Semibeta asset pricing model in the Korean market: An extension study

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Abstract
This study extends the four-semibeta asset pricing model to the Korean stock market, including KOSPI, KOSDAQ and the overall market. Using updated data, it evaluates the model's robustness for more recent market movements, including the analysis of financial crises, such as COVID-19 and the 2022 market decline. Findings show two semibetas consistently significant across all market variants, but the model's performance during recent crises is less clear, indicating potential limitations and area for further research.

1. Introduction

The exploration of downside deviation introduces a transformative perspective in financial studies, shifting the traditional understanding of risk associated with financial assets. Historically, risk has been predominantly defined by the volatility or variance of returns, focusing on how significantly returns deviate from the mean. This traditional measure, while useful, does not fully encapsulate investor behavior, particularly the differing attitudes towards positive (upside) and negative (downside) variances in returns. Investors typically perceive losses, or downside volatility, as a genuine risk, whereas upside volatility is often viewed as beneficial, not risky.

This critical observation challenges the conventional practice of equating total variance with risk, as it erroneously incorporates both upside and downside variances, even though upside variance is generally considered a reward by investors. The notion of separating variance into upside and downside components facilitates a more nuanced analysis of investment risk. This conceptual evolution has led to the practical application of classical financial theories within newer frameworks, such as the adaptation of Modern Portfolio Theory (MPT) (Harry Markowitz, 1952) to Post Modern Portfolio Theory (PMPT) (Rom and Ferguson, 1993; Sortino and van der Meer, 1991) and the refinement of the Capital Asset Pricing Model (CAPM) beta (Sharpe, 1964) into separate downside and upside betas (Ang et al., 2006).

These theoretical advancements have rejuvenated classic, albeit simplistic, theories rooted in the mean-variance framework, allowing them to better reflect reality by focusing on downside volatility. This shift is epitomized by the mean-semivariance framework, which more accurately captures the risk dynamics relevant to investors.

A recent significant progression in this field is the work by Bollerslev et al. (2022), which introduces a nuanced four-way decomposition of CAPM beta into four ‘semibetas’ based on the directional movements of both market and individual stock returns. This method offers a more detailed examination of CAPM beta's explanatory power, providing insights into the specific components of risk that affect asset pricing.

The four-way decomposition of CAPM beta proposed by Bollerslev et al. (2022) has been validated in various international contexts, including the Korean stock market (Chu, 2022), Australian stock market (Li et al., 2024), and the broader international market (Amaya et al., 2023).

This study seeks to further investigate the robustness and applicability of the four-semibeta pricing model in Korea, particularly in light of recent economic events. The research will replicate and extend the analysis originally applied to the Korean stock market in Chu (2022), incorporating additional data from the years 2021 to 2024. This update aims to assess the model's reliability over a newer and possibly more volatile period. Additionally, the study expands the scope of the analysis from the Korea Composite Stock Price Index (KOSPI) to include the Korean Securities Dealers Automated Quotations (KOSDAQ) and the overall Korean stock market, thereby testing the model across a more diverse set of market conditions.

Furthermore, this research expands on the examination of the four-semibeta model’s effectiveness during financial crises, as conducted in Chu (2022). Specifically, it considers the recent impacts of the COVID-19 pandemic and the 2022 stock market decline. The primary objective of this study is, therefore, to evaluate the continued relevance and accuracy of the four-semibeta model in the Korean stock market, considering diverse market conditions and recent financial disruptions.

2. Literature Review

CAPM stands as a foundational framework in asset valuation, proposing a linear relationship between the expected excess returns of an asset and its market-related risk, denoted by the CAPM beta. This model has spurred a host of follow-up studies and adaptations, reflecting its central role in financial theory.

Building on CAPM, Fama and French (1992) introduced a significant extension with their three-factor model, which incorporates size and value factors alongside the traditional CAPM beta to enhance asset pricing accuracy. The success of this model paved the way for further multi-factor models, such as the four-factor model including a momentum factor (Carhart, 1997), and the five-factor model including profitability and investment factors (Fama and French, 2015).

While these developments sought to refine CAPM by introducing additional external risk factors to a multi-factor framework, other researchers focused on refining the CAPM beta itself to capture more nuanced aspects of risk. Ang et al. (2006) explored dividing the CAPM beta into upside and downside components based on the sign of market returns. Their findings revealed that downside beta, which reflects investor responses to negative market movements, provided a stronger explanation of asset returns than the traditional CAPM beta. This insight supported the aforementioned notion that investor aversion to negative volatility might more accurately represent the concept of risk than a general sensitivity to overall volatility.

Furthering this line of inquiry, Bollerslev et al. (2022) identified clear asymmetric dependencies between stocks and market returns through the four-way decomposition of CAPM beta. Consistent with the findings from Ang et al. (2006), only the two semibetas in relation with market downturns were statistically significant. Yet, the two had opposing contributions to asset returns where the semibeta derived from negative market and negative asset returns predicted higher future returns whereas that from negative market and positive asset returns predict lower future returns.

The application of the four-semibeta model to the Korean stock market (Chu, 2022) supported these findings, even demonstrating that three out of four semibetas carry significant risk premiums. In the Korean stock market, the semibeta relating positive stock returns with positive market returns also emerged as significant, alongside the two semibetas associated with market downturns. Furthermore, the study found that the semibeta from negative market and negative asset returns is significant only during financial crisis periods, and that overall risk premiums for the semibetas are greater in magnitude during such times.

4. Method

4.1 Variables

The primary variables in this study are the four semibetas that decompose the traditional CAPM beta. The equations for the four semibetas are defined as follows:

$$
\begin{aligned}
\beta_{t,i}^{N} &= \frac{\sum_{d=1}^{D_t} r_{t,d,i}^{-} m_{t,d}^{-}}{\sum_{d=1}^{D_t} m_{t,d}^{2}}, \quad \beta_{t,i}^{P} = \frac{\sum_{d=1}^{D_t} r_{t,d,i}^{+} m_{t,d}^{+}}{\sum_{d=1}^{D_t} m_{t,d}^{2}}, \\
\beta_{t,i}^{M+} &= \frac{-\sum_{d=1}^{D_t} r_{t,d,i}^{-} m_{t,d}^{+}}{\sum_{d=1}^{D_t} m_{t,d}^{2}}, \quad \beta_{t,i}^{M-} = \frac{-\sum_{d=1}^{D_t} r_{t,d,i}^{+} m_{t,d}^{-}}{\sum_{d=1}^{D_t} m_{t,d}^{2}},
\end{aligned} \tag{1}
$$

For stock i, the return on the d-th day of month t is denoted as $r_{t,d,i}$, and the market return on the same day is represented by $m_{t,d}$. The month t comprises D_t trading days. The positive returns for the stock are calculated as $r_{t,d,i}^{+} = \max(r_{t,d,i}, 0)$, and the negative returns as $r_{t,d,i}^{-} = \min(r_{t,d,i}, 0)$. Similarly, the market's positive and negative daily returns are $m_{t,d}^{+} = \max(m_{t,d}, 0)$ and $m_{t,d}^{-} = \min(m_{t,d}, 0)$, respectively. Daily returns are determined by the change in closing prices relative to the closing price of the previous day.

In this manner, similar to how the CAPM beta is interpreted as a stock return's sensitivity to market returns, β_i^N quantifies how stock i's negative returns react to negative market fluctuations, β_i^P measures the response of stock i's positive returns to positive market movements, β_i^{M+} indicates how stock i's negative returns are influenced by positive market returns, and β_i^{M-} reflects the reaction of stock i's positive returns to negative market movements. For ease of interpretation in later regression analysis, the signs of the 'mixed semibetas' (β_i^{M+} and β_i^{M-}), which model beta values when stock and market returns are opposites, are flipped.

As shown below, the four semibetas provide a direct 'additive' decomposition of the CAPM beta:

$$\beta_{t,i} = \frac{\sum_{d=1}^{D_t} r_{t,d,i} m_{t,d}}{\sum_{d=1}^{D_t} m_{t,d}^2} = \beta_{t,i}^{N} + \beta_{t,i}^{P} - \beta_{t,i}^{M+} - \beta_{t,i}^{M-}. \tag{2}$$

The equations for calculating the four semibetas utilize the equation for realized betas, which Barndorff-Nielsen and Shephard (2004) demonstrated to converge to the true latent beta with sufficient observations per period:

$$\beta_{t,i} = \frac{\sum_{d=1}^{D_t} r_{t,d,i} m_{t,d}}{\sum_{d=1}^{D_t} m_{t,d}^2} \xrightarrow{p} \frac{Cov(r,m)}{Var(m)} \tag{3}$$

4.2 Data

The data used for analysis in this study is sourced from FnGuide. The study involves the analysis of three distinct samples:

1. The first sample includes all constituent stocks of KOSPI spanning from January 1980 to May 2024, with KOSPI used as the market index. This sample is used primarily for the replication of results from Chu (2022).
2. The second sample includes all constituent stocks of KOSDAQ spanning from July 1996 to May 2024, with KOSDAQ used as the market index.
3. The third sample includes all constituent stocks of the MKF2000 index spanning from January 2000 to May 2024. The MKF2000 index includes the top 2000 stocks of the Korean Exchange (KRX), encompassing both KOSPI and KOSDAQ constituents, and effectively serves as the benchmark index of the overall Korean stock market.

In each sample, monthly realized semibetas for each stock are calculated using daily returns data for the corresponding month. To account for biased calculations of semibetas, only months with at least 10 daily observations were sampled (Chu, 2022). To further account for outliers, the realized semibeta values are winsorized at the 1% and 99% thresholds.

Tables 1, 2, and 3 present the summary statistics and correlation matrices of the calculated semibetas for each sample.

Table 1
Summary statistics: KOSPI.

	β	β^N	β^P	β^{M+}	β^{M-}
Mean	0.71	0.52	0.58	0.20	0.19
Median	0.64	0.47	0.49	0.14	0.12
St.Dev.	0.68	0.32	0.40	0.20	0.24
			Correlation matrix		
β	1.00				
β^N	0.61	1.00			
β^P	0.59	0.14	1.00		
β^{M+}	-0.30	0.06	0.23	1.00	
β^{M-}	-0.32	0.10	0.20	0.36	1.00

This table displays the summary statistics of monthly realized semibetas calculated with daily stock returns. Data sample consists of all KOSPI constituent stocks from January 1980 to May 2024.

Table 2
Summary statistics: KOSDAQ.

	β	β^N	β^P	β^{M+}	β^{M-}
Mean	0.77	0.63	0.63	0.25	0.25
Median	0.71	0.56	0.51	0.17	0.13
Std.Dev.	0.78	0.42	0.48	0.26	0.36
			Correlation matrix		
β	1.00				
β^N	0.60	1.00			
β^P	0.56	0.12	1.00		
β^{M+}	-0.24	0.07	0.34	1.00	
β^{M-}	-0.32	0.11	0.24	0.37	1.00

This table displays the summary statistics of monthly realized semibetas calculated with daily stock returns. Data sample consists of all KOSDAQ constituent stocks from July 1996 to May 2024.

Table 3
Summary statistics: Overall.

	β	β^N	β^P	β^{M+}	β^{M-}
Mean	0.76	0.63	0.64	0.26	0.25
Median	0.72	0.58	0.53	0.19	0.14
Std. Dev.	0.78	0.38	0.47	0.26	0.34
		Correlation matrix			
β	1.00				
β^N	0.60	1.00			
β^P	0.53	0.14	1.00		
β^{M+}	-0.31	0.07	0.29	1.00	
β^{M-}	-0.36	0.09	0.24	0.36	1.00

This table displays the summary statistics of monthly realized semibetas calculated with daily stock returns. Data sample consists of all MKF2000 index constituent stocks from January 2000 to May 2024.

The KOSDAQ sample shows higher mean semibeta values across the board, reflecting the more volatile characteristics of the KOSDAQ market compared to KOSPI. It is also notable that the overall market had semibeta values similar to those of KOSDAQ rather than those of KOSPI. The most significant difference was in β^N, where the mean value for the overall market was more than 0.1 higher than that of the KOSPI. Since much of the highest valued companies in Korea are listed in KOSPI, these statistics highlight the increase in overall volatility of KOSPI in the latter half of its existence (from 2000), particularly due to the increase in stock return sensitivity to the market during negative return periods. The correlations between semibetas in the different samples were largely similar.

4.3 Method

The method of empirical analysis employed in this study is a Fama and Macbeth (1973) style regression as shown below:

$$r_{t+1,i} = \theta^C_{t+1} + \theta^N_{t+1}\beta^N_{t,i} + \theta^P_{t+1}\beta^P_{t,i} + \theta^{M+}_{t+1}\beta^{M+}_{t,i} + \theta^{M-}_{t+1}\beta^{M-}_{t,i} + \epsilon_{t+1,i} \tag{4}$$

Since the semibetas are predicted using the realized semibeta equation, the first step of the traditional Fama-Macbeth regression, which involves predicting the overall beta of each stock using a time-series regression, is skipped.

Utilizing the calculated realized semibetas, the second step of the Fama-Macbeth regression involves performing a rolling cross-sectional regression of the semibetas on $r_{t+1,i}$ (monthly return of stock i in month $t+1$) to estimate the risk premium for each semibeta. Unlike the traditional Fama-Macbeth regression, however, since our semibeta values are time-variant, with changing monthly estimates, it must be noted that the rolling cross-sectional regression is applied to a moving subset of data for both the response ($r_{t+1,i}$) and predictor ($\beta^N, \beta^P, \beta^{M+}, \beta^{M-}$) variables.

The final step of the Fama-Macbeth regression remains the same, where we obtain the final estimate of the risk premium coefficients by taking a time-series average of the estimated coefficients:

$$\hat{\theta}^k = \frac{1}{T}\sum_{t=1}^{T}\hat{\theta}_{t+1}^k, \tag{5}$$

The standard error for $\hat{\theta}$ is calculated in the same manner as Chu (2022), utilizing the Newey and West (1987) robust standard error with the number of lags determined by the formula $0.75T^{1/3}$ from Stock and Watson (2015).

5. Result

Table 4 presents the combined results of the Fama-Macbeth regression applied to the three samples. The first two rows report the metrics from the traditional CAPM model, while the rows below show the results from the proposed four-semibeta model.

Table 4
Fama-Macbeth regressions.

	KOSPI	KOSDAQ	Overall
Constant	1.17***	2.18**	1.03**
	(3.18)	(2.29)	(2.29)
β	0.26*	0.05	0.38**
	(1.69)	(0.12)	(2.57)
R^2 (%)	2.98	1.37	1.10
Constant	1.17***	2.87***	1.52***
	(3.33)	(3.34)	(3.65)
β^N	1.08**	0.60	0.23
	(2.14)	(0.62)	(0.60)
β^P	-0.84**	-1.68**	-0.62**
	(-2.69)	(-2.55)	(-2.04)
β^{M+}	1.12*	1.16	0.46
	(1.85)	(1.24)	(0.62)
β^{M-}	-0.93	-2.05***	-2.04***
	(-1.67)	(-2.93)	(-5.42)
R^2 (%)	6.93	3.92	3.20

This table displays the Fama-Macbeth regression results for the three market samples (KOSPI, KOSDAQ, Overall). MKF2000 index is used as a benchmark for the overall market. The displayed coefficient estimates are monthly risk premium (%) for each semibeta. The reported R-squared is a time-series average of all R-squared attained from rolling cross-sectional regressions. Newey–West robust t-statistics are shown in parentheses. ***, **, and * indicate significance at 1%, 5%, and 10% levels respectively.

The first column of the table displays the regression results for the KOSPI sample. In this sample, the traditional CAPM beta is not statistically significant. However, the four-semibeta model shows that β^N and β^P are statistically significant, with risk premiums of 1.08% and -0.84%, respectively. This differs from Chu (2022), which found β^N, β^P, and β^{M-} to be significant, highlighting a discrepancy in the significance of β^{M-}.

The second and third columns of the table show the regression results for the KOSDAQ and overall market samples. In the KOSDAQ sample, the traditional CAPM beta lacks statistical significance, whereas the overall sample demonstrates a significant CAPM beta. For both samples, the four-semibeta model indicates that two semibetas β^P and β^{M-} are significant. It is noteworthy that only the semibetas derived from positive stock returns were identified as significant. This contrasts with Bollerslev et al. (2022), which found the semibetas associated with negative market returns β^N and β^{M-} to be significant in the US market. This difference suggests varying investor behaviors: Korean investors might prioritize stock-level returns, especially when positive, while US investors might place more importance on market returns, particularly during downturns. The significance of β^{M-} in both markets underscores its robustness and international applicability.

The estimated risk premiums for both β^{P} and β^{M-} are negative. This aligns with the notion that investors typically prefer stocks with positive returns, hence no excess reward is associated with holding such stocks. This result is consistent with the fundamental high-risk high-reward and low-risk low-reward mechanisms of the financial market. Only having significant semibetas with negative risk premium also allows for an interesting interpretation of the Korean stock market, where it could highlight the fact that only negative risk premium occurs in a statistically predictable manner while positive risk premium is nearly random and cannot be modeled with significant confidence. This could be due to the highly event-driven return profiles of positive excess returns in the Korean stock market.

In an extended analysis, Chu (2022) examined the performance of the four-semibeta model during financial crises in Korea, including the Asian financial crisis (1997-1998) and the global financial crisis (2007-2009). The analysis of crisis and non-crisis subsamples revealed that β^{P} and β^{M-} are significant during both periods, while β^{N} is only significant during crisis periods. The overall magnitude of risk premiums was higher during crisis periods.

To test the model's performance during more recent financial crises, this study uses data from the COVID-19 pandemic (January 2020 - March 2020) and the 2022 stock market decline (January 2022 - December 2022) as the crisis subsample. Correspondingly, periods from January 2020 to May 2024 excluding these crisis subperiods are considered non-crisis periods for this study.

Table 5
Fama-Macbeth regressions for crisis subsamples

	Non-crisis (KOSPI)	Crisis (KOSPI)	Non-crisis (KOSDAQ)	Crisis (KOSDAQ)	Non-crisis (Overall)	Crisis (Overall)
Constant	1.95**	-2.23	2.36***	-1.73	2.21***	-2.13
	(2.22)	(-1.66)	(3.33)	(-1.32)	(2.97)	(-1.47)
β^N	-0.34	-1.33	-1.18**	-0.51	-0.73*	-0.82
	(-0.46)	(-1.14)	(-2.22)	(-0.38)	(-1.75)	(-0.78)
β^P	1.02**	-0.28	0.57	-2.18**	0.45	-1.22
	(2.48)	(-0.37)	(1.14)	(-2.22)	(1.00)	(-1.27)
β^{M+}	-0.87	3.13	-0.42	1.41	0.13	2.54
	(-0.87)	(0.73)	(-0.26)	(0.39)	(0.11)	(0.66)
β^{M-}	-0.48	-4.25**	-0.56	-1.48	0.27	-1.43
	(-0.65)	(-2.00)	(-1.34)	(-0.74)	(0.80)	(-1.08)
R^2 (%)	3.00	5.79	1.95	3.58	1.84	3.92

This table displays the Fama-Macbeth regression results for the crisis and non-crisis subsamples of each market sample (KOSPI, KOSDAQ, Overall). MKF2000 index is used as a benchmark for the overall market. The displayed coefficient estimates are monthly risk premium (%) for each semibeta. The reported R-squared is a time-series average of all R-squared attained from rolling cross-sectional regressions. Newey–West robust t-statistics are shown in parentheses. ***, **, and * indicate significance at 1%, 5%, and 10% levels respectively.

Table 5 displays the regression results for the crisis subsample analysis. Contrary to findings of Chu (2022), the significance of the four semibetas is less clear for the subsamples in this study. The analysis considered both crisis and non-crisis periods for all three market samples (KOSPI, KOSDAQ, Overall market). None of the six resulting subsamples showed two or more significant semibetas. The crisis period subsample for the overall market showed the poorest performance, with no significant semibetas. Additionally, there was no observable pattern in the significance of semibetas based on whether the period was a crisis or non-crisis. For instance, while the KOSPI crisis period showed β^{M-} as significant, the KOSDAQ crisis period highlighted β^P as significant, and the overall market crisis period showed no significant semibetas.

These underwhelming results may be attributed to the drastic and sudden market decline caused by the COVID-19 pandemic. Unlike previous financial crises, including those analyzed in Chu (2022), COVID-19 induced a sharp yet short period of negative returns in financial markets. This abrupt effect might have caused the inclusion of the COVID-19 period to act as an outlier in the crisis period analysis. A simple further analysis revealed that excluding the COVID-19 period from the crisis subsample improved the performance of semibetas in the KOSDAQ market, resembling results from Chu (2022). However, the other two markets showed little change in performance, and this analysis still leaves questions about the poor performance of non-crisis samples post-2020.

6. Conclusion

This study conducts a comprehensive analysis of applying the four semibeta model to the Korean stock market. The model's performance is evaluated using updated market data, and its applicability is tested across different market segments, including the KOSDAQ and the overall Korean stock market. The findings reveal that, although the specific types of semibetas varied, two semibetas were consistently significant in estimating stock returns across all three market samples.

The analysis demonstrates that different types of semibetas play a significant role in stock return estimation within the KOSPI, KOSDAQ, and overall Korean stock market. This underscores the model's robustness and adaptability across various market conditions.

The lack of significance found in semibetas during recent financial crises, particularly the COVID-19 pandemic, suggests that further investigation is warranted. Understanding the underlying reasons for this discrepancy could provide valuable insights into the model's limitations and potential improvements. Given the short duration of the financial downturn caused by COVID-19, utilizing high-frequency data to estimate daily realized semibetas could be a promising approach. This method may offer a more granular view of the model's performance during rapid market fluctuations, such as those experienced during the COVID-19 crisis.

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