# ROLLING REGRESSION CAPM ON ZAGREB STOCK EXCHANGE – CAN INVESTORS PROFIT FROM IT?

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***ABSTRACT***

*This paper explores possibilities of using rolling regression CAPM on the Zagreb Stock Exchange in portfolio and risk management. Since original model has many flaws, one of them including the assumption of constant parameters in the model, extending the model with the assumption of changing parameters over time could lead to better results regarding portfolio risk and return. Furthermore, the rolling regression approach to CAPM estimation has not yet been observed on the Croatian and similar CEE markets, to the knowledge of the author. Weekly data on five sector indices from Zagreb Stock Exchange and the market index CROBEX with 91 day T-bill rates have been used for the period January 2012 – April 2018 in order to evaluate rolling regression CAPM on the Croatian market. Results from the analysis are used in simulating portfolio strategies in order to evaluate their performance regarding risk and return. Results indicate that such trading strategies could lead to better portfolio risk and return characteristics compared to the CROBEX benchmark, with the inclusion of transaction costs as well.*

**Keywords**: asset pricing, rolling regression, risk hedging

**JEL classification**: G12, C22, G11.

## 1. INTRODUCTION

Risk management today represents one of the most difficult tasks for investors in portfolio management. The reasoning lies upon the facts that many different investment opportunities are available on financial markets, new information is released daily, other types of risks spillover to financial markets, as well as the knowledge needed for estimating and forecasting risks is getting more complex. Most famous asset pricing model within the rational portfolio theories is the CAPM (Capital Asset Pricing Model), developed in 1960s. Although it's many flaws, it is still most used today in practice: more than 2/3 of institutional investors in USA had used CAPM for estimation of systematic risk in 2001 (Graham and Campbell, 2001) and 46% of institutional investors in Europe in 2004 (Brounen et al., 2004). Due to many dynamics on financial, and especially stock markets, simple models often could result with flawed conclusions and expectations. Estimating systematic risk via CAPM betas should result with reliable and unbiased values. Since the original form of the CAPM model assumes that parameters do not change in the model, regardless of markets going up or down, this could potentially lead to misspecifications and inconsistent estimation results. Trecroci (2014) explains that structural changes in economy make reasonable to model risk sensitivity in the asset pricing model with the assumption of time varying parameters, especially over long time spans. This is not something new, since findings in Ferson and Harvey (1991, 1993), where predictability in returns was in a significant fraction explained via changing risk premiums on different stock and bond portfolios. More details can be found in Karolyi and Sanders (1999).

Thus, the purpose of this study is to fulfil the gap in the literature of estimating CAPM betas on the Croatian market by using the rolling regression estimation procedure. In that way, dynamics is included in the model and parameters vary over time. Realistic approach is included in the model in that way, due to adding the assumption that systematic risk of

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a stock or sector varies over time, depending upon specific factors which influence and cause those changes. Previous methodological and empirical work had many different approaches of observing the pricing model. Some research focused on including other factors in the model itself, such as the Fama and French (1992, 1993) model, due to previous empirical findings that small capitalization stocks achieve better results compared to bigger ones (Banz 1981, Reinganum 1981) and stocks with smaller price to earnings ratios having greater returns compared to those stocks having bigger ratios (Basu, 1977). Arbitrage Pricing Theory (APT, Ross, 1976 and Chen et al. 1986) was also introduced as a response to CAPM critics, by observing macroeconomic and other factors which affects stock returns. However, Harvey et al. (2014) found in total 314 factors used in empirical research when observing APT. Newer models include the Carhart (1997) 4-factor model, Fama-French (2015, 2106) 5-factor model, etc. Since CAPM today stays the most used asset pricing model, here the paper focuses on some extensions of the original model itself. The fact that CAPM beta is not constant is a known fact for a long time now (Keim and Stambaugh, 1986; Fama and French, 1989; Chen, 1991; Jagannathan and Wang, 1996). Different approaches have been suggested over the years in order to model the changes in model parameters, such as Kalman filter (see Moonis and Shah, 2003; Mernger and Bulla, 2008), state space models (see Lettau and Ludvigson, 2001), non parametric approaches (Ferreira et al. 2011). Based upon the state of the market regarding its characteristics and investor's preferences, some approaches have advantages over other while having disadvantages at the same time (for a detailed discussion see Nieto et al. 2014). This paper follows a parsimonious approach, by exploring a simple extension of rolling estimates of the CAPM model and its parameters. This topic is not sufficiently explored on the Croatian market even today. Two main hypothesis of the research are as follows. First one assumes that CAPM parameters are varying over time and the second assumes that using results from rolling regression estimates of CAPM parameters enhances portfolio management. The rest of the paper is as follows. Second section deals with previous related research. Third section describes the methodology used in the fourth, empirical section of the paper. The last section concludes the research.

## 2. PREVIOUS RELATED RESEARCH

Empirical evaluation of the CAPM model has been in spotlight for many decades in the foreign literature, and approximately 15 years on the Croatian market. Since the literature is numerous, here the focus is on the related research regarding the methodology in this study, as well as similar markets and previous studies of the Croatian market.

First group of papers which explored pricing models on the Zagreb Stock Exchange (ZSE) were Fruk and Huljak (2003), Perković (2011), Džaja and Aljinović (2013), Tomić (2013) and Odobašić et al. (2014). These papers are grouped in a coherent group due to their approach of empirical testing. All of them observe the original CAPM model, by focusing on mostly liquid stocks on ZSE and apply least squares method of estimation. The conclusions of these papers are the same: authors question the usage of original model betas as measure of systematic risk. The second group of papers includes trying to solve some of the problems of the original models. Here, the following research can be included: Škrinjarić (2014, 2015a, 2015b, 2018), Škrinjarić and Slišković (2018). Škrinjarić (2014) introduced regime switching methodology in order to estimate a CAPM model for bull and bear market respectively. Author concluded that results were economically and statistically significant. Škrinjarić (2015a) estimated bivariate GARCH models in order to obtain changing betas for sector indices on ZSE. This model introduced a feedback from individual returns to the stock market return alongside changing betas. Extended analysis of the previous research was done in Škrinjarić (2015b), where sector indices (for the time span 2013-2015) were extensively analyzed via bivariate GARCH models for changing betas, Value at Risks and several performance measures (such as Sharpe and Treynor ratios) in order to have better portfolio selection over time, both for the conservative and aggressive investors. Škrinjarić (2018) was an even more extensive research on the whole financial market in Croatia (including stock, bond, exchange rates and sector indices on ZSE) via regime switching methodology. Only the CAPM modelling results will be reported here. Two regimes were found to be significant for all of the sectors on ZSE in the observed period (February 2013 – March 2017); industry and construction sector were found to be most aggressive regarding betas in both regimes; and forecasting by using regime switching models was more accurate compared to non switching models. Škrinjarić and Slišković (2018) focused on the pitfalls of the static CAPM as well. Authors observed possibilities of the quantile regression approach of evaluating CAPM betas and found the same sectors to be aggressive as previous mentioned research on ZSE. Conclusions of this research included facts that there exist some potentials of including quantile regression methodology in investment strategies. Thus, it can be seen that although the Croatian stock market has been researched within asset pricing models to some extent, only in the last few years is the analysis being deepened a bit further. Many other questions are left unanswered.

Other related studies which do not focus on the Croatian market are those who apply the methodology used in this research. The following papers are included in this group. Fama and French (1997) estimated rolling regression with 60-month window length CAPM and 3-factor models for 48 value-weighted industry portfolios (in the period July 1963 until December 1994) in USA and found that factor sensitivities vary over time in such a way that it is very difficult to estimate the cost of capital of firms and industries. An overview of other early work is given and discussed in Groenewold and Fraser (1999). Some reasoning for time variation of betas in pricing models is found in Lettau and Ludvigson (2001) and Petkova and Zhang (2003) where it is shown that positive unconditional alphas from pricing models are result of variation in business cycles in the economy. Ang and Chen (2005) based upon their extensive study concluded; among other, that rolling betas provide insights into the autocorrelation and the error of the true conditional beta data generating process. Petkova and Zhang (2005) on a sample of monthly data (January 1927 – December 2000) estimate the conditional betas in the asset pricing models via rolling regression and found that value betas are positively correlated with the expected risk premium whilst growth betas in the model are negatively correlated with the risk premium, i.e. existence of asymmetric betas was found. Based upon 60 years of data, Franzoni (2006) found that market betas have declined over the decades for approximately 75%, due to state of the economy as a whole. Author used monthly data (time span: 1926-2000, US data) and rolling regression approach when estimating pricing models and found a 30% value premium when allowing for beta to vary over time. Ang and Chen (2007) conclude based upon the study on the US market (1926-1963) that CAPM captured the value premium of stocks when allowing for time variation in the beta, while Gregory and Michou (2009) compared several pricing models on the UK market (CAPM alongside the 3-factor, 4-factor and the conditional versions of models) and found that the rolling window (overlapping 60-months) estimates of CAPM beta predict returns no worse than those retrieved from complex models. Bajpai and Sharma (2015) focused on the Indian market (January 2004 – December 2013) and used rolling regression CAPM with 3-year windows. Results indicated that this model can be used on the observed market to evaluate cost of equity. Costa et al. (2014) evaluated 36-month rolling CAPM and Carhart (1997) models on the Australian market (for the period from January 2004 until December 2012) and found significant time variations in alphas and factor loadings in both models. Authors suggest using such approach when evaluating equity fund performance. All of this previous research resulted with conclusions of time varying risk premium on different stock markets, with the focus mostly being on the more developed market. This is why a gap in literature still exists regarding small, illiquid markets such as the Croatian one. Up until writing this research, no similar study was found for other CEE and South European markets as well, meaning that this study can provide contributions in this area.

## 3. METHODOLOGY

Seminal work of (Sharpe 1964, Lintner 1965, Treynor 1961, 1962, Mossin 1966) has developed the simple Capital Asset Pricing Model (CAPM) in the following time series regression form:

$$r_{i,t} - r_{f,t} = \alpha_i + \beta_i \left( r_{M,t} - r_{f,t} \right) + \varepsilon_{i,t}, \quad (1)$$

where $r_{i,t}$ denotes return on the *i*-th stock, portfolio, sector, investment fund, etc. at date *t*; $r_{f,t}$ return on the risk-free rate at date *t*; $r_{M,t}$ the market return at date *t*; with $\alpha_i$ denoting the Jensen's (1967) alpha and $\beta_i$ the measure of the systematic risk. $\varepsilon_{i,t}$ denotes the error term of the model. As it can be seen from equation (1), it is assumed that parameters alpha and beta do not change over time, regardless if the markets undergo bull or bear periods. The model is based upon same assumptions as the Markowitz (1952) model, with the additional assumption of the risk free rate at which all investors can lend and borrow additional funds. When using least squares for estimation of (1), Newey-West (1987) corrections of standard errors can be used if problems of autocorrelation and heteroskedasticity of return series and error term exist. This is more a rule than exception when observing financial time series. Rolling regression of the model (1) is in the following form:

$$r_{i,t} - r_{f,t} = \alpha_{i,\tilde{t}} + \beta_{i,\tilde{t}} \left( r_{M,t} - r_{f,t} \right) + \varepsilon_{i,t}, \quad (2)$$

where alpha and beta are assumed to be time-varying over a certain time span. In that way, by choosing the length of the rolling window in order to estimate (2), dynamics is included in the analysis. Investors have to make decisions on a daily basis, thus giving them detailed information with dynamic estimation could result with better portfolio management over time. There are several approaches to choose windows in order to estimate model (2): fixed window can be used when the number of observations is fixed in each window, so model (2) is estimated on a specific number of windows with equal lengths. This can be done with overlapping of those windows or by choosing the step size to be equal to the length of the window in order for them to not overlap. Second approach is to anchor the starting date at the start and for every step size chosen; the initial window grows (making this recursive rolling estimation). Rolling regression and other types of rolling statistics, their estimation procedure and interpretations can be found in, e.g. Zivot and Wang (2006) or Stock and Watson (2011).

Any asset pricing model can be evaluated additionally via Fama-MacBeth (1973) procedure, in order to test the assumptions of the model itself regarding the linear relationship between stock return and risk and the risk aversion of investors. The procedure is as follows. In the first step, model (1) is estimated for every stock (sector, portfolio, etc.) and estimated betas are extracted from the model. In the second step, a cross-section model is estimated in the following form:

$$r_i - r_f = a_i + b_i \hat{\beta}_i + u_i, \quad (3)$$

where the return of each stock is estimated on the betas from the first step and the value and significance of $b_i$ is observed. If parameter $b_i$ is found to be positive and significant in the model, this implies that a positive risk-return relationship exists on a market. More details on this procedure can be found in Campbell et al. (1997) as well.

## 4. EMPIRICAL RESULTS AND DISCUSSION

For the purpose of the empirical analysis, weekly data on five sector indices was collected from the Zagreb Stock Exchange (2018), as well as the stock market index CROBEX for the period January 2012 until April 2018. Moreover, weekly data on return series on 91 day Treasury bills has been collected from the Ministry of Finance (2018) in order to calculate excess return series for each sector. In the rest of the section, the following notations are used for the five indices, i.e. their return series: IND, FOOD, CON, TUR and TRA (for industry, food, construction, tourism and transport sectors respectively). The time span chosen for the study is based upon the availability of data, since the calculation of the sector indices on ZSE was introduced in 2013, and was retroactively calculated from the beginning of 2012. All of the return series were calculated as continuous returns. In total, each time series consists of

315 observations. Weekly data was chosen due to lowering the transaction costs in the simulation part of the study for the comparison of investment strategies. Before estimating any of the CAPM models for every sector, augmented unit root tests have been performed on each excess return series. The results indicate that all of the series are stationary on usual levels of significance (detailed results are available upon request).

Since this research has less data compared to other previous studies on more developed markets, the initial rolling window length was chosen to be 12 weeks with a step size of 12 as well. In that way, it is assumed that investor reassesses the CAPM parameters every 3 months before making new investment decisions. Thus, anchoring at the start approach is used in this study due to having less data compared to other studies of mature markets. The non overlapping window approach would be more applicable if longer time spans were available. In the first step, the full sample CAPM-s have been estimated, with the Newey-West (1987) corrections of standard errors, due to problems of autocorrelation and heteroskedasticity in residuals. The results are shown in table 1. Thus, if investor observed the full sample the results would indicate that all of the sectors were defansive due to betas being lower than unit value, with the most defansive being TUR. Moreover, this sector had the Jensen's alpha positive and significant, meaning that it achieved excess returns above the market itself, making it more attractive than other sectors. On the other hand, FOOD sector had negative significant Jensen's alpha, making it even less attractive compared to other sectors in the study. This are the results from the static CAM model, based upon the entire sample. However, observing the rolling regressions, some dynamics is included in the model. In that way, investors could get more information about each sector when making decisions on how to allocate his resources on the stock market. The results of estimating a rolling CAPM model for sector IND is shown in table 2. Other sector results are given in tables in the Appendix.

Table 1. Full sample CAPM models for every sector

| Sector / parameter | $\hat{\alpha}$ | $\hat{\beta}$ | $R^2$ |
|---|---|---|---|
| IND | -0.001 (0.668) | 0.869 *** (0.000) | 0.242 |
| FOOD | -0.002 ** (0.022) | 0.926 *** (0.000) | 0.396 |
| CON | -0.002 (0.424) | 0.982 *** (0.000) | 0.154 |
| TUR | 0.004 ** (0.014) | 0.785 *** (0.000) | 0.270 |
| TRA | -0.001 (0.475) | 0.869 *** (0.000) | 0.223 |

Note: *p*-values are given in parenthesis. *, ** and *** denote statistical significance on 10%, 5% and 1% respectively.
Source: author's calculation

By observing the results in table 2, it can be seen that the value of the Jensen's alpha is in the majority cases negative, which is consistent with the OLS alpha from table 1 for the IND sector. There are some cases when this parameter is positive; however, it is not significant in the model. By comparing betas, it can be seen that the value is lower at the beginning of the total time span. As one reaches end of the time sample, the value is growing. This can be seen easily in the Appendix, on figures A1 and A2, where rolling alphas and betas of IND are shown. This could be interpreted that the IND sector got more aggressive over the time, which could be attractive to the more aggressive investors. Other detailed tables for the rest of the sectors are given in tables in the Appendix as well. It can be concluded from those tables that: CON sector had negative values of alphas in majority cases with beta being aggressive only in the beginning of the sample. After it dropped below unit value in June 2012, it grew over time. However, this growth was faster compared to IND sector; meaning that CON sector was getting aggressive even faster. Next, the FOOD sector seems the most passive one, with the most constant alpha and beta over the observed sample. TUR sector experienced growth of alpha and beta in the first third of the observed time span, with the only one having positive alphas in the majority of the sample. This is also consistent with the whole sample results in table 1. TRA sector was the only one which experienced a reducing value of the beta (getting more defansive over time). These changes in the aggressiveness or defansiveness of sectors could not have been obtained only from static model results. Thus, this can provide dynamic changes information about each sector on the stock market. Moreover, these results are in line with conclusions on the aggressiveness and passiveness of each sector in Škrinjarić (2015a, b), which could be interpreted as being robust. The first research hypothesis in this study could be in that way weakly confirmed, due to gradual changes in some of the sectors.

Table 2. Rolling CAPM results for IND sector

| IND sector | $\hat{\alpha}$ | $\hat{\alpha}$ *p-v* | $\hat{\beta}$ | $\hat{\beta}$ *p-v* | $R^2$ |
|---|---|---|---|---|---|
| 4-Jun-12 | 0.0032 | 0.8276 | 0.8535 | 0.0298 | 0.211 |
| 7-Jun-12 | -0.0119 | 0.0750 | 0.6347 | 0.0001 | 0.262 |
| 28-Sep-12 | -0.0046 | 0.5218 | 0.7689 | 0.0001 | 0.304 |
| 21-Dec-12 | -0.0072 | 0.1050 | 0.7036 | 0.0000 | 0.290 |
| 15-Mar-13 | -0.0027 | 0.4001 | 0.7927 | 0.0000 | 0.420 |
| 6-Jul-13 | -0.0012 | 0.6887 | 0.8169 | 0.0000 | 0.420 |
| 30-Aug-13 | -0.0012 | 0.6385 | 0.8039 | 0.0000 | 0.420 |
| 29-Nov-13 | 0.0001 | 0.9703 | 0.8626 | 0.0000 | 0.244 |
| 21-Feb-14 | -0.0014 | 0.6567 | 0.8302 | 0.0000 | 0.226 |
| 5-16-2014 | -0.0024 | 0.4159 | 0.8307 | 0.0000 | 0.211 |
| 8-Aug-14 | -0.0018 | 0.4970 | 0.8599 | 0.0000 | 0.230 |
| 11-Jul-14 | -0.0011 | 0.6513 | 0.8980 | 0.0000 | 0.260 |
| 2-Jun-15 | -0.0013 | 0.5437 | 0.8894 | 0.0000 | 0.252 |
| 15-May-15 | -0.0009 | 0.6772 | 0.8961 | 0.0000 | 0.254 |
| 8-Jul-15 | -0.0006 | 0.7616 | 0.9024 | 0.0000 | 0.260 |
| 30-Oct-15 | -0.0006 | 0.7431 | 0.8822 | 0.0000 | 0.251 |
| 2-May-16 | -0.0004 | 0.8287 | 0.8882 | 0.0000 | 0.247 |
| 5-Jun-16 | -0.0004 | 0.8227 | 0.8870 | 0.0000 | 0.249 |
| 29-Jul-16 | 0.0000 | 0.9902 | 0.9035 | 0.0000 | 0.265 |
| 28-Oct-16 | 0.0000 | 0.9830 | 0.9007 | 0.0000 | 0.266 |
| 27-Jan-17 | -0.0002 | 0.9094 | 0.8923 | 0.0000 | 0.270 |
| 28-Apr-17 | -0.0001 | 0.9351 | 0.8706 | 0.0000 | 0.263 |
| 21-Jul-17 | -0.0001 | 0.9521 | 0.8606 | 0.0000 | 0.252 |
| 13-Oct-17 | 0.0000 | 0.9870 | 0.8614 | 0.0000 | 0.251 |
| 5-Jan-18 | -0.0002 | 0.8578 | 0.8857 | 0.0000 | 0.250 |

Source: author's calculation

Changes of each Jensen's alpha are depicted on figure 1, where it is obvious that only sector TUR had an increase of this parameter over time. Sector CON is experiencing increase of its alpha as well, only at the end of the observed sample. Investors could take this into account for future forecasting and portfolio construction because it could be expected that this sector could achieve some above market returns. However, all of the alphas do seem stable over time. Even the problems with Agrokor's stocks whose prices dropped significantly in March and April 2017 are not visible (these stocks were included in the FOOD sector before they were withdrawn from trading). Similarly to the alphas, on figure 2, all of the betas are compared as well. Majority of changes are visible at the beginning of the observed period, with a stabilization of the parameters afterwards. This could be interpreted that the CAPM parameters are stable over the observed period. However, these results are taken with some caution due to taking 3 month rolling window lengths due to small time sample available.

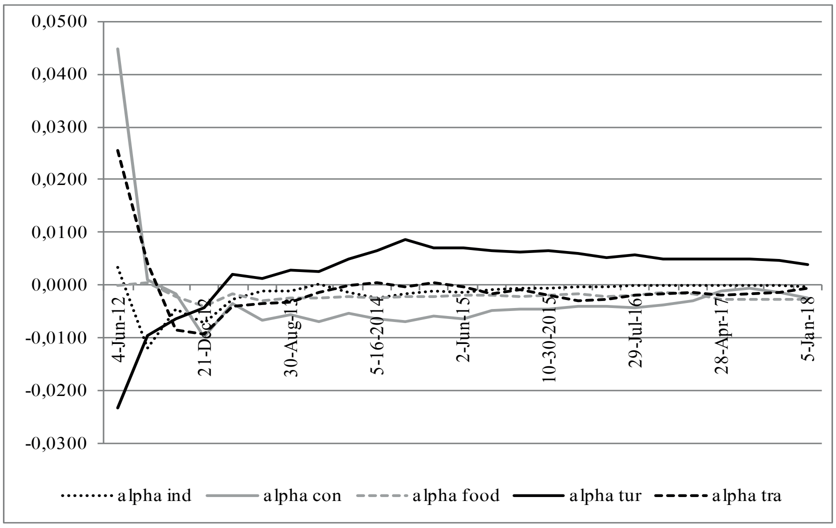


Figure 4.1. Comparison of Jensen's alphas for each sector, rolling regressions
Source: author's calculation

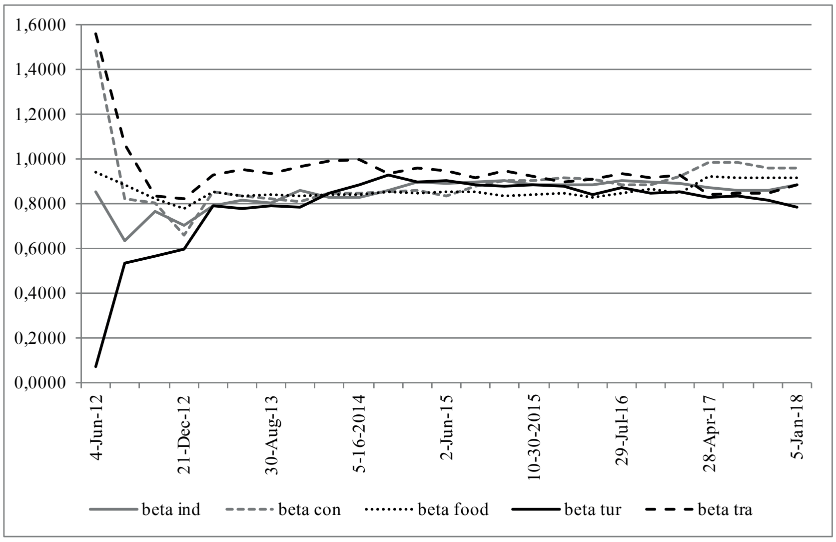


Figure 4.2. Comparison of betas for each sector, rolling regressions
Source: author's calculation

When comparing the results in this research to already existing research on rolling CAPM parameters, some parallels can be drawn, although with caution because different time spans have been observed and longer windows in the estimation procedure. The betas as measures of systematic risk have increased a bit at the beginning of 2017 for CON and FOOSD due to problems, i.e. controversies around Agrokor concern. This is also seen in the drop of alphas of mentioned indices as well. Nieto et al. (2014) obtained similar results for different portfolios for the last financial crisis in 2008. Moreover, as in Gregory and Michou (2009), this research also finds that a parsimonious approach of estimating CAPM betas yields similar results as more complex approaches such as MGARCH models as in Škrinjarić (2015a).

Finally, in order to evaluate the usefulness of the estimated results, simulations were made with the assumption that the investor re-estimates the CAPM every 3 months as this research did; and based upon the results he then forms his portfolios out of the five sectors. As a benchmark, the value of the CROBEX portfolio is used. This means that it is assumed that the investor buys this index at the beginning of the observed period and holds this index the entire time, with only rebalancing the structure of the index as it is revised twice a year. Transaction costs are included in the analysis as well in every strategy considered, and are assumed to be equal to 1% of the entire value of each transaction[1]. Basic strategies based upon the estimated results were simulated as follows. In the first strategy, called Aggressive, it is assumed that every 3 months investor estimates the CAPM model for each sector and compares values of each beta. He invests into the most aggressive sector with its beta being greatest among all of the sectors in the previous 3 months. When another sector becomes more aggressive compared to the one he has in his portfolio, investors sells the entire portfolio and buys the more aggressive sector and holds it until another sector is to be found most aggressive. On the opposite side, Conservative strategy was constructed based upon the most defansive betas in every estimation step. Since these two strategies include only one sector in each quarter, another strategy was considered which can include more sectors in the portfolio in order to achieve better diversification. The third strategy is called beta_w (beta weighted); in which investor holds all of the sectors in the portfolio the entire time and weights are based upon the relative size of each beta in each quarter. The final strategy based upon rolling estimation results is called Alpha strategy. Here, investor observes only positive Jensen's alphas in each quarter in order to invest into sectors in the next three months. In that way, it is assumed that investor cares about excess positive market returns only. In all of the simulated strategies, investor starts with a unit value of a portfolio.

The values of each strategy are shown on figure 3. The observed period experienced a decline of the value of the CROBEX market index, i.e. although the value of the market index was for the majority time stagnating, a strategy based upon rebalancing the portfolio based upon the CROBEX structure realized a loss of value over time. Next, the majority of the rolling regression strategies also experienced a loss of value. However, these losses were less compared to the CROBEX strategy. This means that including some dynamics into the portfolio selection process could lead to, at least, smaller losses compared to the rest of the market. The best portfolio in terms of the portfolio value was the beta_weighted strategy. Its end portfolio value was biggest compared to rest of the strategies, as well as it experienced the greatest value overall in the entire observed period. As expected, the Conservative strategy resulted with the least value of the portfolio due to investing into most defansive sectors in the whole period.

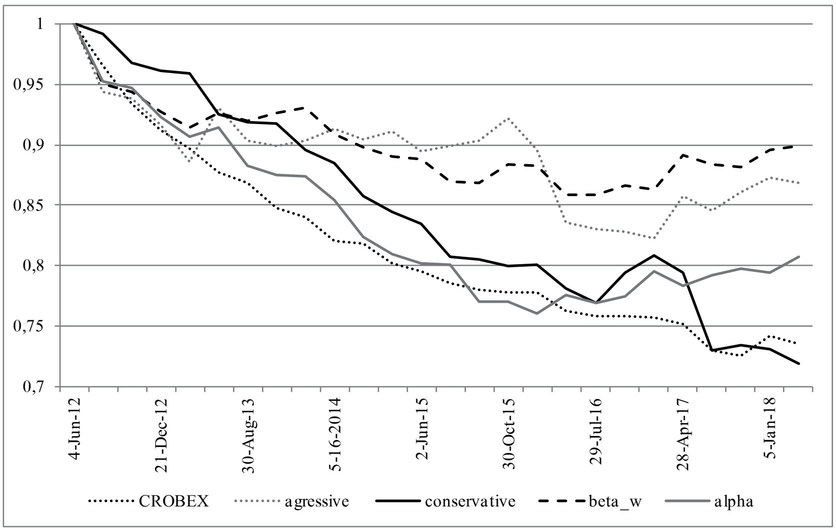


Figure 4.3. Portfolio values of simulated strategies

Source: author's calculation

[1] Details on different values of transaction costs on ZSE can be found in Škrinjarić (2013). 1% value is extremely high assumption.

Descriptive statistics regarding risks and returns of each portfolio strategy were calculated and are given in table 3. Although, there was an average loss for every portfolio, the least losses occurred for the beta_weighted portfolio (mean and median). Moreover, the CROBEX strategy was the least risky, followed by the beta_ weighted portfolio from the rolling regression strategies. Other similar comparisons can be made for the rest of the calculated parameters in the table. The last row gives percentages of time each strategy had a greater portfolio value compared to the market portfolio. It can be seen that all of the rolling regression strategies achieved better portfolio value more than 90% of the time. All of this information is in favour of using the rolling regression when evaluating asset prices over time. In that way, the second research hypothesis of this study is confirmed.

Table 3. Risk and return characteristics of each simulated strategy

| Descriptive statistics | CROBEX | Aggressive | Conservative | Beta_w | alpha |
|---|---|---|---|---|---|
| Mean | -0.0123 | -0.00564 | -0.0131 | **-0.00426** | -0.0085 |
| Median | -0.0099 | -0.00473 | -0.0117 | **-0.00275** | -0.0080 |
| Standard Deviation | **0.0126** | 0.02651 | 0.02106 | 0.01669 | 0.0189 |
| Kurtosis | 124.941 | 0.99799 | 483.171 | 173.467 | **-0.3663** |
| Skewness | **0.45888** | -0.36598 | -11.759 | -0.4829 | -0.2599 |
| Minimum | **-0.0345** | -0.07003 | -0.0836 | -0.0507 | -0.0483 |
| Maximum | 0.02291 | **0.04871** | 0.0317 | 0.0322 | 0.0263 |
| Total return | -0.30802 | -0.14104 | -0.3295 | **-0.1065** | -0.2140 |
| % time greater than CROBEX | | 92 | 92 | **96** | 84 |

Source: author's calculation

Finally, Fama-MacBeth procedure was repeated for the every subsample in the observed period, in order to test for the linearity of risk-return relationship on the Croatian market. Estimated parameter besides betas from model (3) is shown of figure 4. It can be seen that it varies around zero value with one spike in the beginning of 2017. However, this parameter is not significant for the whole sample with exception of 3 times (see table A4 in appendix). Meaning that on the Croatian market unfortunately, bearing greater risk does not result with awards in terms of greater returns. This result is unfortunate, but it is in line with previous findings on the risk-reward relationship on the Croatian market (regarding investment funds, see Gardijan and Škrinjarić, 2015). Results given here are also in line with research such as Marti (2005), where a significant beta-return relationship was not found for the rolling regression approach on the US market.

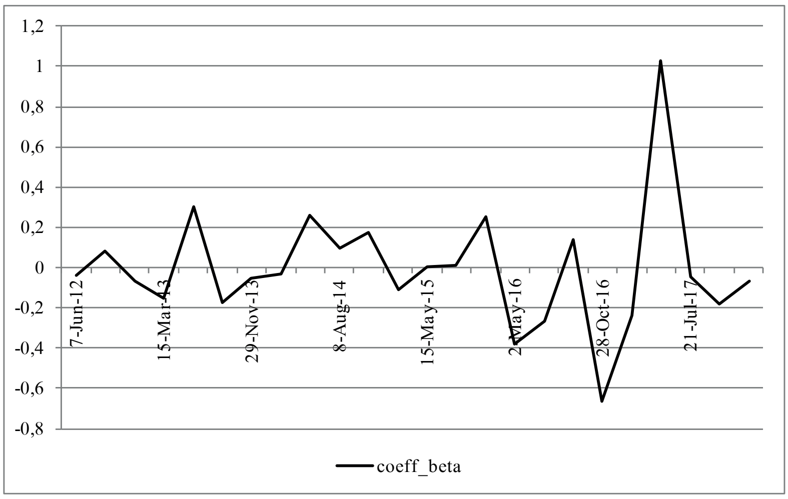


Figure 4.4. Estimated effects of betas on returns in the observed period

Source: author's calculation

## 5. CONCLUSION

Original CAPM model suffers from many problems which have been tackled over the last couple of decades. In the last two decades, research has focused more on how to evaluate time changing parameters. This research extends the original model on the Croatian market by estimating rolling regression parameters. Since results from the analysis show that although the parameters do not change to great extent over time, introducing some dynamics into the analysis can enhance portfolio performance. This simple dynamics adds hope to applying some other popular finance models on ZSE as well, in order to answer other questions on a financial market such as the Croatian one. Several implications arise from the results in this research. First of all, it was found that over time betas more or less stabilized on the ZSE for each of the sector. Few sectors did exhibit a weak increase or decrease of its beta value, meaning that some opportunities for more aggressive or passive investment strategies still do exist on ZSE. The significance of Jensen's alpha is used in empirical studies to evaluate whether the model has captured all of the risk-return relationship. Only in the case of the tourism sector was this parameter significant and positive, meaning that only here some additional factor(s) exist(s) which should have been included in the model. This is not a surprising result, due to the tourism sector in Croatia being one of the most prosperous sectors in the economy in the last decade. This leads to attractiveness of investing into the stocks of that sector. Next, all of the sectors were found to be defansive in the observed period. Since the time span used in this study, this allowed the investor not to lose as much portfolio value as the rest of the market if he would have had the approach of investing as in the simulation part of this study. Finally, investment strategies based upon rolling regression results could lead to better risk and/or return performance of the portfolio over time. This is because investor can update his set of information about changes on the market and rebalance his portfolio accordingly.

Some of the shortfalls of the research were as follows. This research used only sector indices in the study but investors are often interested in particular stocks. Since this is a first study of such kind on the Croatian market, initial information on the usefulness of such methodology when considering investment strategies was obtained. That is why future work is going to include evaluating individual stocks as well. Moreover, the time span included in the analysis is short. This is due to problems of not having longer time spans available from the market on sector indices. Future work is going to check for robustness of the results in this study by including longer time spans and applying the fixed length window in the rolling regression evaluation of the model. Finally, only basic investment strategies were observed in the simulation part of the study. That is why a motivation exists to extend the existing work by focusing only on the investment strategies based upon rolling CAPM results. With longer time spans in the analysis, sources of changing betas can be explained in the future as well. As it can be seen, many questions are left for future work to focus on. However, some basic questions were, hopefully, answered in this study as well and the future research on these topics will revive investment activity on the Croatian market and future needed research in order to answer other questions.

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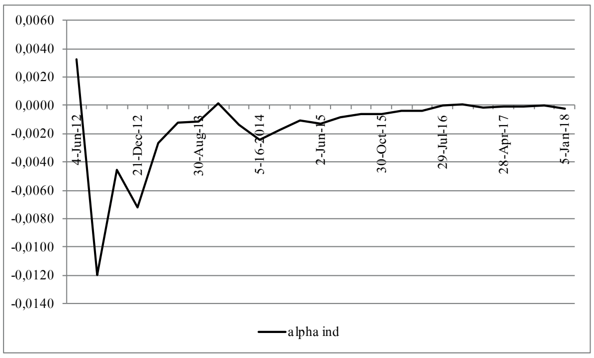
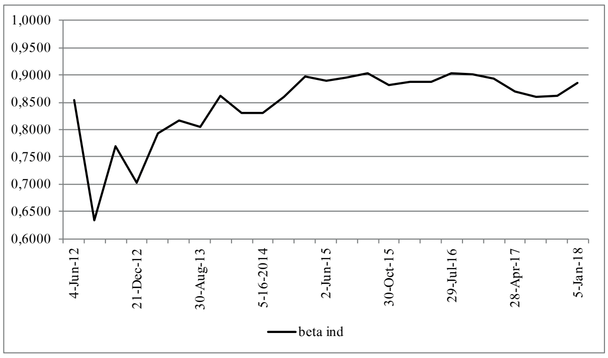
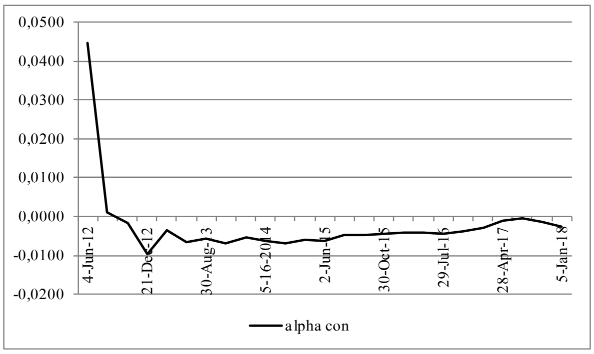
## APPENDIX

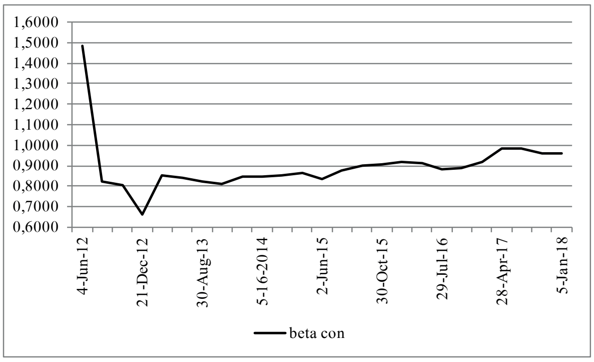



Figures A1 and A2. Rolling Jensen's alpha and beta, IND sector

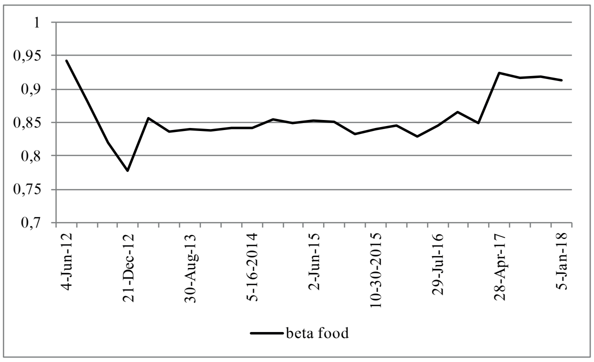
Source: author's calculation



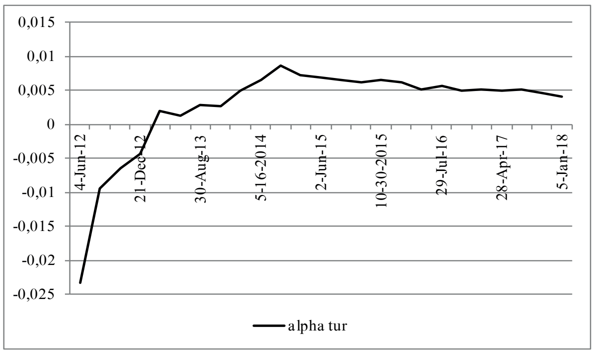

Figures A3 and A4. Rolling Jensen's alpha and beta, CON sector

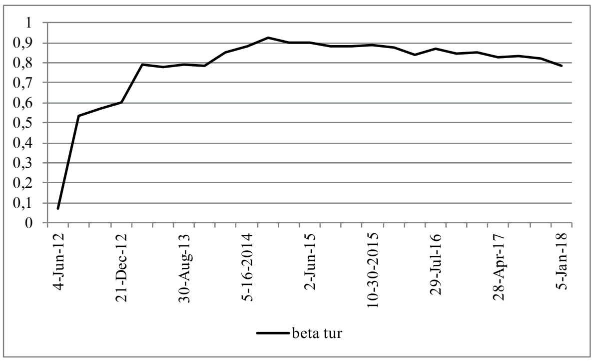
Source: author's calculation


Figures A5 and A6. Rolling Jensen's alpha and beta, FOOD sector

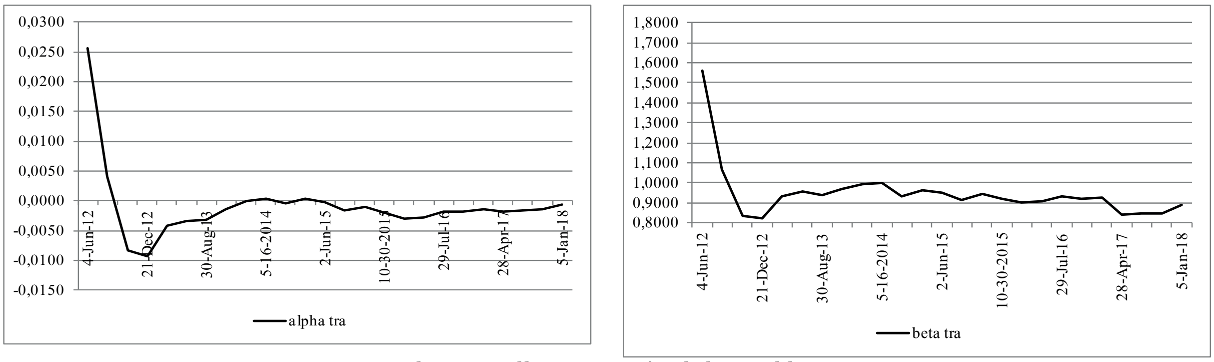
Source: author's calculation




Figures A7 and A8. Rolling Jensen's alpha and beta, TUR sector

Source: author's calculation




Figures A9 and A10. Rolling Jensen's alpha and beta, TRA sector

Source: author's calculation

Table A1. Rolling CAPM betas, CON sector

| CON sector | $\hat{\alpha}$ | $\hat{\alpha}$ *p-v* | $\hat{\beta}$ | $\hat{\beta}$ *p-v* | $R^2$ |
|---|---|---|---|---|---|
| 4-Jun-12 | 0.0447 | 0.5453 | 14.870 | 0.2652 | 0.0860 |
| 7-Jun-12 | 0.0010 | 0.9743 | 0.8244 | 0.1132 | 0.0748 |
| 28-Sep-12 | -0.0016 | 0.9153 | 0.8065 | 0.0075 | 0.0868 |
| 21-Dec-12 | -0.0097 | 0.4050 | 0.6602 | 0.0142 | 0.0656 |
| 15-Mar-13 | -0.0036 | 0.6916 | 0.8532 | 0.0007 | 0.1423 |
| 6-Jul-13 | -0.0067 | 0.4010 | 0.8382 | 0.0008 | 0.1311 |
| 30-Aug-13 | -0.0057 | 0.3903 | 0.8206 | 0.0003 | 0.1274 |
| 29-Nov-13 | -0.0068 | 0.2534 | 0.8104 | 0.0003 | 0.1184 |
| 21-Feb-14 | -0.0054 | 0.3098 | 0.8449 | 0.0001 | 0.1263 |
| 5-16-2014 | -0.0064 | 0.2025 | 0.8456 | 0.0001 | 0.1178 |
| 8-Aug-14 | -0.0069 | 0.1119 | 0.8531 | 0.0000 | 0.1237 |
| 11-Jul-14 | -0.0059 | 0.1423 | 0.8625 | 0.0000 | 0.1334 |
| 2-Jun-15 | -0.0063 | 0.0894 | 0.8339 | 0.0000 | 0.1237 |
| 15-May-15 | -0.0048 | 0.1691 | 0.8777 | 0.0000 | 0.1328 |
| 8-Jul-15 | -0.0047 | 0.1452 | 0.9014 | 0.0000 | 0.1439 |
| 30-Oct-15 | -0.0045 | 0.1341 | 0.9046 | 0.0000 | 0.1473 |
| 2-May-16 | -0.0041 | 0.1552 | 0.9179 | 0.0000 | 0.1510 |
| 5-Jun-16 | -0.0041 | 0.1366 | 0.9116 | 0.0000 | 0.1485 |
| 29-Jul-16 | -0.0044 | 0.0813 | 0.8842 | 0.0000 | 0.1422 |
| 28-Oct-16 | -0.0039 | 0.0994 | 0.8866 | 0.0000 | 0.1460 |
| 27-Jan-17 | -0.0030 | 0.1953 | 0.9207 | 0.0000 | 0.1524 |
| 28-Apr-17 | -0.0010 | 0.7192 | 0.9833 | 0.0000 | 0.1700 |
| 21-Jul-17 | -0.0006 | 0.8389 | 0.9829 | 0.0000 | 0.1625 |
| 13-Oct-17 | -0.0014 | 0.5960 | 0.9613 | 0.0000 | 0.1580 |
| 5-Jan-18 | -0.0024 | 0.3736 | 0.9589 | 0.0000 | 0.1524 |

Source: author's calculation

Table A2. Rolling CAPM betas, FOOD sector

| FOOD sector | $\hat{\alpha}$ | $\hat{\alpha}$ p-v | $\hat{\beta}$ | $\hat{\beta}$ p-v | $R^2$ |
|---|---|---|---|---|---|
| 4-Jun-12 | -0.0002 | 0.9912 | 0.9429 | 0.0083 | 0.4625 |
| 7-Jun-12 | 0.0005 | 0.9688 | 0.8830 | 0.0024 | 0.3731 |
| 28-Sep-12 | -0.0023 | 0.7165 | 0.8206 | 0.0000 | 0.3798 |
| 21-Dec-12 | -0.0040 | 0.3432 | 0.7772 | 0.0000 | 0.3487 |
| 15-Mar-13 | -0.0016 | 0.6706 | 0.8567 | 0.0000 | 0.4675 |
| 6-Jul-13 | -0.0029 | 0.3900 | 0.8358 | 0.0000 | 0.4508 |
| 30-Aug-13 | -0.0023 | 0.3931 | 0.8399 | 0.0000 | 0.4610 |
| 29-Nov-13 | -0.0024 | 0.3203 | 0.8380 | 0.0000 | 0.4589 |
| 21-Feb-14 | -0.0023 | 0.2591 | 0.8426 | 0.0000 | 0.4675 |
| 5-16-2014 | -0.0025 | 0.2246 | 0.8418 | 0.0000 | 0.4353 |
| 8-Aug-14 | -0.0022 | 0.2144 | 0.8553 | 0.0000 | 0.4566 |
| 11-Jul-14 | -0.0021 | 0.1745 | 0.8496 | 0.0000 | 0.4658 |
| 2-Jun-15 | -0.0019 | 0.1799 | 0.8530 | 0.0000 | 0.4671 |
| 15-May-15 | -0.0018 | 0.1650 | 0.8515 | 0.0000 | 0.4670 |
| 8-Jul-15 | -0.0022 | 0.0695 | 0.8324 | 0.0000 | 0.4529 |
| 30-Oct-15 | -0.0019 | 0.0953 | 0.8397 | 0.0000 | 0.4607 |
| 2-May-16 | -0.0018 | 0.1005 | 0.8461 | 0.0000 | 0.4503 |
| 5-Jun-16 | -0.0022 | 0.0328 | 0.8299 | 0.0000 | 0.4480 |
| 29-Jul-16 | -0.0019 | 0.0587 | 0.8462 | 0.0000 | 0.4578 |
| 28-Oct-16 | -0.0014 | 0.1585 | 0.8649 | 0.0000 | 0.4662 |
| 27-Jan-17 | -0.0018 | 0.0731 | 0.8496 | 0.0000 | 0.4597 |
| 28-Apr-17 | -0.0028 | 0.0281 | 0.9244 | 0.0000 | 0.3957 |
| 21-Jul-17 | -0.0028 | 0.0149 | 0.9177 | 0.0000 | 0.3893 |
| 13-Oct-17 | -0.0026 | 0.0176 | 0.9191 | 0.0000 | 0.3908 |
| 5-Jan-18 | -0.0026 | 0.0136 | 0.9137 | 0.0000 | 0.3915 |

Source: author's calculation

Table A3. Rolling CAPM betas, TUR sector

| TUR sector | $\hat{\alpha}$ | $\hat{\alpha}$ p-v | $\hat{\beta}$ | $\hat{\beta}$ p-v | $R^2$ |
|---|---|---|---|---|---|
| 4-Jun-12 | -0.0234 | 0.4432 | 0.0698 | 0.9051 | 0.0011 |
| 7-Jun-12 | -0.0095 | 0.3525 | 0.5325 | 0.0201 | 0.1440 |
| 28-Sep-12 | -0.0065 | 0.2210 | 0.5687 | 0.0019 | 0.1783 |
| 21-Dec-12 | -0.0043 | 0.2313 | 0.5999 | 0.0002 | 0.2227 |
| 15-Mar-13 | 0.0020 | 0.6809 | 0.7893 | 0.0000 | 0.3840 |
| 6-Jul-13 | 0.0013 | 0.7557 | 0.7795 | 0.0000 | 0.3817 |
| 30-Aug-13 | 0.0029 | 0.4085 | 0.7900 | 0.0000 | 0.3838 |
| 29-Nov-13 | 0.0026 | 0.4152 | 0.7862 | 0.0000 | 0.3740 |
| 21-Feb-14 | 0.0050 | 0.1658 | 0.8506 | 0.0000 | 0.3079 |
| 5-16-2014 | 0.0066 | 0.0510 | 0.8823 | 0.0000 | 0.3065 |
| 8-Aug-14 | 0.0086 | 0.0051 | 0.9271 | 0.0000 | 0.3275 |
| 11-Jul-14 | 0.0072 | 0.0186 | 0.8974 | 0.0000 | 0.3097 |
| 2-Jun-15 | 0.0069 | 0.0157 | 0.9032 | 0.0000 | 0.3028 |
| 15-May-15 | 0.0065 | 0.0154 | 0.8835 | 0.0000 | 0.2813 |
| 8-Jul-15 | 0.0062 | 0.0098 | 0.8791 | 0.0000 | 0.2864 |
| 30-Oct-15 | 0.0065 | 0.0043 | 0.8856 | 0.0000 | 0.2892 |
| 2-May-16 | 0.0061 | 0.0055 | 0.8762 | 0.0000 | 0.2819 |
| 5-Jun-16 | 0.0052 | 0.0147 | 0.8401 | 0.0000 | 0.2711 |
| 29-Jul-16 | 0.0056 | 0.0068 | 0.8697 | 0.0000 | 0.2836 |
| 28-Oct-16 | 0.0050 | 0.0089 | 0.8449 | 0.0000 | 0.2817 |
| 27-Jan-17 | 0.0050 | 0.0049 | 0.8542 | 0.0000 | 0.2920 |
| 28-Apr-17 | 0.0050 | 0.0034 | 0.8289 | 0.0000 | 0.2916 |
| 21-Jul-17 | 0.0051 | 0.0022 | 0.8339 | 0.0000 | 0.2909 |
| 13-Oct-17 | 0.0047 | 0.0033 | 0.8181 | 0.0000 | 0.2856 |
| 5-Jan-18 | 0.0040 | 0.0121 | 0.7874 | 0.0000 | 0.2694 |

Source: author's calculation

Table A3. Rolling CAPM betas, TRA sector

| TRA sector | $\hat{\alpha}$ | $\hat{\alpha}$ p-v | $\hat{\beta}$ | $\hat{\beta}$ p-v | $R^2$ |
|---|---|---|---|---|---|
| 4-Jun-12 | 0.0256 | 0.4627 | 15.575 | 0.0427 | 0.3800 |
| 7-Jun-12 | 0.0041 | 0.7781 | 10.639 | 0.0020 | 0.4112 |
| 28-Sep-12 | -0.0084 | 0.3087 | 0.8323 | 0.0002 | 0.3303 |
| 21-Dec-12 | -0.0093 | 0.0995 | 0.8203 | 0.0000 | 0.3545 |
| 15-Mar-13 | -0.0041 | 0.3484 | 0.9290 | 0.0000 | 0.4590 |
| 6-Jul-13 | -0.0035 | 0.3949 | 0.9552 | 0.0000 | 0.4343 |
| 30-Aug-13 | -0.0032 | 0.3603 | 0.9382 | 0.0000 | 0.4321 |
| 29-Nov-13 | -0.0013 | 0.6821 | 0.9690 | 0.0000 | 0.4263 |
| 21-Feb-14 | -0.0001 | 0.9862 | 0.9936 | 0.0000 | 0.4029 |
| 5-16-2014 | 0.0004 | 0.8912 | 0.9981 | 0.0000 | 0.3929 |
| 8-Aug-14 | -0.0004 | 0.8753 | 0.9324 | 0.0000 | 0.3540 |
| 11-Jul-14 | 0.0003 | 0.8973 | 0.9592 | 0.0000 | 0.3752 |
| 2-Jun-15 | -0.0003 | 0.8993 | 0.9472 | 0.0000 | 0.3646 |
| 15-May-15 | -0.0016 | 0.5080 | 0.9163 | 0.0000 | 0.3419 |
| 8-Jul-15 | -0.0010 | 0.6921 | 0.9468 | 0.0000 | 0.3399 |
| 30-Oct-15 | -0.0020 | 0.3938 | 0.9218 | 0.0000 | 0.3266 |
| 2-May-16 | -0.0029 | 0.2164 | 0.8993 | 0.0000 | 0.3006 |
| 5-Jun-16 | -0.0028 | 0.1992 | 0.9076 | 0.0000 | 0.2988 |
| 29-Jul-16 | -0.0018 | 0.3927 | 0.9332 | 0.0000 | 0.3001 |
| 28-Oct-16 | -0.0018 | 0.3740 | 0.9173 | 0.0000 | 0.2831 |
| 27-Jan-17 | -0.0014 | 0.4677 | 0.9279 | 0.0000 | 0.2856 |
| 28-Apr-17 | -0.0018 | 0.3395 | 0.8395 | 0.0000 | 0.2495 |
| 21-Jul-17 | -0.0017 | 0.3461 | 0.8464 | 0.0000 | 0.2427 |
| 13-Oct-17 | -0.0015 | 0.3915 | 0.8478 | 0.0000 | 0.2412 |
| 5-Jan-18 | -0.0006 | 0.7195 | 0.8869 | 0.0000 | 0.2336 |

Source: author's calculation

Table A4. Fama-Macbeth estimation results for beta value in model (3)

| Date | $\hat{b}$ | $\hat{b}$ p-v | Date | $\hat{b}$ | $\hat{b}$ p-v |
|---|---|---|---|---|---|
| 7-Jun-12 | -0.0382 | 0.0273 | 15-May-15 | 0.0068 | 0.9864 |
| 28-Sep-12 | 0.0792 | 0.3354 | 8-Jul-15 | 0.0118 | 0.9582 |
| 21-Dec-12 | -0.0705 | 0.2588 | 30-Oct-15 | 0.2529 | 0.4692 |
| 15-Mar-13 | -0.1510 | 0.0261 | 2-May-16 | -0.3795 | 0.3457 |
| 6-Jul-13 | 0.3050 | 0.3901 | 5-Jun-16 | -0.2635 | 0.5575 |
| 30-Aug-13 | -0.1749 | 0.3036 | 29-Jul-16 | 0.1368 | 0.3665 |
| 29-Nov-13 | -0.0523 | 0.8861 | 28-Oct-16 | -0.6640 | 0.0098 |
| 21-Feb-14 | -0.0304 | 0.8871 | 27-Jan-17 | -0.2390 | 0.3895 |
| 5-16-2014 | 0.2573 | 0.4043 | 28-Apr-17 | 10.294 | 0.1352 |
| 8-Aug-14 | 0.0994 | 0.5676 | 21-Jul-17 | -0.0489 | 0.9153 |
| 11-Jul-14 | 0.1738 | 0.3165 | 13-Oct-17 | -0.1820 | 0.0938 |
| 2-Jun-15 | -0.1092 | 0.5100 | 5-Jan-18 | -0.0676 | 0.7788 |

Source: author's calculation