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Evolving Efficiency of Stock Returns and Market Conditions: The Case from Croatia

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ABSTRACT

The main purpose of this paper is to evaluate Croatian stock market under adaptive market hypothesis. Methodology/approach: Following recent and robust variance ratio test with stronger statistical power and fix-length rolling window on daily CROBEX returns from September 1997 up to July 2021 market (in)efficiency of Croatian stock market were considered. To establish a link between market conditions and its inefficiency classification problem was formulated and evaluated using logistic regression approach. Empirical findings suggested time-varying nature of stock market while price levels and trading volumes being significant signals of (in) efficiency. Conclusion: Findings from this paper supported validity of the adaptive market hypothesis for Croatian stock market. Furthermore, periods lower prices and higher liquidity were more likely to be inefficient and might serve as a signal of trading opportunities on Croatian stock market.

INTRODUCTION

E. Fama (1970) suggested that markets were efficient with random walk dynamics of prices. Numerous empirical papers followed and confirmed findings from Fama (1970). Consequently, debate about market efficiency or inefficiency has started supporting one or another hypothesis. A. Lo (2004; 2005) came up with adaptive market hypothesis as an alternative to efficient market hypothesis. Rational behind the adaptive market hypothesis were magnitude of profit opportunities and market participants adaptability. However, a financial market can hardly be consider as fully efficient or fully inefficient and the true is always somewhere in between. Hence, real question is to what extent a market is efficient and when and why its adaptivity starts. Another strand of literature formulates regression problem and evaluates various predictors of returns (Chen, 2012; Rapach and Zhou, 2013; Zhang et al., 2019; Jing et al., 2020; Zhao et al., 2020 and Khuong et al. 2019 among others).

Therefore, drivers of stock returns were studied in empirical literature while drivers of its predictability are still under-examined. This paper aims to make a step ahead while providing empirical evidence from Croatian stock market. Periods of inefficiency on Croatian stock market were detected firstly using a set of recent and robust tests with stronger power properties and a fixed-length rolling window. Afterwards, binary classification problem was formulated and using logistic regression approach periods of efficiency and adaptivity were further explained with market conditions or more precisely, with level of prices and trading volumes.

1. BRIEF LITERATURE OVERVIEW

As introductory emphasized there was a debate about market inefficiency. In this section, brief overview of contemporary literature will be provided. Ali et al. (2018) examined market efficiency hypothesis for Islamic and conventional stock markets and suggested Islamic stock markets more efficient in comparison to conventional stock markets. Similar aspects of Islamic conventional and non-conventional stock markets were investigated by many scholars (Yahya et al., 2021; Qizam, 2020). Mensi et al. (2018) considered five GCC stock markets, global, Islamic and regional markets and pointed out time-varying nature of persistence in returns. Tiwari et al. (2019) considered stock markets efficiency for developed markets (Canada, France, Germany, Italy, Japan, Switzerland, UK and USA) as well as for two emerging markets (India and South Africa). Also Khodaparasti (2014) and Yacob et al., (2020) presented also differences in the stock markets in developed and emerging markets.

The empirical findings suggested time-varying nature of stock market efficiency. Bhuyan et al. (2020) employed variance ratio test and considered market adaptivity hypothesis for Bombay Stock Exchange and the National Stock Exchange in India. The results suggested evolving predictability dependent on economic and non-economic events in global and regional economy. Lekhal and Oubani (2020) considered Moroccan financial market using linear and nonlinear statistical tests on rolling window samples. The empirical findings supported Adaptive Market Hypothesis. Therefore, depending on degree of market efficiency and market conditions profit opportunities appears from time to time.

A. Sonje et al. (2011) considered Croatian and US stock market during 2002-2010 period and found the markets inefficient. These findings were explained with 2008 financial crisis while in the period before the crisis both markets were found efficient. Sonje et al. (2011) concluded that inefficiency varied across markets as well as in the same markets over time. However, the driving factors behind inefficiency remained unexplained. Consequently, contemporary literature mainly suggests validity of adaptive market hypothesis. However, drivers of market adaptivity were carried out following narrative approach mostly.

Empirical literature dealing with stock market predictability considered several predictors and formulates the issue as a regression problem. D. Rapach and G. Zhou (2013) used inflation represented by consumer price index (CPI). M. Bosnjak et al. (2021) employed wavelet coherence approach and illustrated no link between CPI and CROBEX returns in Croatia. S. Gupta et al. (2018) and L. Nicolescu et al. (2020) suggested dynamic linkage between stock returns and trading volumes. T. Schabek et al. (2019) suggested the semi-strong form of Croatian stock-market efficiency in line with markets of advanced economies. I. Novak (2019) considered efficiency of CROBEX returns and found autocorrelation of returns dependent on sign and magnitude of its endogenous shocks pointing out asymmetries in returns predictability. Despite suitability of the approach for the topic under consideration quantile autoregression provides no time information about periods of market inefficiency. Conclusively, literature presented in this section suggest time-varying nature of market efficiency while drivers of inefficiency were not clear. This paper aims to identifies periods of efficiency and adaptivity in CROBEX returns and suggest potential drivers of market inefficiency.

2. METHODOLOGY

Financial time series usually exhibits non-normality and heteroscedasticity. These properties bear important implication for empirical evaluation of market efficiency. Therefore, to test autocorrelation among CROBEX returns and derive conclusions regarding stock market efficiency in Croatia automatic portmanteau test (Escanciano and Lubato, 2009) and wild bootstrap automatic variance ration test (Kim, 2009) were employed. Both test poses desirable properties in case of small samples with heteroscedasticity and non-normality Charleset al., 2011). Automatic portmanteau test (Escanciano and Lubato, 2009) is a version of Ljung-Box Q statistics that addresses assumption of independence and identical distribution of returns as well as an arbitrary selection of autocorrelation (ρ_k) considered as major weakness of conventional method. In case of the automatic portmanteau test) optimal lag selection is being determined following Bayesian information criterion (BIC) or Akaike information Criterion (AIC). Test statistic for the automatic portmanteau test was provided in equation (1):

$$AQ_k^* = T \cdot \sum_{i=1}^{k} \rho_i^2 \qquad (1)$$

Where T represents total number of observations, ρ_i represents ith order of autocorrelation and k optimal lag length. AQ statistics follow chi-square distribution with one degree of freedom. Automatic portmanteau test assumes no autocorrelation ($\rho_i = 0,$ for all i) under null hypothesis. To provide robustness of empirical results advanced version of variance ratio test (Choi, 1999) was employed. Kim (2009) illustrated weakness of variance ratio test (Choi, 1999) in case of small sample and presence of heteroscedasticity and suggested wild bootstrap procedure to overcome the issues. Test statistic of the wild bootstrap automatic variance ratio test was given in equation (2):

$$AVR(k) = \sqrt{\frac{T}{k}} \cdot \frac{[VR(K)-1]}{\sqrt{2}} \xrightarrow{d} N(0,1) \qquad (2)$$

Implementation of the wild bootstrap automatic variance ratio test follows procedure with three steps:

- Formation of bootstrap sample of size $T, Y_t^* = \eta_t Y_t$ for $t = 1, \cdots$,T, where η_t represents a rendom sequence withe zero mean and unit variance;
- Calculate $AVR^*(K)$ obtained from $\{Y_t^*\}_{t=1}^{T}$ and
- Repeat steps 1) and 2) BS times in order to generate bootstrap distribution of the AVR statistics$\{AVR^*(k,j)\}_{j=1}^{BS}$.

Two-tailed p-value for this test was calculated by deriving proportion of absolute values of $\{AVR^*(k,j)\}_{j=1}^{BS}$ greather than absolute values of$AVR(K)$.

To consider drivers of stock market inefficiency logistic regression model in equation (3) was estimated.

$$ME_t = \beta_1 \cdot AVGTO_t + \beta_1 \cdot AVGIL_t \qquad (3)$$

Where ME_t is a binary categorical variable taking value 1 in case of market inefficiency and 0 in case of market efficiency, AVGTO represents average trading volumes and AVGIL represents average CROBEX level.

3. RESEARCH DATA

Research data sample in this study consists of CROBEX daily data from the Zagreb Stock Exchange (ZSE) since September 1997 up to July 2021. Base value of CROBEX was set on 1000 points while its composition is changed and adjusted semi-annually to best represent dynamics of stock market. CROBEX returns (r_t) at day (t) was calculated as given in equation (4):

$$r_t = log\left(\frac{y_t}{y_{t-1}}\right) \cdot 100 \qquad (4)$$

Development of CROBEX returns (r_t) across period under consideration was provided in Figure A1 in Appendix while its descriptive statistics was provided in Table A1 in the appendix. Visual inspection of Figure A1 in the Appendix illustrates the highest volatility at the beginning of the observation period. Prominent volatility can be detected as contagion effect of 2008 financial crises as well as at beginning of covid-19 pandemic crises. Following Table A1 in the appendix, Jarque-Bera test results suggest non-normality in distribution of CROBEX returns while ARCH test results suggest heteroscedasticity of variance as it is often the case when observing financial time series. To consider market efficiency of CROBEX returns automatic portmanteau test and the wild bootstrap automatic variance ratio test were employed. The tests were performed using fixed-length rolling window of 500 observations (2 years approximately). Therefore, moving by one observation 5.378 successive samples were considered. When the p-value is less than 0.05 the sample was considered ineffective or in line with adaptive market hypothesis. Following Charles et al. (2011) and Lim et al. (2013) among others, this sample size is enough to hold statistical power and desired properties of test.

In order to put some light on drivers of Croatian stock market adaptivity, 500–days average trading volumes (5) and 500–days average index levels (6) were constructed. Trading volumes have been available from ZSE since beginning of 2010.

$$AVTO_t = \frac{\sum_{i=t-499}^{t} TV_i}{500} \quad (5)$$

$$AVIL_t = \frac{\sum_{i=t-499}^{t} IL_i}{500} \quad (6)$$

Where TV_i and IL_i represent trading volume and CROBEX index level at day i, respectively. Therefore, $AVTO_t$ (Figure A2 in the appendix) and $AVIL_t$ (Figure A3 in the appendix) represents 500–days average trading volumes and 500–days average index levels at day t, respectively. Descriptive statistics for $AVTO_t$ and $AVIL_t$ was provided in Table A2 in the appendix. Following results of the automatic portmanteau test and the wild bootstrap automatic variance ratio test with 1000 bootstrap samples, two variables were defined APT_t and WBAVR_t each representing market efficiency. In case of the p-value from automatic portmanteau test was less than 0.05 APT_t variable takes value 1 otherwise APT_t variable takes value 0. In a same way, if the p-value from the wild bootstrap automatic variance ratio test was less than 0.05 WBAVR_t takes value 1 otherwise WBAVR_{t_t} variable takes value 0. In order to provide to evaluate robustness of the results model specification in equation (3) was estimated using APT_t as dependent variable representing market inefficiency (ME_t) as well as using WBAVR_t as dependent variable representing market (in)efficiency (ME_t).

4. EMPIRICAL RESULTS AND DISCUSSION

Following methodological procedure, p-values obtained from the automatic portmanteau test and the wild bootstrap automatic variance ratio test were illustrated in Figure 1 and Figure 2, respectively. Horizontal lines parallel to x-axis represent 5% significance level. Therefore, p-value below the line represents existence of autocorrelation and market inefficiency while p-value on the line and above the line represents no autocorrelation and market efficiency I the corresponding period.

Empirical results in Figure 1 reveals periods of market efficiency and periods of market inefficiency. Therefore, empirical results were in line with adaptive market hypothesis. P-values falls below 5% as of April and May 2002 suggesting serial dependence of CROBEX returns for the period of previous two years. Therefore, it might be potentially attributed to contagion effect of dot-com bubble started to collapse in 1999. Second time p-values falls below 5% was in May 2007 suggesting another episode of market inefficiency for periods started in 2005 and lasted for about year and half. This period of inefficiency might be explained with strong growth of CROBEX level often considered as a bubble. The longest period of CROBEX returns inefficiency started in 2008 and can potentially be linked with global financial crises. This episode was the longest one that lasted for three years. Empirical results from the wild bootstrap automatic variance ratio test were illustrated Figure 2.

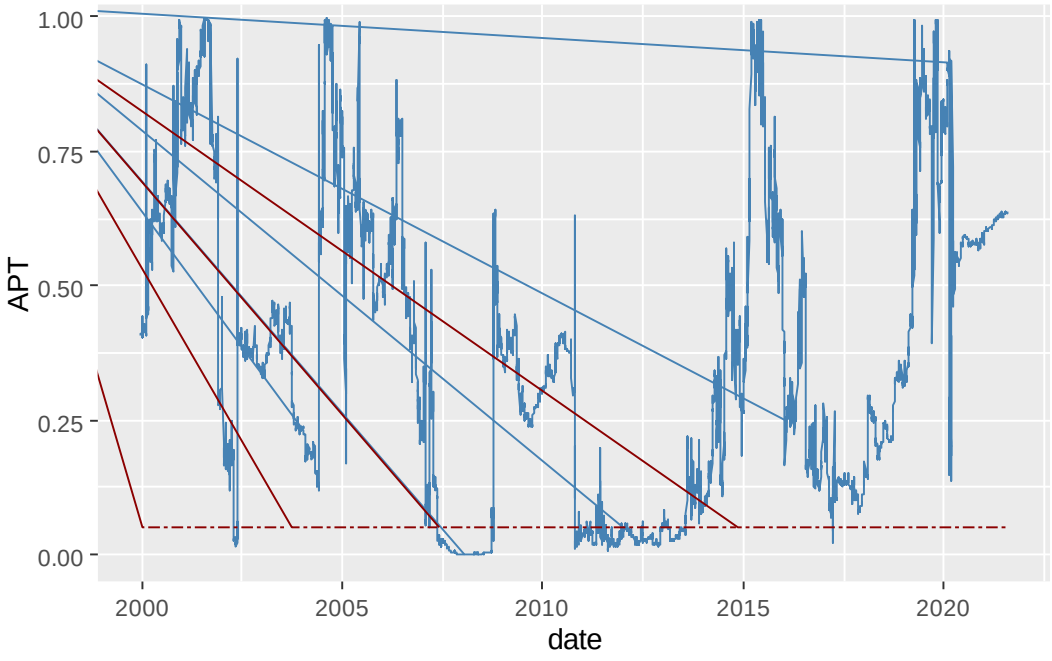

Figure 1. p-values from automatic portmanteau test

Source: Author.

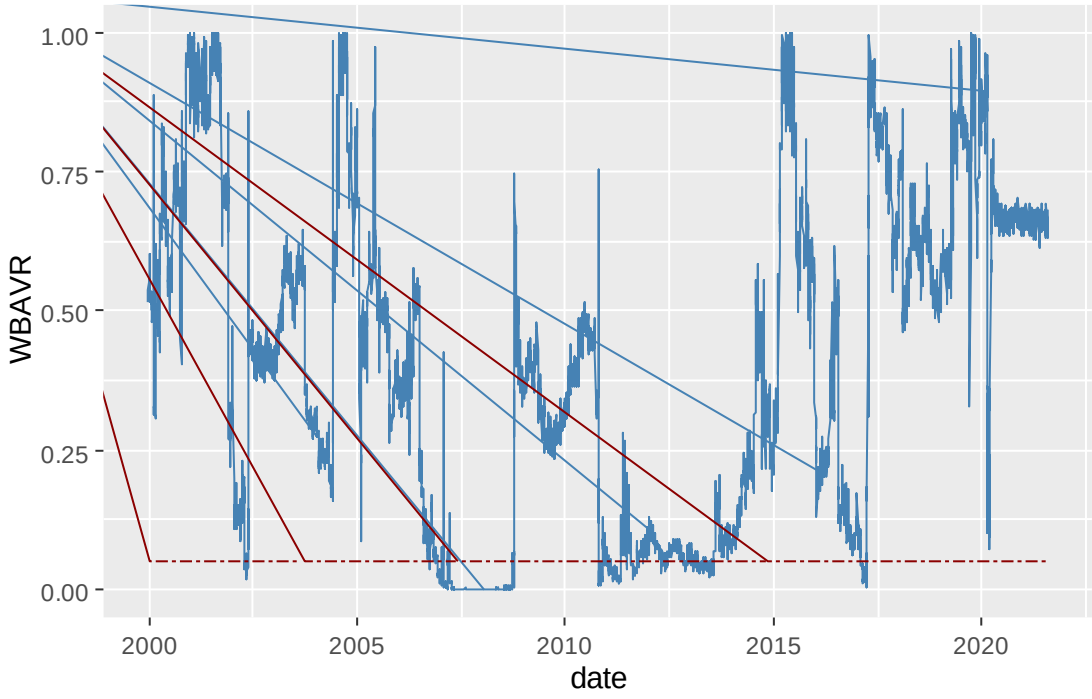

Figure 2. p-values from the wild bootstrap automatic variance ratio test with 1000 bootstrap samples

Source: Author.

The same conclusion can be derived from Figure 2 supporting validity of empirical finding. Visual inspection and comparison of Figure 1 and Figure 2 reveal similar results suggesting validity of adaptive market hypothesis. To illustrate level of efficiency of Croatian stock market efficient and inefficient 500-days periods were counted and reported in Table 1.

Table 1. Level of efficiency

Test	*Inefficiency*	*Efficiency*	*Total*
Automatic portmanteau test	942	4436	5378
Wild bootstrap automatic variance ratio test with 1000 bootstrap samples	768	4610	5378

Source: author.

Following results in Table 1 Croatian stock market was mostly efficient. Based on the automatic portmanteau test inefficiency appeared in 17,52% of cases while based on the Wild bootstrap automatic variance ratio test with 1000 bootstrap samples inefficiency appeared in 14,28% of cases. On average, Croatian stock returns were in line with efficient market hypothesis in 84,10% of cases.

As it is explained earlier in section entitled methodology, link between stock market inefficiency and market conditions described by CROBEX level and its trading volume (liquidity) were evaluated. Model specification in equation (3) was estimated while indicator of inefficiency was obtained using the automatic portmanteau test results. The estimates were summarized in Table 2.

Table 2. Drivers of inefficiency following the automatic portmanteau test results

	Estimate (Std. Error)	*t - value*	*p - value*
AVGTO	9.274e-08 (1.392e-09)	66.64	<2e-16
AVGIL	-3.291e-04 (6.556e-06)	-50.19	<2e-16

Source: author.

Following estimates in Table 2, periods with higher average trading volumes (liquidity) were more likely to be inefficient. More specifically, an increase of trading volume for 10,000.00 kuna was associated with increase of odds ratio for 0,93. Similarly, lower average CROBEX level was more likely to be inefficient. More precisely, a decrease of CROBEX for 1000 basis points increase odds ratio for 0,33. Both considered variables obtained statistical significance of 5%. To analyse robustness of the results model specification in equation (3) was estimated but this time indicator of inefficiency was obtained from the wild bootstrap automatic variance ratio test results. The estimates were reported in Table 3.

Table 3. Drivers of inefficiency following the wild bootstrap automatic variance ratio test

	Estimate (Std. Error)	*t - value*	*p - value*
AVGTO	2.175e-08 (1.732e-09)	12.553	< 2e-16
AVGIL	-5.489e-05 (8.160e-06)	-6.727	2.17e-11

Source: author.

Table 3 illustrated slightly smaller effect from average trading volumes as well as from average CROBEX level to stock market inefficiency. However, results in Table 3suggest that increase in average trading volumes increases likelihood of market inefficiency while decrease in average CROBEX level increases likelihood of market efficiency as well. Therefore, similar results were found in both cases. Con-

clusively, Croatian stock market exhibits properties of evolving efficiency. In about 85% cases CROBEX returns were not predictable. Periods of serial dependence or predictability might be associated with higher trading volumes and lower index level.

CONCLUSIONS

There are several conclusions that can be drown out of research presented in this paper. Firstly, Contemporary literature suggests validity of adaptive market hypothesis and evolving efficiency of financial markets. Empirical findings from recent and robust variance ratio test with stronger statistical power and fix-length rolling window supported validity of adaptive market hypothesis for Croatian stock market. Based on empirical findings from this paper, Croatian stock market was efficient in 85% of cases while serial dependence was detected in 15% of cases. Market conditions in terms of trading volumes (liquidity) and index level (prices) were further considered during periods of efficiency and predictability. Therefore, classification problem was formulated and following logistic regression approach estimates were obtained. The estimates revealed that periods with serial dependence were more likely to be present during the periods with higher trading volumes and lower prices. Conclusively, lower prices and higher liquidity might be a signal of trading opportunities for Croatian stock market.

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APPENDIX

Table A1. Descriptive statistics

CROBEX RETURNS	
Mean	0.009342
Median	0.017170
Maximum	17.57476
Minimum	-19.42264
Std. Dev.	1.435303
Skewness	-0.198519
Kurtosis	28.58011
Jarque-Bera	160270.6
Probability	0.000000
ARCH test:	
F-statistic: 141.0115	p-value: 0.0000
No. of observations	5877

Source: Author

Table A2. Descriptive statistics for average index level (AVGIL) and average trading volumes (AVGTO)

	AVGIL	*AVGTO*
Mean	1828.352	8006306.
Median	1817.899	6766577.
Maximum	2038.718	18157595
Minimum	1732.436	4918574.
Std. Dev.	63.13442	3189756.
Skewness	0.987193	1.984806
Kurtosis	3.792007	5.844563
Jarque-Bera	450.4732	2374.004
Probability	0.000000	0.000000
Observations	2389	2389

Source: Author.

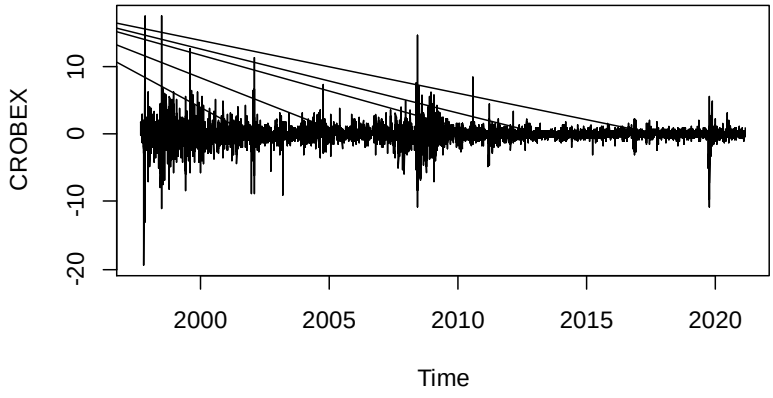

Figure A1. Development of CROBEX returns

Source: Author.

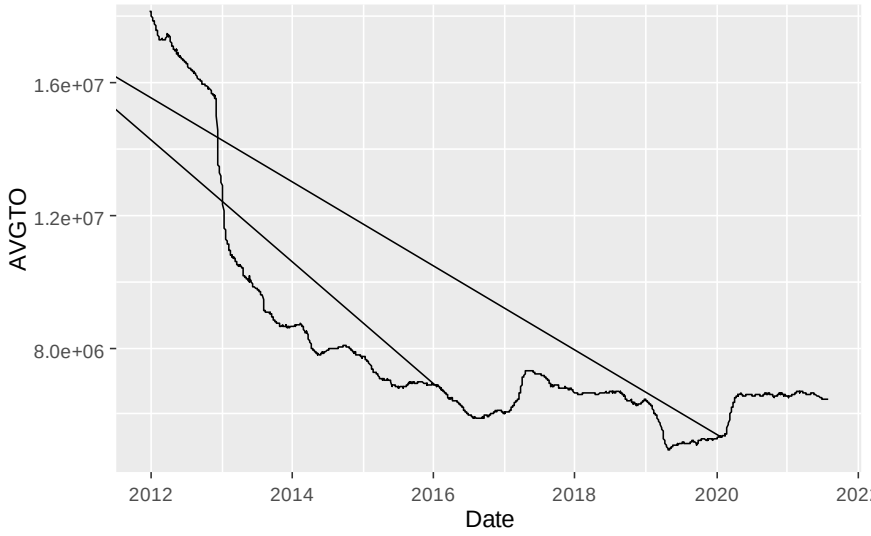

Figure A2. Development of average trading volumes

Source: Author.

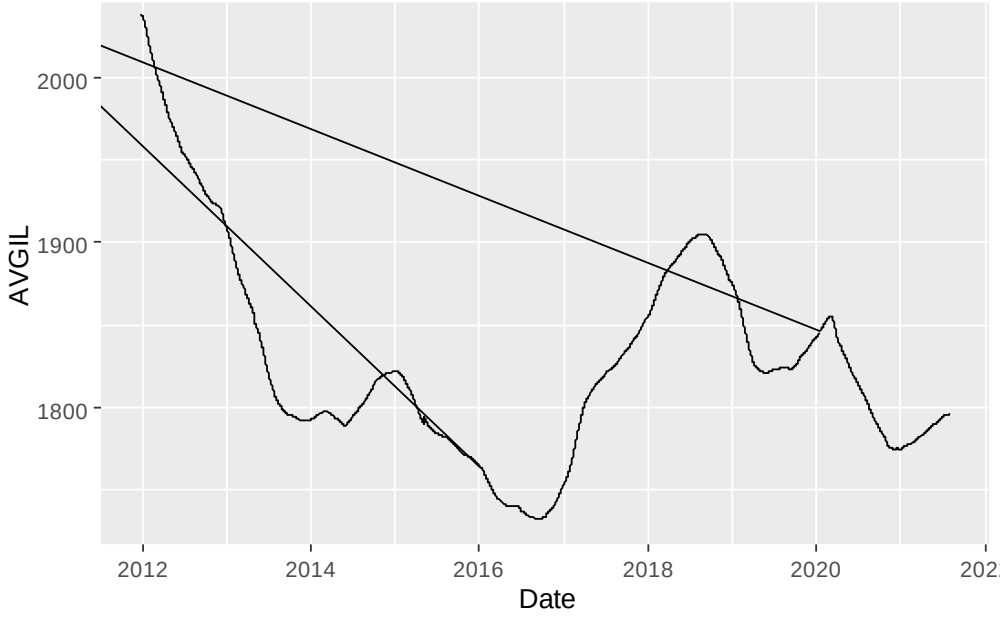

Figure A3. Development of average CROBEX level

Source: Author.