detailed references to the theoretical multi-factor model used in this approach. In the second part we use the Markowitz model with some amendments focused on optimization criteria, input variables and technical issues.

1.1. Equity risk premia (ERP) approach

1.1.1. Model overview

In this study we use a seven-factor Markov-switching model with additional variables common to all countries (CV) and variables country-specific for developed/emerging markets (CspV)[5]. These variables were previously presented and described in detail in Sakowski, Ślepaczuk, and Wywiał [2016]. The model has the following functional form:

$$\begin{aligned}(R_i - Rf)_t = {} & \alpha_i + \beta_{MKT,i}(Rm - Rf)_t + \\ & + \beta_{HML,i}HML_t + \beta_{SMB,i}SMB_t + \beta_{WML,i}WML_t + \beta_{VMC,i}VMC_t + \\ & + \beta_{QMS,i}QMS_t + \beta_{SMBrel,i}SMBrel_t + \boldsymbol{\beta}_{\mathbf{CV}}\mathbf{CV}_t + \boldsymbol{\beta}_{\mathbf{CspV}}\mathbf{CspV}_t + \varepsilon_{i,t}, \quad (1)\end{aligned}$$

where:

- (*Ri* – *Rf*) – the weekly return of the equity index in excess of the weekly risk free rate,
- (*Rm* – *Rf*) – an equally weighted equity index less than the risk free rate (the index was equally weighted across all 81 countries),
- *HML* – the weekly premium on the book-to-market factor (high minus low),
- *SMB* – the weekly premium on the size factor (small minus big),
- *WML* – the weekly premium on the winners-minus-losers factor (winners minus losers),
- *VMC* – the weekly premium on volatile minus calm (VMC) equity indices (volatile minus calm),
- *QMS* – the weekly premium on equity indices characterized by positive minus negative percentage deviation of nominal GDP from its 5 year moving average (quick minus slow),
- *SMBrel* – similar to the SMB factor with one important exception, i.e. the sorting of equity indices to each decile group is based on the ratio of index capitalization to GDP of the given country instead of capitalization only (small minus big relative),

[5] We refer to this model as 7F+Markov+CV+CspV.

CV – denotes variables common for all countries, among them S&P Goldman Sachs Commodity Index (GSCI), CBOE SKEW index (SKEW), average of annualized monthly realized volatility of crude oil prices and CBOE GVZ volatility index (OVXGVZ), average of CBOE VIX, VXEEM, VXEWZ and VXFXI volatility indices (VX), USD index (DXY), a dummy variable which has value of 1 when the crude oil price is lower than 65 USD and 0 otherwise (CLF dummy), CBOE VVIX index (VVIX),

CspV – denotes country specific variables, amongst them short-term interest rates, long-term interest rates and currencies for emerging and developed countries. CV and CspV are described in detail in Sakowski, Ślepaczuk and Wywiał [2016].

The set of common variables used has been limited to VX, OVXGVZ, DXY and the CLF dummy variable in order to minimize collinearity of the model. In addition to the linear form out-lined in the equation above the model is augmented with a Markov-switching model with two states which resemble periods of high and low market volatility. The model is estimated using a standard Expectation Maximization procedure separately for each of 81 indices during the period 2000–2015. The output of the estimation procedure contains two sets of parameters, one for a high-volatility and one for a low-volatility regime. Based on the estimated probability of each state in a given week we select the parameter set for a regime with greater probability. Using these parameters theoretical risk premia are calculated and used in the investment algorithm outlined below.

1.1.2. Investment algorithm for an ERP approach

Based on this model we obtain weekly theoretical equity risk premia for all equity indices which then will be compared with their practical weekly realization. The investment algorithm works as follows:

$$\text{ERP approach buy/sell signal}_t = \begin{cases} \text{long if } \text{ERP}_{\text{theoretical}, t} > \text{ERP}_{\text{realized}, t}, \\ \text{long if } \text{ERP}_{\text{theoretical}, t} < \text{ERP}_{\text{realized}, t}, \end{cases} \tag{2}$$

where:

$\text{ERP}_{\text{theoretical}, t}$ – denotes the theoretical equity risk premium in week t calculated from a seven-factor Markow-switching model with additional CV and CspV,

$\text{ERP}_{\text{realized}, t}$ – denotes the practical realization of equity risk premium in week t.

Based on the signal from period t we make the decision about buying or selling the given equity index in the period $t + 1$.

1.2. Markowitz model

1.2.1. Investment algorithm for the Markowitz model

The second algorithm does not use any specific multi-factor model but it focuses only on risk factors. Seven of them, RmRf, HML, SMB, WML, VMC, QMS and SMBrel, have been calculated and described in detail in Sakowski, Ślepaczuk, and Wywiał [2016]. Additionally we use a modified betting-against-beta factor (BAB) calculated for worldwide equity indices based on the methodology presented in Frazzini and Pedersen [2014]. Our modifications focus on a more aggressive leveraging of low-beta indices and applying lower leverage to high-beta indices. The purpose of these modifications is to limit the volatility of the factor and increase its stability, in particular during extreme market moves. We use these eight risk factors as input data in the Markowitz portfolio optimization framework.

The risk factors mentioned above are treated as investable indices with the initial value of 100. This value then changes in time according to the returns obtained by the specific risk factor in each week. For example, the dynamics of the WML factor is described by:

$$\mathrm{WML}_{\text{investable index}, T} = 100 \cdot \prod_{t=1}^{T} \mathrm{WML}_{\text{return}, T}, \tag{3}$$

where:

$\mathrm{WML}_{\text{investable index}, T}$ – denotes the value of investable index based on the WML risk factor for a seven-factor Markow-switching model with CV and CspV at the moment *T*,

$\mathrm{WML}_{\text{return}, T}$ – denotes the single week returns from WML risk factor at the moment *t*.

1.2.2. Visualization of all risk factors

A visualization of all risk factors in comparison with the market index can be found on Figure 1. This chart presents risk factor dynamics in the period between 2000–2015 for the seven-factor Markov-switching model with CV and CspV + BAB risk factor compared with the market index (Rm). Investable indices for risk factors were calculated starting from value 100 as a cumulative return of each risk factor separately. Market index (RmRf) was obtained starting from value of 100 as a cumulative return of equally weighted returns of all equity indices under investigation. Dynamics of risk factors presented in Figure 1 shows that their correlations with broad market index returns are time-variant. What is more important is that these correlations could be positive as well as negative, depending on the time frame considered.

Table 1 shows profitability statistics for investable indices based on risk factors which are inputs to the Markowitz model in the period from 2000 to 2015.

Cagr means the annualized rate of return. Sharpe denotes the average yearly rate of return divided by volatility. Volatility means annualized standard deviation of returns. MAXDD is maximum drawdown. VaR means value at risk whilst CVaR denotes conditional VaR.

Table 1. Profitability statistics for investable indices based on risk factors which are inputs for the Markowitz model

	RmRf	HML	SMB	WML	VMC	QMS	SMB.rel	BAB
Cagr	5.59	7.8	3.95	15.16	1.07	0.28	5.59	9.25
Sharpe	0.42	0.5	0.32	0.79	0.17	0.09	0.39	1.52
Volatility	15.81	18.03	16.22	20.53	25.8	15.13	17.72	5.94
MaxDD	–65.69	–54.73	–46.68	–38.22	–65.4	–60.49	–71.29	–21.05
VaR	–3.26	–3.52	–3.43	–4.56	–5.23	–3.21	–3.69	–1.17
CVaR	–5.71	–5.01	–5.11	–6.44	–7.58	–4.55	–5.19	–1.73

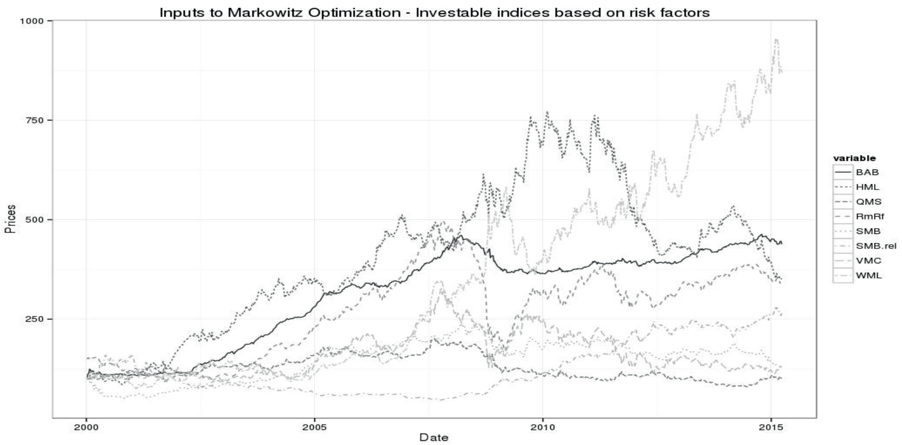

Figure 1. Investable indices based on risk factors from the seven-factor model + BAB risk factor which are inputs to the Markowitz model versus market index

We can see on Table 1 and Figure 1 that the risk return ratio (Sharpe ratio) of these investable indices ranges between 0.09 and 1.52 indicating that a few of them can make quite good investments.

2. Data

The analysis was performed on weekly data from 2000 to 2015 for 81 of the most representative and investable equity indices covering all continents. We include data for 27 developed and 54 emerging markets indices. The detailed list of all equity indices and their descriptive statistics can be obtained upon request.

Apart from price data for equity indices we required the following weekly data in order to properly calculate investable indices for seven risk factors: risk free interest rate (3mLiborUSD), book value for equity indices, currency rates, market capitalization for equity indices recalculated from local currency into USD and quarterly GDP data for all countries.

Additionally in order to calculate all necessary variables for 7F-Markov+CV+CspV we used the following data: skew for S&P500 index, GSCI index, VIX, VVIX, OVX and GVZ volatility indices, DXY index, crude oil prices, short-term and long-term interest rates and currencies for emerging and developed countries. It is important to underline that although our analysis was performed in the period between 2000–2015 the results for the Markowitz model starts in 2001 whilst the results for the ERP algorithm starts in 2003. The reason for the different start point is connected with the lookback period for Markowitz model (52 weeks) and minimal amount of data which was left in order to estimate our model (3 years).

Moreover it is important to underline that the series were appropriately lagged in order to ensure that no strategy suffered from look ahead bias. Also we made efforts to avoid other flaws often encountered in investment research such as sample selection bias or the overoptimization effect. This is additionally confirmed by sensitivity analysis in Section 3.3.

3. Results

This section is divided into three subsections. Two of them describe two investment strategies whilst Subsection 3.3 addresses the detailed sensitivity analysis of the results.

3.1. Equity risk premia approach results

Equity risk premia investment strategy is based on following assumptions:
- ERP calculations are based on the 7F-Markov+CV+CspV model,
- Degree of financial leverage (DFL) for long and for short positions are set at 100%,
- Percentage of stocks where we go long and short in the strategy equal 20%.

Buy/sell signals were generated according to the rules presented in Subsection 1.1.2. Profitability statistics for the ERP approach are reported in Table 2 whilst

Figure 2 presents equity lines. DFLlong and DFLshort presented in Table 2 mean that we invest only 100% of an asset in the long and short leg of the strategy and that we do not use any additional leverage. Figure 2 presents equity lines for the ERP approach. The black thick line shows results for long-short strategy. The black thin line shows results only for the long leg of the strategy. The black thin dotted line shows results only for short leg of the strategy.

We can see that the main version of our investment strategy does not produce any cumulative returns across the whole investment horizon. The difference between long and short leg equity lines is negligible and what results in final equity lines oscillate around 0% returns almost for the whole period. Unfortunately it can mean that the investment algorithm proposed for the extraction of information hidden in ERP estimated by our model is not able to produce abnormal returns. This is also in contrast with the results of a similar research found in Mulvey [2010] who achieved a Sharpe ratio as high as 2.07. We try to analyze and explain this issue more deeply in Section 3.3.

Table 2. Profitability statistics for ERP approach

	ERP-strategy_20%-80%_model_10%-90%_m12
Cagr	–0.85%
Volatility	11.41%
MD	40.32%
Sharpe	–0.07
Sharpe / MD	–0.18
Sharpe * Cagr / MD	0
DFL Long	100%
DFL Short	100%

3.2. Markowitz model results

The second investment approach shows entirely different results. We decided to take the following assumptions with respect to the Markowitz model:

– optimization criteria: target risk 8% (TRISK.8), target return 12% (TRET.12), max Sharpe ratio (MS), min variance (MV) and equally weighted (EW),
– long/short restriction: long only,
– lookback for variance-covariance matrix: 1 year, rebalancing: quarterly, weights restrictions: from 0 to 100% for single asset, weekly data, DFL for the strategy equals 100%.

Table 3 presents profitability statistics for the Markowitz model with five different optimization criteria: target risk 8% (TRISK.8), target return 12% (TRET.12), maximum Sharpe ratio (MS), minimum variance (MV) and equal-

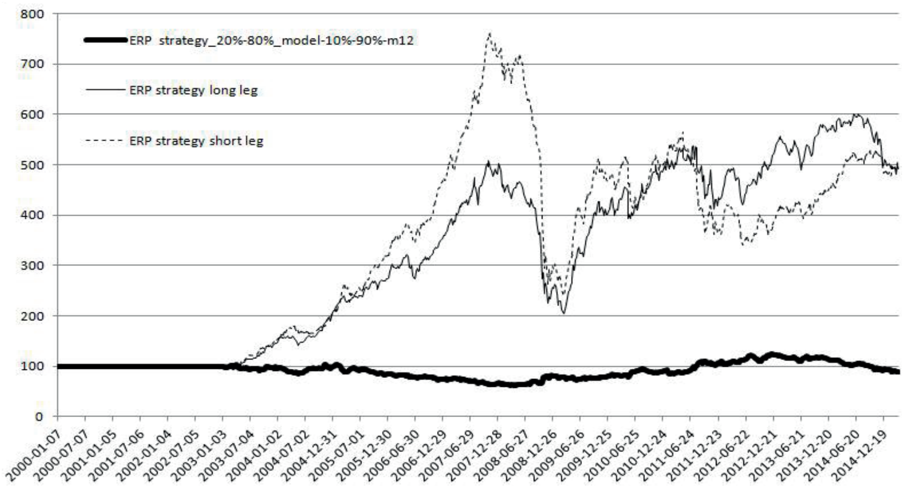

Figure 2. Equity lines for ERP approach

ly weighted (EW). Cagr means annualized rate of return. Sharpe denotes the average yearly rate of return divided by volatility. Volatility means standard deviation of returns. MAXDD is maximum drawdown. VaR means value at risk. The lookback period for the variance-covariance matrix is set at 52 weeks. Rebalancing is done every quarter. The long/short restriction is set to long only positions. We can see that our second investment algorithm produces very promising results with a relatively high return to risk ratio. What is more important is that our results are quite stable across different optimization criteria. We can see that the Sharpe ratio oscillates around 1.9, which is a relatively high value for strategies working on frequencies lower than daily. Additionally risk statistics like MaxDD, VaR or CVaR are 3 to 4 times lower than the same for buy&hold strategies on equity indices for the same period. Most notably Markowitz models consequently outperform in terms of the Sharpe ratio both

Table 3. Profitability statistics for the Markowitz model with various optimization criteria

	TRISK.8	TRET.12	MS	MV	EW
Cagr	9.09	8.17	12.48	7.72	8.15
Sharpe	1.93	1.99	1.98	1.92	1.65
Volatility	4.54	3.98	6.03	3.91	4.81
MaxDD	−17.31	−12.71	−10	−16.78	−12.5
VaR	−0.91	−0.74	−1.07	−0.74	−0.91
CVaR	−1.32	−1.15	−1.77	−1.13	−1.25

in individual factor and equally-weighted portfolios. The investment approach presented enabled us to practically insulate our investment against all main financial crashes or bear markets encountered in our research period (2000–2002, 2008–2009, August 2011).

Figure 3 presents equity lines for the Markowitz model for five various optimization criteria with assumptions summarized at the beginning of this section. Equity lines present results for 5 different optimization criteria. TRISK.8 means total risk with an 8% threshold. TRET.12 denotes total return with a 12% threshold. MS means maximum Sharpe ratio. MV denotes minimum variance. EW means equally weighed factors which do not change for the whole period. The lookback period for the variance-covariance matrix is set at 52 weeks. Rebalancing is done every quarter. The long/short restriction is set only to long positions.

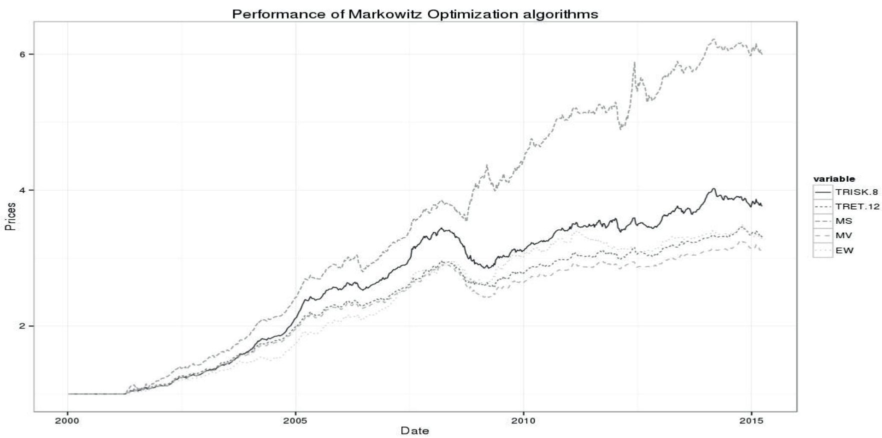

Figure 3. Equity lines for the Markowitz model with five various optimization criteria

3.3. Sensitivity analysis

3.3.1. Equity risk premia approach

In order to check the robustness of the results we decided to perform a sensitivity analysis of our results focusing on the main assumptions. We focused on:

- DFL for long and short positions. We checked the following version: DFLlong = 100% and DFLshort = 25%,
- The number of stock – we decided to go long or short based on the highest departure of practical ERP from theoretical ERP. We checked two variants: 10% and 50%.

Table 4 presents the profitability statistics for the ERP approach when we change the assumptions concerning an equal DFL for both legs of the strategy (long and short). DFLlong and DFLshort means that we invest only 100% of the asset in long and 25% in the short leg of the strategy and that we do not use any additional leverage. Ranks means that we took only 20% of the indices with the highest difference between realized and theoretical ERP. The rationale for such a parameter change can be twofold. The first is to just check the sensitivity of our results against one of the parameters. The second is that we wanted to check to what extent the assumptions of the strategy should take into account the fact that the average broad market was in upward trend in the investment horizon examined.

Table 4. Profitability statistics for an ERP approach with various DFL

	ERP-strategy_20%-80%_model_10%-90%_m12
Cagr	8.23
Volatility	13.74
MD	46.24
Sharpe	0.6
Sharpe / MD	1.29
Sharpe * Cagr / MD	0.11
DFL Long	100%
DFL Short	25%
ranks	20%

Figure 4 presents the equity lines for the ERP approach. The black thick line shows results for long-short strategy. The black thin line shows results only for the long leg of the strategy. The black thin dotted line shows results only for the short leg of the strategy. We can observe much better results in comparison to the main version presented in Section 3.1 The difference between long and short leg equity lines is quite substantial and it could be compared by the Sharpe ratio (0.6 versus –0.07) presented in Table 4. The problem is that any observed improvement in results should be mainly attached to the larger weight of the long position (100% versus 25% for the short leg) in upward trend instead of the much better efficiency of the investment algorithm used.

The second change with respect to sensitivity analysis for the ERP approach focused on the number of indices used in our analysis. Table 5 presents profitability statistics for the ERP approach. DFLlong and DFLshort means that we invest only 100% of the asset in the long and short leg of the strategy and that we do not use any additional leverage. Ranks means that we took only 10% (or

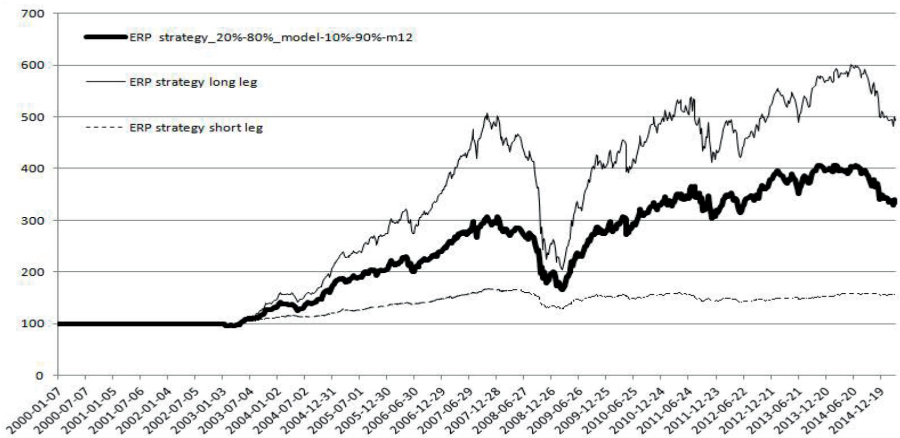

Figure 4. Equity lines for the ERP approach. DFLlong = 100%. DFLshort = 25%

50%) of the indices with highest difference between realized and theoretical ERP. We can see that these changes did not affect results in comparison to the main version. The Sharpe ratio is still very close to zero or even smaller (for Ranks = 50%). We can observe that generally better results can be obtained when we focus only on indices with the highest differences between realized and theoretical ERP (left column from Table 5).

These observations are confirmed in Figures 5 and 6 where equity lines for two versions of ERP strategy presented in Table 5 are shown. The black thick line on these figures shows results for long-short strategy. The black thin line shows results only for the long leg of the strategy. The black thin dotted line shows results only for the short leg of the strategy. DFLlong and DFL short equals 100%.

Table 5. Profitability statistics for ERP approach with various Ranks (10% and 50%)

	ERP-strategy_50%_ model_10%-90%_m12	ERP-strategy_10%_ model_10%-90%_m12
Cagr	–1.77	0.325
Volatility	5.99%	16.53%
MD	33.6%	44.36%
Sharpe	–0.29	0.02
Sharpe / MD	–0.88	0.04
Sharpe * Cagr / MD	0.02	0
DFL Long	100%	100%
DFL Short	100%	100%
ranks	50%	10%

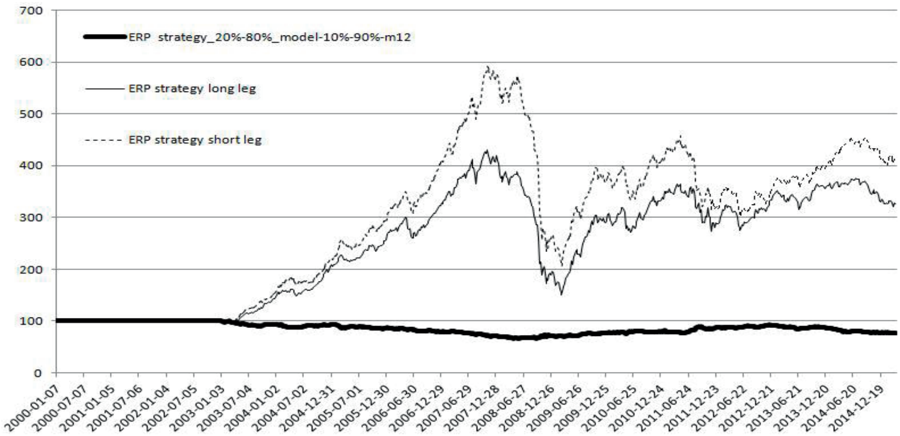

Figure 5. Equity lines for the ERP approach (Ranks = 50%)

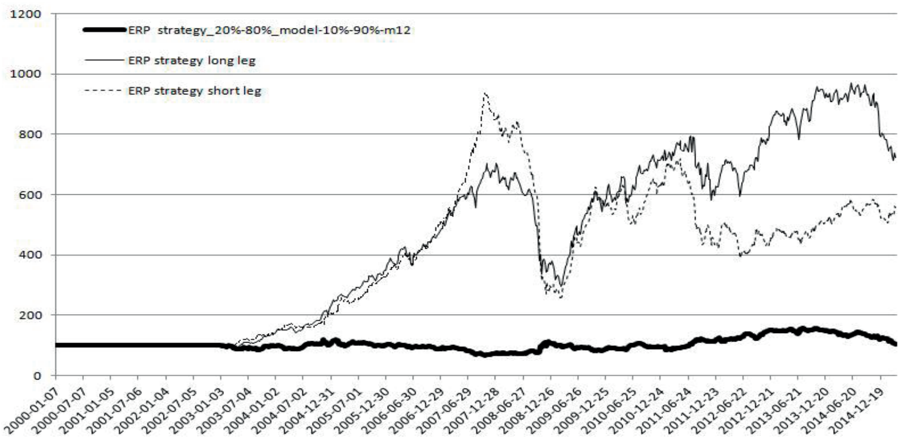

Figure 6. Equity lines for the ERP approach (Ranks = 10%)

To summarize results for the first algorithm tested (its main version and alternative modifications examined sensitivity analysis) it is necessary to admit that better results were expected. We noticed that the only promising result in this approach was obtained when we set DFLlong on a much higher level than DFLshort. As a result we change the profile of the strategy from market neutral to heavy long biased. As a result it cannot account for the strength of the model (not mentioning the possible overfitting or data-snooping bias). Taking into account all the results mentioned above we acknowledge that the first algorithm, although based on a relatively complex multi-factor model, is not able to produce returns characterized by a high return to risk ratio.

3.3.2. Markowitz model

We decided to check the robustness of our results to changes in the following assumptions:

– lookback for variance-covariance matrix: 0.5 year and 2 years (instead of 1 year), rebalancing: monthly and yearly (instead of quarterly),
– rebalancing: monthly and yearly (instead of quarterly).

Table 6 presents profitability statistics for the Markowitz model with the lookback period changed to 26 weeks whilst in Table 7 we can see results for a much longer lookback period set at 2 years. These tables present profitability statistics for the Markowitz model with five optimization criteria: target risk 8% (TRISK.8), target return 12% (TRET.12), maximum Sharpe ratio (MS), minimum variance (MV) and equally weighted (EW). Cagr means annualized rate of return. Sharpe denotes average yearly rate of return divided by volatility. Volatility means standard deviation of returns. MaxDD is maximum drawdown. VaR means value at risk. The lookback period for the variance-covariance matrix is set at 26 weeks (in Table 6) and 104 weeks (in Table 7).

Table 6. Profitability statistics for the Markowitz model with various optimization criteria and a lookback period set at 26 weeks (with quarterly rebalancing)

	TRISK.8	TRET.12	MS	MV	EW
Cagr	9.61	9.22	13.02	8.14	8.07
Sharpe	1.79	2.02	1.84	1.82	1.59
Volatility	5.17	4.39	6.75	4.33	4.94
MaxDD	–17.03	–9.35	–10.8	–16.85	–12.5
VaR	–0.98	–0.82	–1.38	–0.85	–0.93
CVaR	–1.48	–1.24	–1.95	–1.26	–1.28

Table 7. Profitability statistics for the Markowitz model with various optimization criteria and the lookback period set at 104 weeks (with quarterly rebalancing)

	TRISK.8	TRET.12	MS	MV	EW
Cagr	7.6	7.3	10.25	7.23	7.19
Sharpe	1.75	1.84	1.89	1.83	1.52
Volatility	4.22	3.86	5.23	3.85	4.62
MaxDD	–18.73	–18.61	–9.98	–18.59	–12.5
VaR	–0.76	–0.7	–1.01	–0.71	–0.87
CVaR	–1.26	–1.11	–1.51	–1.11	–1.24

Rebalancing is done every quarter. The long/short restriction is set only to long positions.

We observe that generally the results presented in Tables 6 and 7 do not differ in comparison to the main version presented in Table 3. They show that the outcome of our second algorithm are rather stable with respect to the lookback period (although for a longer lookback period they are slightly worse) and that this algorithm enables us to produce high risk adjusted returns when we compare Sharpe ratios between the above mentioned tables. Small differences can be found when we pay attention to the best and worst results in each table taking into account optimization criteria. However and what is more important is that for every lookback period we can see that EW results are much worse in comparison to four other optimization criteria. The last observation regards maximum returns. In each table maximum Cagr is obtained for the maximum Sharpe ratio optimization criterion.

Figure 7 and Figure 8 additionally confirm our observations based on the above tables. These charts present equity lines for Markowitz model. Equity lines present results for 5 different optimization criteria. TRISK.8 means total risk with 8% threshold. TRET.12 denotes total return with 12% threshold. MS means a maximum Sharpe ratio. MV denotes minimum variance. EW means equally weighed factors which do not change for the whole period. The lookback period for variance-covariance matrix is set at 26 weeks (in Figure 7) and 104 weeks (in Figure 8). Rebalancing is done every quarter. The long/short restriction is set only to long positions. We can see very smooth upward fluctuations of the equity lines no matter which optimization criterion we focus on. The next important issue we wanted to check within the sensitivity analysis was the frequency of rebalancing. Instead of quarterly rebalancing (Section 3.2)

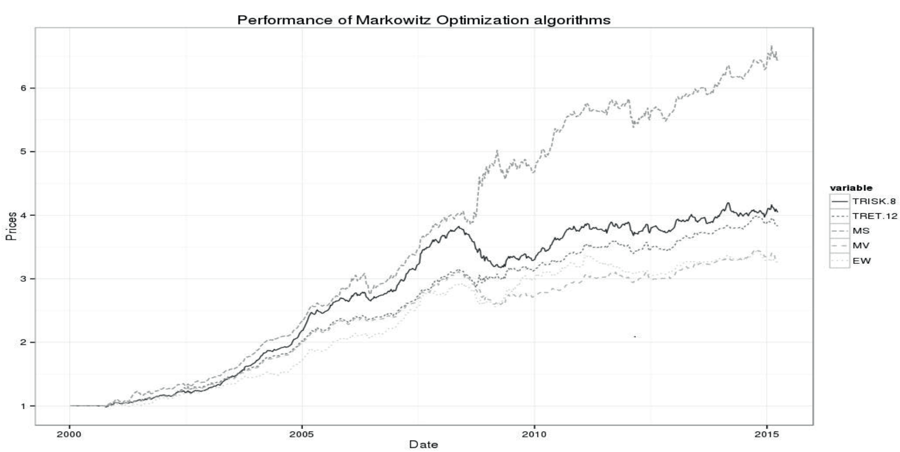

Figure 7. Equity lines for the Markowitz model with five different optimization criteria and the lookback period set at 26 weeks (with quarterly rebalancing)

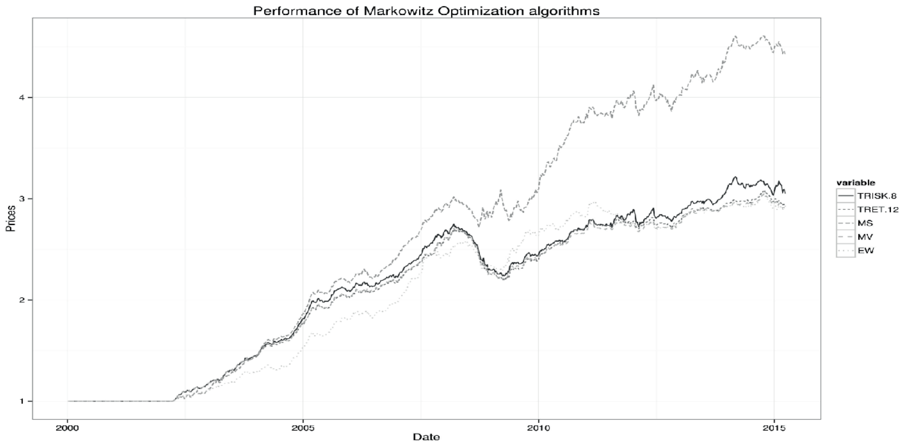

Figure 8. Equity lines for the Markowitz model with five various optimization criteria and the lookback period set at 104 weeks (with quarterly rebalancing)

we repeated our analysis with monthly rebalancing (Table 8) and with yearly rebalancing (Table 9).

Again we can see that the differences between various values of rebalancing are rather irrelevant although they are slightly better for the shorter frequency of rebalancing. Additionally, we can see that MaxDD slightly increases when we rebalance more frequently. Figure 9 and Figure 10 confirm these conclusions.

Generally the sensitivity analysis confirms the preliminary results for our second investment algorithm. We can see that the results are quite robust with regard to the initial assumptions about the lookback window and rebalancing period. We can observe that they can be even slightly enhanced when we shorten the rebalancing period and lookback window at the same time.

Table 8. Profitability statistics for Markowitz model with five optimization criteria and the lookback period set at 52 weeks (with monthly rebalancing)

	TRISK.8	TRET.12	MS	MV	EW
Cagr	9.46	8.15	12.74	7.68	7.75
Sharpe	2.02	2.01	1.95	1.96	1.56
Volatility	4.5	3.93	6.22	3.8	4.84
MaxDD	−17.27	−13.8	−8.69	−17.18	−13.57
VaR	−0.81	−0.77	−1.16	−0.76	−0.88
CVaR	−1.28	−1.12	−1.82	−1.08	−1.27

Table 9. Profitability statistics for the Markowitz model with various optimization criteria and the lookback period set at 52 weeks (with yearly rebalancing)

	TRISK.8	TRET.12	MS	MV	EW
Cagr	7.97	7.1	8.94	7.04	7.86
Sharpe	1.7	1.72	1.54	1.73	1.62
Volatility	4.55	4.01	5.64	3.96	4.73
MaxDD	–21.08	–18.46	–20.52	–18.94	–9.87
VaR	–0.83	–0.74	–1.08	–0.72	–0.91
CVaR	–1.36	–1.16	–1.82	–1.14	–1.25

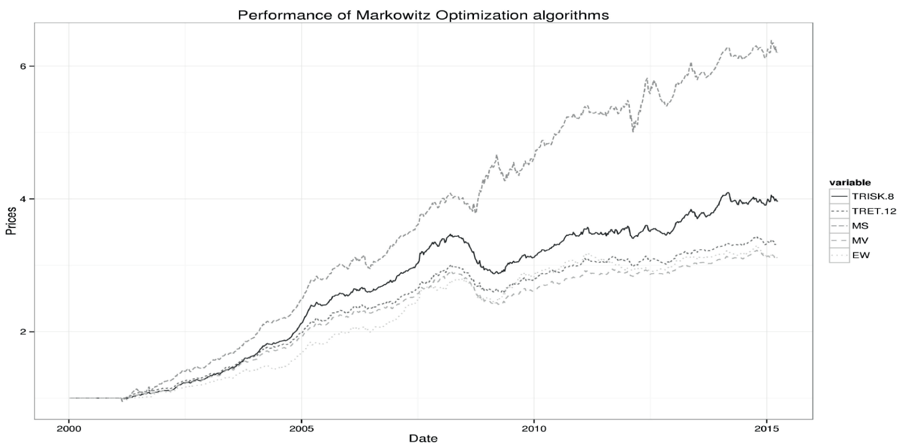

Figure 9. Equity lines for the Markowitz model with five optimization criteria and the lookback period set at 52 weeks (with monthly rebalancing)

Conclusions

The most important result of this study is that based on the information hidden in the multi-factor models with which we can build profitable investment algorithms. The point is that extraction of this information is not straightforward. We proposed two types of investment strategies.

The first one was based on comparison of the realized and theoretical ERP estimated with a seven-factor Markov-switching model with additional variables common for all countries (CS) and variables specific to emerging and developed markets (CspV). The second strategy was based on utilizing the risk factor as investable indices in a Markowitz framework.

Based on detailed analyses it meant that these two approaches led us to two different results. The results of the first approach show that the proposed

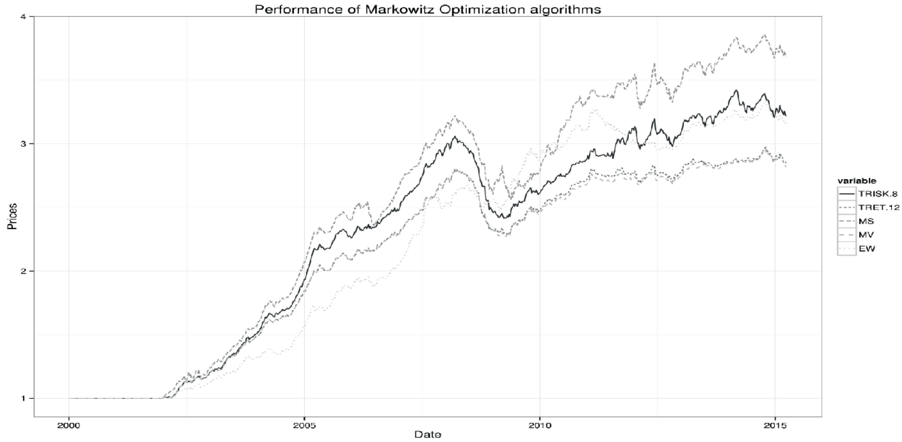

Figure 10. Equity lines for the Markowitz model with five various optimization criteria and the lookback period set at 52 weeks (with yearly rebalancing)

method of information extraction does not lead us to profitable results when we consider risk adjusted return, perhaps counter intuitively and contrary to what has been suggested by literature so far. Entirely different results can be observed in case of the second investment algorithm. We can see that simple a Markowitz framework applied to risk factors from multi-factor models can lead to abnormal risk-adjusted returns (Sharpe ratio close to 2).

After performing the sensitivity analysis we can confirm that our preliminary results do not differ when we change our main assumptions. In fact we noticed that they can be even improved when we shorten the lookback period and rebalancing frequency. This is consistent with the current financial practice of factors investing and the search for smart beta. However what is most remarkable is that the simple but time-tested and robust approach of portfolio selection can greatly enhance the investment results beyond investing in a single factor or in an equally-weighted factor portfolio.

In finally we can state that the answer to the main research question is positive. It is possible to extract information from the multi-factor models in order to build investment algorithms that produce returns that significantly exceed those of the benchmarks. However it is important to note that such extraction is not simple and rather requires precise and thorough analysis in order to do this properly. In particular the employment of risk factors as separate asset classes in the Markowitz model allows the consistent achievement of abnormally high returns whilst direct application of the multi-factor equity risk premium model to generate trading signals does not.

References

Amenc, N., Goltz, F., Sivasubramanian, S., Lodh, A., 2015, *Robustness of Smart Beta Strategies*, The Journal of Index Investing, 6(1): 17–38.

Ammann, M., Verhofen, M., 2006, *The Effect of Market Regimes on Style Allocation*, Financial Markets and Portfolio Management, 20(3).

Ang, A., 2014, *Asset Management: A Systematic Approach to Factor Investing*, Oxford University Press (UK).

Angelidis, T., Tessaromatis, N., 2014, *Global Portfolio Management under State Dependent Multiple Risk Premia*, in: Proceedings of Economics and Finance Conferences, no. 0400966, International Institute of Social and Economic Sciences.

Arshanapalli, B.G., Coggin, T.D., Doukas, J., 1998, *Multifactor Asset Pricing Analysis of International Value Investment Strategies*, The Journal of Portfolio Management, 24(757):10–23.

Asness, C., Frazzini, A., Pedersen, L.H., 2013, *Quality Minus Junk*, available at SSRN.

Asness, C.S., 1995, *The Power of Past Stock Returns to Explain Future Stock Returns*, Unpublished working paper Applied Quantitative Research.

Cakici, N., Fabozzi, F.J., Tan S., 2013, *Size, Value, and Momentum in Emerging Market Stock Returns*, Emerging Markets Review, 16: 46–65.

Carhart, M.M., 1997, *On Persistence in Mutual Fund Performance*, The Journal of Finance, 52(1): 57–82.

Cazalet, Z., Grison, P., Roncalli, T., 2013, *The Smart Beta Indexing Puzzle*, Available at SSRN 2294395.

Chen, L., Novy-Marx, R., Zhang, L., 2011, *An Alternative Three-Factor Model*, SSRN Electronic Journal.

Connor, G., Sehgal, S., 2001, *Tests of the Fama and French Model in India*, London School of Economics and Political Science, Discussion paper, 379: 1–23.

Fama, E.F., French, K.R., 1992, *The Cross-Section of Expected Stock Returns*, Journal of Finance, XLVII(2).

Fama, E.F., French, K.R., 2012, *Size, Value, and Momentum in International Stock Returns*, Journal of Financial Economics, 105(3): 457–472.

Foye, J., Mramor, D., Pahor, M., 2013, *A Respecified Fama French Three-Factor Model for the New European Union Member States*, Journal of International Financial Management & Accounting, 24(1): 3–25.

Frazzini, A., Pedersen, L.H., 2014, *Betting Against Beta*, Journal of Financial Economics, 111(1): 1–25.

Griffin, J.M., 2002, *Are the Fama and French Factors Global or Country Specific?*, Review of Financial Studies, 15: 783–803.

Hammerschmid, R., Lohre, H., 2014, *Regime Shifts and Stock Return Predictability*, Available at SSRN 2445086.

Hou, K., Karolyi, G.A., Kho, B.C., 2011, *What Factors Drive Global Stock Returns?*, Review of Financial Studies, 24: 2527–2574.

Hu, O., 2003, *Forecasting Ability of the Fama and French Three-factor Model – Implications for Capital Budgeting*.

Jegadeesh, N., Titman S., 1993, *Returns to Buying Winners and Selling Losers: Implications for Stock Market Efficiency*, The Journal of Finance, 48(1): 65–91.

Komatsu, T., Makimoto, N., 2011, *Dynamic Investment Strategy for Factor Portfolios with Regime Switches*, Financial Modeling and Analysis, 1736 (20510126): 5–17.

Lieksnis, R., 2010, *Multifactor Asset Pricing Analysis of the Baltic Stock Market*, Ekonomika, 89(4): 85–95.

Liev, J., Vassalou M., 2000, *Can Book-to-market, Size and Momentum Be Risk Factors that Predict Economic Growth?*, Journal of Financial Economics, 57:221–245.

Ma, Y., Maclean, L., 2011, *A Portfolio Optimization Model with Regime-Switching Risk Factors for Sector Exchange Traded Funds*.

Markowitz, H., 1952, *Portfolio Selection*, The Journal of Finance, 7(1): 77–91.

Mulvey, J.M., 2010, *An Investment Model via Regime-Switching Economic Indicators*, Risk Management, (November).

Rahim, R.A., Noor, A.H. S.M., 2006, *A Comparison between Fama and French Model and Liquidity-Based Three-Factor Models*, Asian Academy of Management Journal and Finance, 2(2): 43–60.

Sakowski, P., Ślepaczuk, R., Wywiał, M., 2016, *Applying Exogenous Variables and Regime Switching to Multifactor Models on World Equity Indices*, Ekonomia, forthcoming.

Sharpe, W.F., 1964, *Capital Asset Prices: A Theory of Market Equilibrium under Conditions of Risk*, The Journal of Finance, 19(3): 425–442.

Tan, M., 2013, *Regime Switching Behaviour of the UK Equity Risk Premium*, Ph.D. thesis, University of Birmingham.

Vassalou, M., 2000, *The Fama-French Factors as Proxies for Fundamental Economic Risks.*

Aims and Scope

Economics and Business Review is the successor to the Poznań University of Economics Review which was published by the Poznań University of Economics and Business Press in 2001–2014. The Economics and Business Review is a quarterly journal focusing on theoretical and applied research work in the fields of economics, management and finance. The Review welcomes the submission of articles for publication dealing with micro, mezzo and macro issues. All texts are double-blind assessed by independent reviewers prior to acceptance.

Notes for Contributors

1. Articles submitted for publication in the Economics and Business Review should contain original, unpublished work not submitted for publication elsewhere.
2. Manuscripts intended for publication should be written in English and edited in Word and sent to: review@ue.poznan.pl. Authors should upload two versions of their manuscript. One should be a complete text, while in the second all document information identifying the author(s) should be removed from files to allow them to be sent to anonymous referees.
3. The manuscripts are to be typewritten in 12' font in A4 paper format and be left-aligned. Pages should be numbered.
4. The papers submitted should have an abstract of not more than 100 words, keywords and the Journal of Economic Literature classification code.
5. Acknowledgements and references to grants, affiliation, postal and e-mail addresses, etc. should appear as a separate footnote to the author's name[a, b, etc] and should not be included in the main list of footnotes.
6. Footnotes should be listed consecutively throughout the text in Arabic numerals. Cross-references should refer to particular section numbers: e.g.: See Section 1.4.
7. Quoted texts of more than 40 words should be separated from the main body by a four-spaced indentation of the margin as a block.
8. Mathematical notations should meet the following guidelines:
   - symbols representing variables should be italicized,
   - avoid symbols above letters and use acceptable alternatives (Y*) where possible,
   - where mathematical formulae are set out and numbered these numbers should be placed against the right margin as... (1),
   - before submitting the final manuscript, check the layout of all mathematical formulae carefully (including alignments, centring length of fraction lines and type, size and closure of brackets, etc.),
   - where it would assist referees authors should provide supplementary mathematical notes on the derivation of equations.
9. References in the text should be indicated by the author's name, date of publication and the page number where appropriate, e.g. Acemoglu and Robinson [2012], Hicks [1965a, 1965b]. References should be listed at the end of the article in the style of the following examples:

   Acemoglu, D., Robinson, J.A., 2012, *Why Nations Fail. The Origins of Power, Prosperity and Poverty*, Profile Books, London.

   Kalecki, M., 1943, *Political Aspects of Full Employment*, The Political Quarterly, vol. XIV, no. 4: 322–331.

   Simon, H.A., 1976, *From Substantive to Procedural Rationality*, in: Latsis, S.J. (ed.), *Method and Appraisal in Economics*, Cambridge University Press, Cambridge: 15–30.
10. Copyrights will be established in the name of the E&BR publisher, namely the Poznań University of Economics and Business Press.

More information and advice on the suitability and formats of manuscripts can be obtained from:

Economics and Business Review
al. Niepodległości 10
61-875 Poznań
Poland
e-mail: secretary@ebr.edu.pl
www.ebr.ue.poznan.pl

Subscription

Economics and Business Review (E&BR) is published quarterly and is the successor to the Poznań University of Economics Review. The E&BR is published by the Poznań University of Economics and Business Press.

E&BR is listed in ProQuest, EBSCO, and BazEkon.

Subscription rates for the print version of the E&BR: institutions: 1 year – €50.00; individuals: 1 year – €25.00. Single copies: institutions – €15.00; individuals – €10.00. The E&BR on-line edition is free of charge.

Correspondence with regard to subscriptions should be addressed to: Księgarnia Uniwersytetu Ekonomicznego w Poznaniu, ul. Powstańców Wielkopolskich 16, 61-895 Poznań, Poland, fax: +48 61 8543147; e-mail: info@ksiegarnia-ue.pl.

Payments for subscriptions or single copies should be made in Euros to Księgarnia Uniwersytetu Ekonomicznego w Poznaniu by bank transfer to account No.: 96 1090 1476 0000 0000 4703 1245.