IBIMA Publishing
Communications of International Proceedings
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Vol. 2026 (1), Article ID 4726726

Bayesian Analysis of Time-Varying Systematic Risk: Evidence from the Warsaw Stock Exchange*

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*Presented at the 47th IBIMA International Conference, 29-30 June 2026, Madrid, Spain

Abstract

This study investigates the time variation of systematic risk for companies listed on the Warsaw Stock Exchange (WSE) during the period 2011 - 2025. The empirical analysis combines rolling-window estimation with Bayesian approaches to structural instability and stochastic risk dynamics. The results reveal instability of beta coefficients, particularly during the COVID-19 pandemic and the subsequent energy and inflation shocks. The evidence for structural changes is considerably stronger for residual variance than for beta coefficients themselves. Dynamic Bayesian models further indicate that systematic risk evolves continuously over time and exhibits persistent but stationary dynamics, strongly rejecting random-walk-type behavior of beta coefficients. Banking sector companies display relatively stable market exposure, whereas growth-oriented and energy-related firms exhibit significantly stronger beta instability. The findings suggest that the assumption of constant beta coefficients may be difficult to justify for companies listed on the WSE and support the application of dynamic asset pricing models in emerging equity markets.

Keywords: Bayesian analysis, stochastic beta, Warsaw Stock Exchange, dynamic asset pricing models.

Introduction

Asset pricing models constitute one of the fundamental areas of modern financial economics. Their primary objective is to explain the relationship between expected returns and risk, as well as to identify the determinants of cross-sectional differences in asset returns. Their theoretical foundations are rooted in the Capital Asset Pricing Model (CAPM) proposed by Sharpe (1964), which links expected returns to systematic market risk measured by the beta coefficient. Despite the subsequent development of multifactor frameworks, including the Fama-French and Carhart models, CAPM remains one of the most widely applied tools in empirical finance, portfolio management, and cost-of-capital estimation.

A growing body of literature indicates, however, that systematic risk is not constant over time. Numerous studies document that beta coefficients may vary substantially across market regimes and become particularly unstable during periods of elevated market uncertainty and financial crises. This problem is especially relevant for emerging markets, where changing macroeconomic conditions, lower market depth, and higher volatility may amplify the instability of asset pricing relationships. Consequently, the assumption of constant beta coefficients underlying the classical CAPM framework may be difficult to justify in empirical applications.

The problem of asset pricing model applicability has also been extensively studied for the Warsaw Stock Exchange (WSE). Early studies focused primarily on testing the classical CAPM framework in the Polish market environment. Subsequent research extended the analysis toward intertemporal and multifactor specifications, including ICAPM and Fama-French-type models (e.g. Urbański, 2007; Czapkiewicz and Skalna, 2010). More recent studies additionally examined various return anomalies and cross-sectional determinants of stock returns

Cite this Article as: Tomasz WÓJTOWICZ Vol. 2026 (1) "Bayesian Analysis of Time-Varying Systematic Risk: Evidence from the Warsaw Stock Exchange " Communications of International Proceedings, Vol. 2026 (1), Article ID 4726726, https://doi.org/10.5171/2026.4726726

on the Polish market, including idiosyncratic risk, momentum, liquidity, and trading activity effects (e.g. Czapkiewicz et al. 2023). Nevertheless, relatively limited attention has been devoted to the dynamic and stochastic properties of CAPM beta coefficients for companies listed on the Warsaw Stock Exchange.

Recent empirical literature increasingly emphasizes the usefulness of Bayesian methods in modeling time-varying systematic risk and structural instability in asset pricing relationships. Bayesian approaches provide a flexible framework for estimating dynamic beta processes, identifying structural changes, and quantifying parameter uncertainty, particularly in periods of elevated market volatility. These issues gained additional importance after the COVID-19 pandemic and the subsequent inflation and energy shocks, which generated disturbances in global financial markets and may have significantly altered the systematic risk exposure of publicly traded firms. Recent studies examining European and emerging markets additionally document increased instability and non-stationarity of CAPM beta coefficients during crisis periods.

The aim of this study is therefore to investigate the stability and dynamic behavior of CAPM beta coefficients for companies included in the WIG20 and mWIG40 indices of the Warsaw Stock Exchange. The analysis focuses on firms continuously listed over the period January 2011 – December 2025 and combines three complementary approaches. First, rolling-window CAPM estimations are used to examine the evolution of beta coefficients over time. Second, Bayesian structural breakpoint models are applied to identify potential regime shifts in both beta coefficients and residual variance. Finally, Bayesian dynamic CAPM with stochastic AR(1) beta processes are estimated in order to analyze the persistence and mean-reverting properties of systematic risk dynamics.

The study contributes to the existing literature in several ways. First, it provides comprehensive evidence on the instability of CAPM relationships for large and liquid companies listed on the Warsaw Stock Exchange. Second, it compares discrete structural break models with continuously evolving stochastic beta specifications within a unified Bayesian framework. Third, the analysis demonstrates that periods of market stress affect not only the level of systematic risk, but also the uncertainty and persistence properties of dynamic beta processes.

The remainder of the paper is organized as follows. Section 2 reviews the relevant literature on asset pricing models and beta instability. Section 3 describes the data and research methodology. Section 4 presents the empirical results. The final section concludes the paper.

Literature Review

Asset pricing models are rooted in the Capital Asset Pricing Model (CAPM) proposed by Sharpe (1964), which links expected returns to systematic market risk measured by the beta coefficient. Subsequent extensions incorporated additional sources of risk, including the Fama-French factor models (Fama and French, 1993, 2015, 2018), the Carhart momentum specification (Carhart, 1997), and mispricing-related factors emphasized by Stambaugh and Yuan (2017). These developments suggest that asset pricing relationships are multidimensional and may evolve over time, particularly in emerging markets characterized by higher volatility and changing market structures.

Research on asset pricing models for the Warsaw Stock Exchange (WSE) has developed substantially over the last two decades. Previous research on the Warsaw Stock Exchange examined both classical CAPM specifications and multifactor asset pricing models, including Fama–French-type approaches (e.g. Urbański, 2007; Czapkiewicz and Skalna, 2010, 2014). More recent studies further expanded the literature on asset pricing for the Polish market. In particular, Czapkiewicz and Wójtowicz (2014) show that multifactor models may improve the explanatory power of traditional CAPM specifications. Other studies document the existence of additional return patterns and market anomalies on the WSE, including the high-volume return premium analyzed by Wójtowicz (2017). Recent research also emphasizes the role of idiosyncratic risk and other market-specific factors in emerging European markets, including Poland (Czapkiewicz et al., 2023). Collectively, these findings suggest that the Polish equity market exhibits evolving and heterogeneous risk-return relationships typical of emerging financial markets.

Despite the growing importance of multifactor models, CAPM remains the benchmark framework for measuring systematic risk. The beta coefficient continues to serve as one of the most widely used measures of market sensitivity in both academic research and practical financial analysis. At the same time, a notable body of literature indicates that beta coefficients are not constant over time. Numerous empirical studies document instability and time variation in beta estimates across different market conditions, investment horizons, and crisis periods. This issue appears particularly relevant for emerging markets, where structural changes and increased volatility occur more frequently. For example, Mikołajek-Gocejna (2021) documents instability and non-stationarity of beta coefficients across emerging equity markets during the period 2005–2021. The problem of beta stability has also been examined for the WSE. Dębski et al. (2014) analyze beta stability during bull and bear market periods and show that systematic risk changes significantly across market regimes. Previous studies on the Polish market therefore suggest that the assumption of constant beta coefficients may be difficult to justify for WSE companies.

Recent studies increasingly link beta instability to large-scale macroeconomic disruptions. In particular, the COVID-19 pandemic and the subsequent energy and inflation shocks generated abrupt changes in market volatility and cross-sector comovement patterns. Szczepocki and Feder-Sempach (2025) identify structural changes in CAPM relationships for European companies during the COVID-19 pandemic, highlighting the importance of accounting for parameter instability in risk estimation models.

In parallel with the growing interest in beta instability, Bayesian and dynamic approaches to asset pricing have become increasingly important in financial econometrics. Bayesian methods allow the incorporation of parameter uncertainty and facilitate the modeling of time-varying systematic risk. Feder-Sempach and Szczepocki (2022) apply Bayesian methods to estimate industry beta coefficients for the Polish and German markets, while Feder-Sempach et al. (2023) employ Kalman filter techniques to analyze long-run instability of beta estimates for major US companies.

Another important issue concerns the distinction between systematic and idiosyncratic risk dynamics. Czapkiewicz et al. (2023) show that idiosyncratic risk constitutes an important determinant of stock returns in emerging European markets. This suggests that changes in CAPM beta coefficients and changes in residual variance may represent different dimensions of market risk and therefore should be analyzed separately.

Despite the extensive literature on asset pricing and CAPM estimation, relatively little attention has been devoted to combining Bayesian structural break detection with dynamic stochastic beta modeling for companies listed on the WSE. Existing studies on the Polish market rely predominantly on classical econometric methods, rolling regressions, or static Bayesian estimation. The present study contributes to the literature by applying a multi-stage framework combining rolling beta estimation, Bayesian change point detection, and dynamic Bayesian CAPM models to analyze the stability of systematic risk for major Polish listed companies.

Data and Methodology

Data Preparation

The empirical analysis concerns companies currently included in the WIG20 and mWIG40 indices of the Warsaw Stock Exchange. These indices comprise the largest and most liquid firms listed on the WSE, with WIG20 containing the 20 largest companies and mWIG40 representing the subsequent 40 medium-sized firms. To ensure sufficiently long time series for the analysis of beta stability, the sample includes only companies continuously listed for at least the last 15 years. As a result, 37 out of the 60 companies included in the two indices qualify for the study. The dataset covers the period from January 2011 to December 2025. Monthly stock returns ($R_{i,t}$) are calculated using monthly closing prices. The WIG20 index is used as a proxy for the market portfolio ($R_{m,t}$), while WIBOR 3M represents the risk-free rate $R_{f,t}$. CAPM parameters are estimated using the standard market model:

$$R_{i,t} - R_{f,t} = \alpha_i + \beta_i\left(R_{m,t} - R_{f,t}\right) + \varepsilon_{i,t}.$$

Rolling Beta Estimation

As a preliminary step, the stability of CAPM beta coefficients is examined using rolling-window regressions. For each company, the CAPM is estimated over rolling windows of 36 monthly observations. The estimation window moves forward one month at a time, generating time-varying beta estimates for the entire sample period. The rolling-window estimates provide a preliminary view of beta instability and help identify periods of increased systematic risk variability prior to the Bayesian analysis.

Bayesian Change Point Detection

To identify potential structural changes in CAPM relationships, Bayesian breakpoint models with zero, one, and two structural breakpoints are estimated. The first stage investigates structural changes in CAPM beta coefficients by allowing regression parameters to vary across regimes separated by unknown breakpoints estimated from the data. The second stage focuses on structural changes in residual variance. Bayesian estimation is performed using

MCMC simulation with four chains and 4,000 iterations. Posterior distributions of breakpoint locations and regime-specific parameters are used to evaluate the timing and magnitude of structural changes. Model comparison is conducted using leave-one-out cross-validation (LOO), while convergence diagnostics are evaluated using the Gelman–Rubin statistic. Uniform priors and minimum regime-length constraints are imposed to avoid economically implausible breakpoint partitions.

Bayesian Dynamic CAPM

The final stage of the analysis applies a Bayesian dynamic CAPM model with a time-varying beta coefficient estimated in a state-space framework. In contrast to rolling-window and breakpoint approaches, the dynamic specification models beta as a continuously evolving latent stochastic process. The beta coefficient follows an autoregressive AR(1) process:

$$\beta_t = \mu_\beta + \varphi(\beta_{t-1} - \mu_\beta) + \eta_t$$

The parameter φ captures the persistence of beta dynamics, while η_t represents stochastic shocks affecting systematic risk over time. An AR(1) specification is adopted instead of a random walk process because systematic risk for large and liquid companies is expected to fluctuate around long-run levels rather than drift indefinitely over time.

The models are estimated using MCMC simulation with four chains. Posterior beta distributions are subsequently used to analyze the magnitude, persistence, and uncertainty of systematic risk dynamics.

All empirical analyses are conducted in the R environment. Bayesian breakpoint models are estimated using the *mcp* package (Lindeløv, 2020), while dynamic Bayesian CAPM models are estimated in Stan through the *rstan* interface (Stan Development Team, 2025). Posterior summaries, highest posterior density intervals (HPDI), and MAP estimates are computed using the *bayestestR* package (Makowski et al., 2019).

Empirical Results

Rolling Beta Analysis

The rolling-window analysis indicates pronounced time variation in CAPM beta coefficients across WSE companies. Average beta values differ considerably between firms, ranging from values close to zero for defensive companies to values exceeding 1.4 for more cyclical firms. Important sectoral differences are also observed. Banking sector companies, including PKO BP, Pekao, mBank, and Millennium, generally exhibit relatively high and persistent beta coefficients, whereas energy and utilities companies, such as PGE, Tauron, and Enea, display visibly stronger fluctuations in systematic risk.

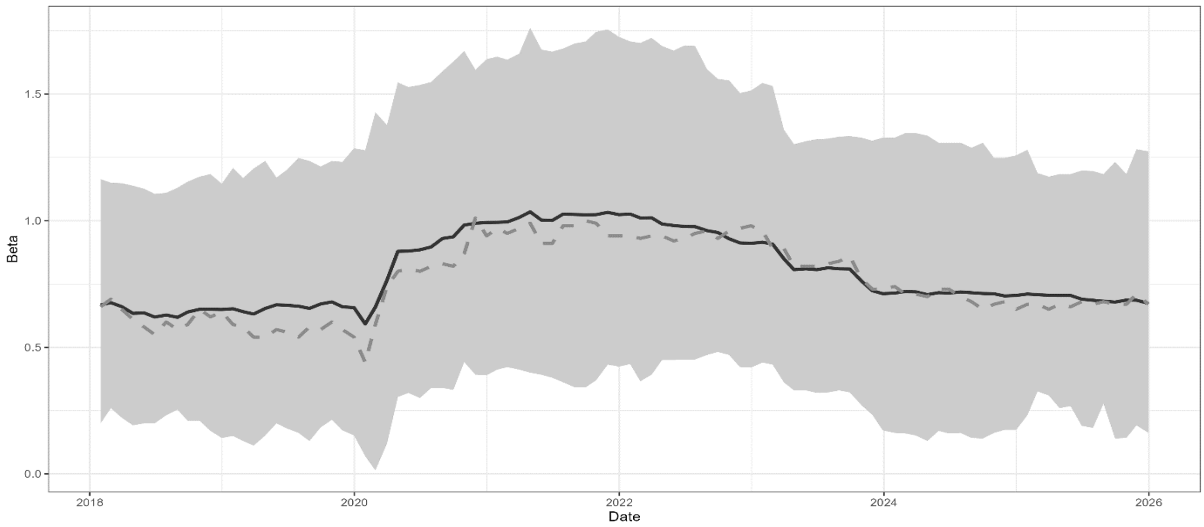

Figure 1. Cross-Sectional Distribution of Rolling CAPM Beta Coefficients

Notes: The figure presents cross-sectional statistics of rolling CAPM beta coefficients estimated using 36-month rolling windows. The solid line represents the cross-sectional mean beta, the dashed line represents the median beta, and the shaded area corresponds to the 10th - 90th percentile range.

Figure 1 presents the cross-sectional distribution of rolling beta estimates. Both the level and dispersion of systematic risk increase during the period 2020–2022. The cross-sectional mean beta rises from approximately 0.65 in 2018–2019 to values close to 1.0 during the COVID-19 pandemic and the subsequent period of heightened market volatility. At the same time, rolling betas temporarily exceed 2.5 for some firms.

Abrupt changes observed rolling beta estimates may partly result from the sensitivity of short rolling-window regressions to extreme market observations and volatility shocks. The above analysis indicates that the assumption of constant systematic risk may be difficult to justify and motivates the application of Bayesian structural break and dynamic beta models.

Bayesian Breakpoint Results

The Bayesian breakpoint analysis provides only limited evidence for discrete structural breaks in CAPM beta coefficients. Although rolling-window estimates indicate beta instability, posterior breakpoint distributions are generally characterized by considerable uncertainty and wide HPDI. For one-breakpoint models, posterior mean estimates are typically concentrated near the middle of the sample period, while MAP estimates vary across firms. Estimated HPDI for breakpoint locations are frequently very wide, often exceeding 100 monthly observations. Model comparison based on ΔLOO also provides only weak support for breakpoint specifications.

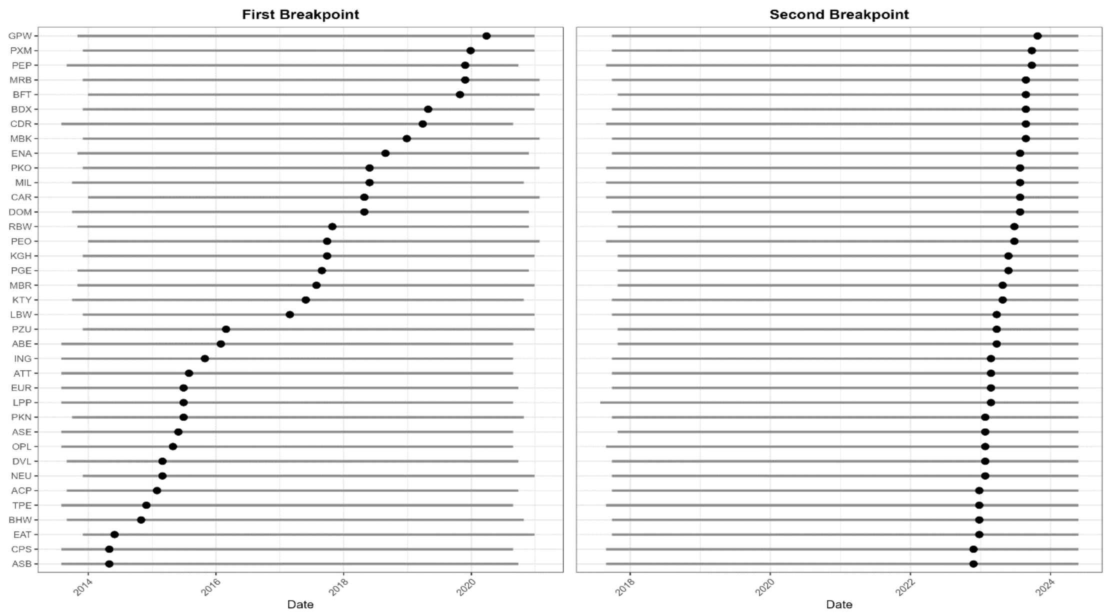

Figure 2. Posterior MAP Estimates and 95% HPDI for Bayesian CAPM Beta Breakpoints

Notes: The figure presents posterior mode (MAP) estimates and 95% HPDI for breakpoint locations obtained from Bayesian two-breakpoint CAPM models. Horizontal segments represent HPDI, while points denote MAP breakpoint estimates.

Similar conclusions emerge for two-breakpoint models. Estimated breakpoints tend to cluster around the periods 2018 - 2019 and 2021 - 2022, broadly coinciding with the increased instability visible in rolling beta estimates and major episodes of market uncertainty. However, as illustrated in Figure 2, breakpoint HPDI remain wide for most firms, suggesting that systematic risk evolves in a relatively gradual and continuous manner rather than through sharply defined structural breaks.

Variance Breakpoint Results

The Bayesian analysis of variance breakpoints provides considerably stronger evidence of regime changes than the corresponding analysis of CAPM beta coefficients. Compared with beta breakpoint models, variance specifications are characterized by narrower HPDI, larger ΔLOO improvements, and higher posterior probabilities of parameter changes.

The strongest and most systematic variance shifts are observed for energy and utilities companies, including Tauron (TPE), PGE, and Enea (ENA). These firms exhibit strong increases in residual variance together with very high posterior probabilities of variance regime changes, particularly during periods of elevated market uncertainty. For Tauron, the posterior probability of a large variance increase reaches almost 1.0, while ΔLOO exceeds 6.17. Similar results are obtained for Enea (ΔLOO ≈ 4.02) and PGE (ΔLOO ≈ 3.41). In these cases, residual variance increases strongly between estimated regimes, indicating changes in volatility dynamics during periods of market stress.

For two-breakpoint models, estimated breakpoint locations cluster primarily around the periods 2018–2020 and 2022–2024. As illustrated in Figure 3, HPDI for variance breakpoints are generally narrower and more concentrated than those obtained for beta breakpoints, although substantial uncertainty remains for several firms. The estimated breakpoints broadly coincide with the COVID-19 pandemic, the subsequent inflation shock, and the European energy crisis.

The above results suggest that episodes of elevated market uncertainty affect primarily the volatility structure of stock returns rather than generating abrupt changes in systematic market exposure. While CAPM beta coefficients appear to evolve relatively gradually over time, residual variance exhibits more pronounced and identifiable regime shifts.

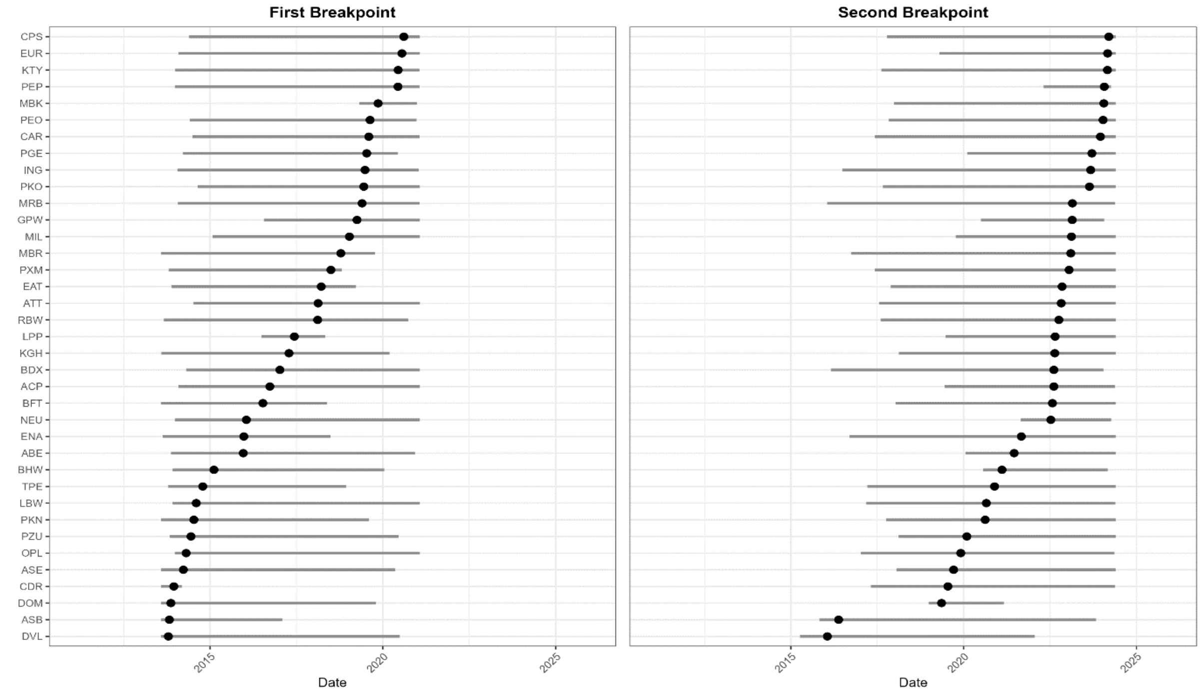

Figure 3. Posterior MAP Estimates and 95% HPDI for Bayesian CAPM Variance Breakpoints

Notes: The figure presents MAP estimates and 95% HPDI for breakpoint locations obtained from Bayesian two-breakpoint variance models. Horizontal segments represent HPDI, while points denote MAP breakpoint estimates. Uniform priors are imposed on breakpoint locations in order to ensure a minimum number of observations within each regime and avoid economically implausible segment partitions. Consequently, some HPDI are partially influenced by these prior restrictions.

Dynamic CAPM Results

The Bayesian dynamic CAPM results reveal strong heterogeneity in systematic risk dynamics across companies listed on the Warsaw Stock Exchange. Both the average level of market exposure and the magnitude of beta fluctuations differ considerably across firms and sectors.

Table 1 provides selected firm-level summaries of posterior stochastic beta estimates obtained from the Bayesian dynamic CAPM model and illustrates cross-sectional differences in both the level and persistence of systematic risk dynamics. The highest beta instability is observed for growth-oriented and technology-related companies, including CD Projekt (CDR), Rainbow Tours (RBW), and AMREST (EAT). For example, the estimated beta coefficient for CDR varies between approximately −0.75 and 2.33, while the corresponding 95% HDI width exceeds 3.30. Similarly, AMREST exhibits beta values ranging from −0.44 to above 4.0, indicating exceptionally strong time variation in systematic risk.

Table 1. Selected Firm-Level Characteristics of Dynamic Bayesian Betas

Firm	Sector	Mean β	$SD(\beta)$	β Range	Mean HPDI Width	φ	$Prob(\lvert\varphi\rvert < 1)$
MBK	Banking	1.33	0.01	1.30–1.37	1.03	0.04	0.997
PKO	Banking	1.07	0.15	0.46–1.81	1.32	-0.44	1
CDR	Gaming	0.78	0.27	-0.45–2.36	3.31	0.38	0.999
EAT	Consumer	0.61	0.52	-0.29–4.07	3.07	0.46	1
PGE	Energy	1.06	0.18	0.22–1.88	2.34	-0.26	1
TPE	Utilities	0.96	0.04	0.85–1.08	1.96	-0.51	0.994

Notes: The table reports selected firm-level posterior summaries obtained from the Bayesian dynamic CAPM with stochastic AR(1) beta processes. Mean β denotes the posterior mean of the time-varying beta coefficient, while $SD(\beta)$ represents the posterior standard deviation of beta dynamics over time. β Range corresponds to the minimum and maximum posterior MAP beta estimates. Mean HPDI Width denotes the average width of the 95% HPDI for beta estimates. The parameter φ represents *the autoregressive coefficient governing beta persistence, and $Prob(|\varphi| < 1)$ denotes the posterior probability of stationary and mean-reverting beta dynamics. Firms were selected to illustrate sectoral differences in systematic risk behavior across representative industries.*

Banking sector companies generally display persistently high but relatively more stable beta coefficients. mBank (MBK), PKO BP (PKO), and Pekao (PEO) maintain average beta values close to or above one throughout the whole sample period. In particular, mBank exhibits one of the highest average betas in the sample (approximately 1.32) while simultaneously displaying relatively limited beta variability compared with other high-beta companies.

Considerable variation in beta dynamics is also observed for energy and utilities companies, including PGE, Tauron (TPE), and Enea (ENA). These firms experience pronounced increases in systematic risk during periods of increased market uncertainty, with beta coefficients temporarily exceeding values of 1.5 - 2.0. The results are broadly consistent with the structural changes identified previously in variance breakpoint models and reflect the sensitivity of the sector to energy price shocks and macroeconomic instability.

Figure 4 illustrates the cross-sectional evolution of posterior MAP beta estimates and posterior uncertainty measures over time. During tranquil market conditions, average beta values remain relatively stable, typically fluctuating around 0.75 - 0.85. However, periods of increased market stress are associated with both higher average systematic risk and increased cross-sectional dispersion of beta coefficients. The strongest changes are observed during the COVID-19 market turmoil in 2020 and during the energy and inflation shock of 2022. During these periods, the upper decile of posterior beta estimates increases sharply, suggesting that a large subset of firms became considerably more sensitive to aggregate market movements. At the same time, the lower decile also becomes more volatile, reflecting increased heterogeneity in firms' responses to adverse macroeconomic conditions. Figure 4 also presents the evolution of posterior uncertainty measured by the width of highest posterior density intervals (HPDI). An economically interesting pattern emerges during crisis periods, when the average HPDI width declines despite the simultaneous increase in beta volatility. This result suggests that episodes of market-wide turbulence strengthen common factor comovement across firms, thereby improving the statistical identifiability of systematic risk exposure.

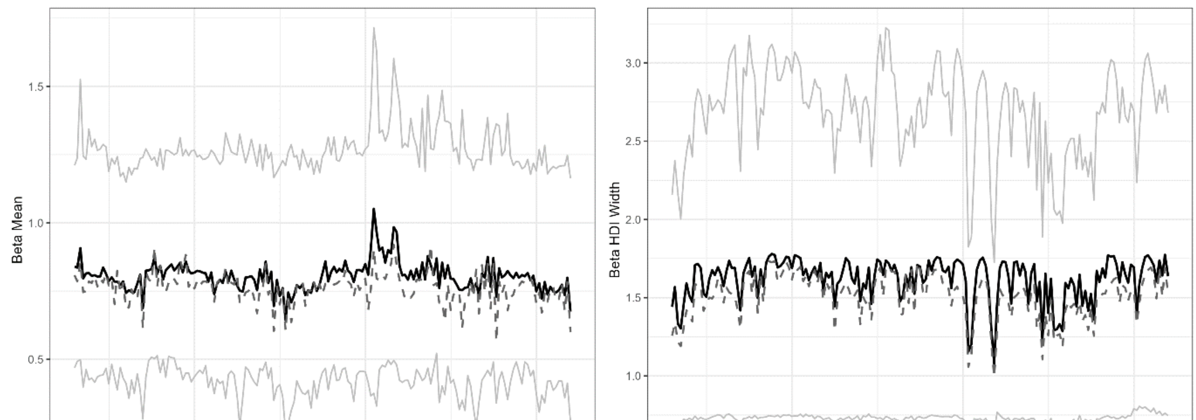

Figure 4. Cross-Sectional Distribution and Posterior Uncertainty of Dynamic CAPM Beta Estimates

Notes: The figure presents cross-sectional statistics of posterior MAP beta estimates and posterior uncertainty measures obtained from Bayesian AR(1) stochastic beta CAPM. The left panel reports the cross-sectional distribution of posterior MAP beta coefficients, while the right panel presents the distribution of HPDI widths. Solid lines denote cross-sectional means, dashed lines represent medians, and grey lines correspond to the 10th and 90th percentiles.

Additional evidence on the properties of dynamic beta processes is provided in Table 2. The average posterior beta across firms equals approximately 0.80, while the cross-sectional median remains close to 0.78. The estimated dispersion of beta dynamics is economically meaningful, with the average standard deviation of beta processes equal to 0.16 and the upper decile exceeding 0.39. Moreover, the average width of posterior HDI intervals equals approximately 1.62, although uncertainty differs considerably across firms, ranging from values below 0.60 to more than 3.5 for the most unstable companies.

The persistence properties of stochastic beta dynamics also reveal important heterogeneity across firms. Although the average autoregressive parameter φ remains slightly positive (approximately 0.03), its cross-sectional distribution ranges from -0.55 to 0.84. Approximately 40% of firms exhibit negative autoregressive coefficients, indicating oscillatory mean-reverting dynamics with relatively rapid adjustments toward long-run beta levels. However, posterior probabilities of stationarity and mean reversion remain extremely high across the entire sample. The average value of $Prob(|\varphi| < 1)$ equals 0.996, while even the minimum observed value exceeds 0.96. These results strongly reject random-walk-type beta dynamics and indicate that systematic risk exposures evolve as persistent but ultimately stationary stochastic processes fluctuating around long-run levels.

The above results indicate that systematic risk on the Warsaw Stock Exchange evolves gradually rather than through abrupt structural shifts. Periods of higher macroeconomic uncertainty are associated not only with higher average beta levels, but also with notably greater cross-sectional heterogeneity. These findings support the use of dynamic Bayesian CAPM specifications with persistent but mean-reverting beta processes.

Table 2. Cross-Sectional Statistics of Bayesian Dynamic CAPM Parameters

Statistic	Mean β	Mean MAP β	$SD(\beta)$	Mean HDI Width	φ	$Prob(\|\varphi\| < 1)$
Min	0.209	0.169	0.010	0.584	-0.552	0.962
Q10	0.462	0.465	0.019	0.726	-0.382	0.993
Mean	0.804	0.806	0.155	1.622	0.034	0.996
Median	0.779	0.784	0.100	1.561	0.027	0.997
Q90	1.190	1.197	0.395	2.655	0.417	1.000
Max	1.458	1.463	0.650	3.548	0.841	1.000
SD	0.311	0.315	0.161	0.777	0.318	0.006

Notes: The table reports cross-sectional descriptive statistics for posterior beta estimates and persistence parameters obtained from Bayesian AR(1) stochastic beta CAPM models. Mean β and $SD(\beta)$ denote time-series averages of posterior beta means and posterior beta standard deviations for individual firms. Mean HPDI Width represents the average width of the 95% HPDI for beta estimates. The parameter φ denotes the autoregressive coefficient in the stochastic beta process, while $Prob(|\varphi| < 1)$ denotes posterior probabilities of stationary and mean-reverting beta dynamics.

Conclusions

This study investigates the stability of CAPM beta coefficients for the largest and the most liquid companies on the Warsaw Stock Exchange (WSE) using monthly data for the period January 2011 – December 2025. The analysis combines rolling-window estimation, Bayesian structural breakpoint models, and Bayesian dynamic CAPM specifications with stochastic AR(1) beta processes.

The results provide strong evidence that systematic risk exposures on the WSE vary substantially over time. Rolling-window estimates and dynamic Bayesian models reveal pronounced heterogeneity across firms and sectors, particularly during periods of increased market uncertainty such as the COVID-19 pandemic and the subsequent energy and inflation shocks. Growth-oriented and cyclical firms exhibit the strongest beta instability, whereas banking sector companies maintain relatively high but more stable market exposure.

The breakpoint analysis suggests that systematic risk evolves gradually rather than through sharply defined structural shifts. While evidence for discrete beta breakpoints remains relatively weak, considerably stronger support is obtained for structural changes in residual variance, especially during major crisis periods. This indicates that episodes of market stress affect primarily the volatility structure of stock returns rather than generating abrupt and permanent changes in market exposure. The dynamic Bayesian CAPM models additionally show that beta processes are persistent but stationary, strongly rejecting random-walk-type behavior of systematic risk. The results therefore support the use of dynamic and mean-reverting beta specifications in empirical asset pricing models for emerging equity markets.

The findings suggest that assuming constant beta coefficients may lead to misleading estimates of systematic risk, particularly during periods of increased macroeconomic uncertainty. Dynamic Bayesian approaches may therefore provide a more adequate framework for risk measurement, portfolio management, and cost-of-capital estimation on the Warsaw Stock Exchange.

The study focuses exclusively on single-factor CAPM specifications and monthly return data. Future research could extend the analysis toward dynamic multifactor asset pricing models, stochastic volatility frameworks, and sector-specific systematic risk dynamics.

Acknowledgment

Research project supported by AGH University of Krakow through an institutional subsidy for maintaining research capacity (Research Capacity Grant) and by program „Excellence initiative – research university" for the AGH University of Krakow.

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