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Predicting Recessions and Information About Yield Curves and Stock Markets in Japan

Hokuto Ishii [a,*]

[a] *School of Policy Studies, Chukyo University, Aichi, Japan*

ABSTRACT

Using data from the Japanese government bonds and stock markets, this study examines the predictability of Japanese recessions based on a probit model with instrument variables. By decomposing the term spread into the expected short-term interest rate and the term premium, this study analyzes the relationship between the components of the term spread and recessions. The results show that the predictive power of the term spread for recessions has declined since 1999—when Japan began employing an unconventional monetary policy. Additionally, stock market capitalization relative to nominal GDP is a useful predictor of recessions.

KEYWORDS

Recession forecast; Term spread; Stock market capitalization; Yield curve

* Corresponding author: Hokuto Ishii
E-mail address: hishii@mecl.chukyo-u.ac.jp

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1. Introduction

Predicting recession is of interest to both households and policymakers. Several studies (Estrella and Hardouvelis, 1991; Estrella and Mishkin, 1997, 1998; Bernard and Gerlach, 1998; Moneta, 2005) reported that differences in long- and short-term interest rates (hereafter, term spread) are useful in predicting recessions, particularly in the U.S. and Europe. However, Hasegawa and Fukuta (2011) find that the term spread does not contain the information on future recession following the year 1996 in Japan. In particular, the implementation of the zero interest rate policy in 1999 and the quantitative easing policy in 2001 are major turning points in Japan's monetary policy. Since the implementation of the zero interest rate policy, commitment and quantitative easing policies that influence expected short-term interest rates have reduced the level of long-term interest rates (Okina and Shiratsuka 2004). Changes in the shape of the yield curve owing to monetary policy (particularly maintaining short-term interest rates near zero while lowering long-term interest rates and flattening the yield curve) limit the effectiveness of recession forecasting based on yield curves, particularly term spreads. Okimoto and Takaoka (2017) report the modest predictive power of term spreads for business cycles. Therefore, this study constructs a recession prediction model for Japan by extending the previous recession forecast model. Specifically, it decomposes the yield spread, analyzes the relationship between the components of the yield curve and recession probability, and forecasts a recession by employing stock market information as an additional variable.

First, following Hamilton and Kim (2002), this study decomposes term spreads into expected short-term interest rates and term premiums. This allows us to analyze the relationship between future monetary policy expectations and long-term interest rate recessions. Next, I improve the accuracy of recession forecasts using stock market information in addition to term spreads. Stock market information is a reasonable variable for predicting future business fluctuations because it theoretically reflects firms' expected cash flows. I use stock market capitalization and trading volume, as defined by Erdogan, Bennett, and Ozyildirim (2015), as variables related to the stock market.

The remainder of this paper is organized as follows: Section 2 presents the models used to forecast a future recession in Japan. Section 3 presents the in-sample and out-of-sample forecasts of future recessions in Japan for each model and discusses the findings. Finally, Section 4 concludes the study.

2. Models

This study employs a probit model to construct the relationship between recession probability and term spreads.

$$P(X_t = 1) = \Phi\left(\alpha_j + \beta_{SPREAD,j} \times SPREAD_{t-j}\right) \tag{1}$$

where X_t is a dummy variable representing an economic recession or expansion. $X_t = 1$ when the economy is in recession, $X_t = 0$ when the economy is in expansion at time t, and $\Phi(.)$ where denotes the cumulative standard density function. j denotes the time lag, and the time frequency is quarterly. This study computes SPREAD as the difference between the interest rates of Japanese government bonds with 10- and 1-year maturity terms. Equation (1) is defined in Model 1.

As Hamilton and Kim (2002) demonstrate, SPREAD can be broken down into expected short-term interest rates and premium terms. The long-term interest rate with a time-varying term premium TP_t can be defined as follows:

$$i_t^{10} = \frac{1}{40}\sum_{k=0}^{39} E_t i_{t+k}^{1} + TP_t \tag{2}$$

where $i_t^{10}$and i_t^1 denote the 10-year (i.e., long-term interest rate) and 1-year interest rates (i.e., short-term interest rate), respectively. $\frac{1}{40}\sum_{k=0}^{39} E_t i_{t+k}^1$ denotes the average market expectation of the short-term interest rate and TP_t represents the term premium, which includes both liquidity and risk premiums. Using Equation (2), I can rewrite SPREAD as follows[1]:

$$SPREAD_t = \left(\frac{1}{40}\sum_{k=0}^{39} E_t i_{t+k}^1 - i_t^1\right) + \left(i_t^{10} - \frac{1}{40}\sum_{k=0}^{39} E_t i_{t+k}^1\right) \tag{3}$$

where $SPREAD_t = i_t^{10} - i_t^1$. The first term on the right-hand side of Equation (3) is the difference between the expected short-term interest rate over the next 40-quarter period and the current rate (hereafter, expected). The second term is the term premium (TP).

Substituting Equation (3) into Equation (1), I can extend Equation (1) under the rational expectations hypothesis, as follows:

$$P(X_t = 1) = \Phi\left[\alpha_j + \beta_{Expected,j} \times \left(\frac{1}{40}\sum_{k=0}^{39} i_{t+k-j}^1 - i_{t-j}^1\right) + \beta_{TP,j} \times \left(i_{t-j}^{10} - \frac{1}{40}\sum_{k=0}^{39} i_{t+k-j}^1\right)\right] \tag{4}$$

Equation (4) is defined as Model 2. In this study, I consider the property of the error term of the probit model of Equation (4). The probit model can also be expressed using latent variables as follows: $P(X_t = 1|z_t) = P(\varphi_t^* > 0|z_t) = \Phi(.)$, where z_t represents the dependent variables and φ_t^* denotes an unobserved latent variable. Subsequently, the recession dummy X_t is linked to the latent variable as follows:

$$X_t = \begin{cases} 1 & if \ \ \varphi_t^* > 0 \\ 0 & if \ \ \varphi_t^* \leq 0 \end{cases} \tag{5}$$

To ensure simplicity, I assume $j = 0$. I can define the latent variable φ_t^* as

$$\varphi_t^* = \alpha + \beta_{Expected} \times \left(\frac{1}{40}\sum_{k=0}^{39} E_t i_{t+k}^1 - i_t^1\right) + \beta_{TP} \times \left(i_{t-j}^n - \frac{1}{40}\sum_{k=0}^{39} E_t i_{t+k}^1\right) + e_t \tag{6}$$

where e_t represents the error term that complies with the classical assumption. Let v_{t+n} denote the error in forecasting future short-term interest rates:

$$v_{t+n} = \frac{1}{40}\sum_{k=0}^{39} i_{t+k}^1 - \frac{1}{40}\sum_{k=0}^{39} E_t i_{t+k}^1 \tag{7}$$

Subsequently, by substituting (7) into (6), I obtain

$$\varphi_t^* = \alpha + \beta_{Expected} \times \left(\frac{1}{40}\sum_{k=0}^{39} i_{t+k}^1 - i_t^1\right) + \beta_{TP} \times \left(i_{t-j}^n - \frac{1}{40}\sum_{k=0}^{39} i_{t+k}^1\right) + u_t \tag{8}$$

where $u_t = e_t + (\beta_{TP} - \beta_{Expected})v_{t+n}$.

I estimate the model using the instrumental variables method. The instrumental variable method can be

[1] See Hamilton and Kim (2002) for details on the derivation.

employed under the conditions that the covariates are correlated with the error term while the instrumental variable remains uncorrelated with the error term. The error term u_t reflects the forecast error between the future and expected short-term interest rates and may be correlated with the expected short-term interest rate and the term premium. Therefore, this study employs the probit model with instrumental variables. Specifically, the expected short-term interest rate and the term premium are influenced by the current and past interest rates for each maturity, making them endogenous variables with respect to the interest rates. Short-term interest rates are considered a monetary policy variable, while long-term interest rates reflect expected future interest rates or inflation. Additionally, under the rational expectations hypothesis, all available information at time t is reflected in the financial markets, and current interest rates at time t are uncorrelated with the error term u_t. Therefore, the 1-year and 10-year interest rates are used as instrumental variables.

The study focuses on recessions and term spreads. The information contained in Japanese term spreads is limited in predicting business cycles (Okimoto and Takaoka 2017). Nevertheless, according to Erdogan, Bennett, and Ozyildirim (2015), both interest rate and stock market information are useful for forecasting recessions. Following their study, I extend Equation (4) to incorporate macro-depth (MD)[2] and macro-liquidity deviation (MLD). MLD is the first-order difference of the residuals[3], with ML (trading volume to GDP) as the dependent variable and MD as the independent variable. The extended model is expressed as follows:

$$P(X_t = 1) = \Phi\left[\alpha_l + \beta_{Expected,j} \times Expected_{t-j} + \beta_{TP,j} \times TP_{t-j} + \beta_{DMD,l} \times DMD_{t-l} + \beta_{MLD,l} \times MLD_{t-l}\right] \quad (9)$$

where j and l denotes the time lag. DMD_t is the first difference in MD. Equation (9) is defined in Model 3.

3. Results and Discussion

3.1. Data

This study uses Japanese government bonds and stock market data. Yield data are obtained from the Japanese Ministry of Finance and Refinitiv EIKON.[4] This study calculates the spot rates by using the boot strapping method.[5] Stock market capitalization and trading volume data are obtained from the Japan Exchange Group database.[6] Nominal gross domestic product (GDP) data and recession dates are available on the Japan Cabinet Office website. Quarterly data are used for this study. After 2013, the Bank of Japan employed quantitative and qualitative monetary easing, and COVID-19 shocks occurred. For these reasons, the analysis period in this study is from 1994: Q1 to 2012: Q1.

3.2. In-sample-fit

This subsection shows the estimation results of each model in Section 2. Table 1 shows the estimation results of Model 1. From Table 1, the model with the term spread of 8-period lag is the best fit, so the expected short-term

[2] Erdogan Bennett, and Ozyildirim (2015) defined the ML and MD as the ratio of market capitalization to nominal GDP and the ratio of trading volume to the nominal GDP, respectively.
[3] To control for the look-ahead bias in this study, MLD is estimated using recursive rolling regression analysis based on information available up to time t. The MLD for 1994: Q2 is estimated using data from 1985: Q1 to 1994: Q2. Since then, MLD has been estimated by extending the sample period for each estimation period.
[4] This study employs the data available on the Ministry of Finance website (https://www.mof.go.jp/jgbs/reference/interest_rate/index.htm) and Refinitiv EIKON.
[5] Technically, the 6-month JGB should be used as the initial value for the sequential calculation of spot rates because JGBs are 6-month compounded. However, in this study, JGBs are treated as 1-year compounded when calculating spot rates for 2-year and beyond as an approximation, except for the calculation of 1-year spot rates.
[6] Data are available on the Japan Exchange Group website (https://www.jpx.co.jp/markets/statistics-equities/misc/index.html).

interest rate term and the term premium terms for the 8-period lag are used in the subsequent estimation.

Table 1. Average marginal effects of Equation (1).

Lags(j)	$\beta_{SPREAD,t-j}$	Pseudo-R^2	Number of observations
1	−0.212* (0.109)	0.05	71
2	−0.119 (0.107)	0.02	70
3	−0.023 (0.106)	0.00	69
4	0.043 (0.109)	0.00	68
5	0.121 (0.107)	0.02	67
6	0.196* (0.101)	0.05	66
7	0.262*** (0.090)	0.10	65
8	0.345*** (0.063)	0.18	64
9	0.327*** (0.068)	0.16	63
10	0.292*** (0.081)	0.12	62
11	0.237*** (0.092)	0.07	61
12	0.182* (0.101)	0.04	60

*Notes: Table 1 shows the average marginal effect of Model 1. The values in parentheses are robust standard errors. Asterisks ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10% levels, respectively. In all the estimation results, the expected and TP are 8-period lags.*

Table 2 shows the estimation results of Model 3. The parameters are average marginal effects. From the pseudo log-likelihood, the models using stock market data for the 1- and 7-period lags are a good fit for the in-sample-fit. These models also show contrasting signs of the DMD parameters. The sign of the 1-period lag DMD parameter is negative, meaning that a 1% increase in DMD lowers the recession probability by 2.2%. In contrast, the DMD parameter is positive at the 7-period lag, indicating that a 1% increase in the DMD increases the recession probability by 2%. The estimation results in Table 2 suggest a cyclical relationship between stock market capitalization and recession probability.

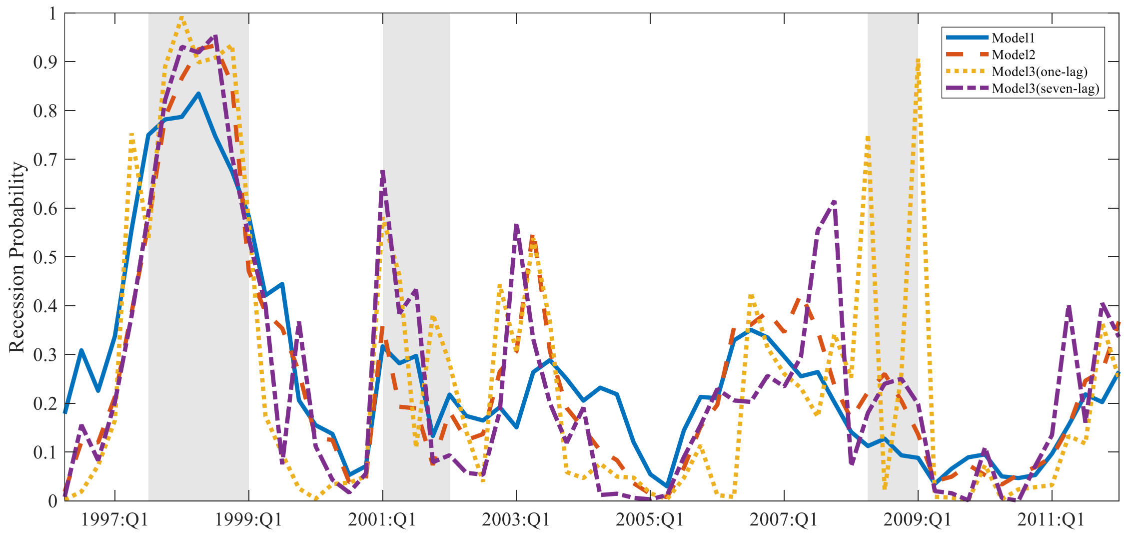
Given that each variable increases from the median to third quartile, the increases in the expected short-term interest rate, term premium, and DMD are approximately 0.25%, 0.37%, and 5.2%, respectively. When expected short-term interest rates and term premiums increase from the median to the third quartile in models based on the DMD and MLD of 1-period lag, the expected short-term interest rates and term premiums increase the recession probability by 12.1% and 8.2%, respectively. By contrast, a 5.2% increase in the DMD of the 1-period lag is associated with an 11.5% decrease in the probability of recession. By contrast, a 5.2% increase in DMD contributes to a 10.4% increase in the recession probability from the model estimates based on the DMD of a 7-period lag. An increase in DMD decreases the probability of recession in the short run but predicts recession in the long run (increases the probability of recession). Consistent with prior studies (Hasegawa and Fukuta, 2011; Erdogan, Bennett, and Ozyildirim, 2015), this study found that stock market information is useful in predicting recessions.

Figure 1 shows the estimated recession probabilities for Models 1, 2, and 3. Comparing the predicted recession probabilities of Model 1 and Model 2 in Figure 1, the accuracy is not high due to the look-ahead bias, and there is no significant difference between the predicted values of Model 1 (term spread only model) and Model 2. This is because short-term interest rates have remained low in Japan, which has adopted an ultra-low interest rate policy for a long time, and therefore the expected value of short-term interest rates has also remained low, and the forecast error is considered to be small.

Table 2. Average marginal effects of Equation (9).

Lags(l)	$\beta_{Expected,t-8}$	$\beta_{tp.t-8}$	$\beta_{DMD,t-l}$	$\beta_{MLD,t-l}$	Pseudo log-likelihood	Number of observations
1	0.484*	0.366*	−0.022***	55.533	−94.869	64
	(0.255)	(0.209)	(0.066)	(36.538)		
2	0.676***	0.514***	−0.019***	24.278	-98.349	64
	(0.226)	(0.175)	(0.007)	(35.644)		
3	0.740***	0.570***	−0.016**	19.442	-99.992	64
	(0.236)	(0.184)	(0.007)	(36.037)		
4	0.830***	0.644***	−0.021***	−0.429	-98.027	64
	(0.276)	(0.209)	(0.008)	(37.415)		
5	0.963***	0.721***	−0.010	17.018	-101.803	64
	(0.288)	(0.216)	(0.007)	(44.272)		
6	0.866***	0.634***	0.005	−9.552	-98.955	64
	(0.302)	(0.235)	(0.009)	(50.392)		
7	0.786**	0.572**	0.020*	−47.050	-94.114	64
	(0.321)	(0.260)	(0.011)	(56.915)		
8	0.812**	0.620**	0.017	−22.266	-98.106	64
	(0.321)	(0.246)	(0.012)	(51.496)		

*Notes: Table 2 shows the average marginal effect of Model 3. The values in parentheses are robust standard errors. Asterisks ***, **, and * indicate statistical significance at the 1 %, 5 %, and 10% levels, respectively. In all the estimation results, the Expected and TP are 8-period lags. The instrument variables are 1- and 10-year interest rates.*



Note: Figure 1 shows the in-sample fit predictions of the three models from 1996: Q2 to 2012: Q1. The shaded parts in the figure indicate the recession periods in Japan.

Figure 1. In-sample-fit forecast of the recession probability.

For Model 3 in Figure 1, the recession probabilities predicted based on the DMD and MLD for the 1- and 7-period lag are shown. The shaded parts in the figure indicate the recession periods in Japan. Figure 1 shows that the power of term spreads to predict recessions has declined since 1999, when the BOJ employed the unconventional monetary policy. In contrast, models that incorporate stock market information accurately capture recessions. In particular, the first and second recession periods in Figure 1 appear to be associated with the increase in term spreads and recessions, while the third recession period appears to be associated with the decrease in term spreads and recessions. The results suggest that some structural change in the relationship between interest rates and recession may have occurred during this period.

The coefficient for DMD is statistically significant and negative, similar to the findings reported in Erdogan, Bennett, and Ozyildirim (2015). Market capitalization relative to GDP in Japan also reflects expected information about recessions. By contrast, the coefficient of the MLD is not statistically significant in this study's model, indicating that the Japanese stock market MLD measure cannot explain future recessions. Erdogan, Bennett, and Ozyildirim (2015) report that the MLD measure with a two-quarter lag in the U.S. stock market is useful for estimating U.S. recession probabilities; however, this study does not yield the same result for Japan. For example, Lehmann and Modest (1994) provide evidence that differences in the structure of the Japanese and U.S. stock markets are not a necessary condition for well-functioning financial markets. However, given the results of this study, it is necessary to examine the differences in the information possessed by the Japanese and U.S. stock markets.

3.2 Out-of-sample results

Finally, I compare the accuracy of the out-of-sample forecasts in the three models using the root mean square error, quadratic probability score, and log probability score. Due to data-availability constraints and estimation stability, the out-of-sample forecast period is set from 2006: Q4 to 2012: Q1. In the out-of-sample forecast, this study employs the 8-period lag of the expected short-term interest rates and term premium, and the 1-period lag of the DMD and MLD, as Model 3. Table 3 shows that Model 3 is superior in all prediction accuracy scores. Therefore, a model that incorporates stock market information is more accurate in predicting Japanese recessions after 2006, compared to a traditional spread-only model.

Table 3. Evaluation of forecast accuracy.

	Root mean square error	Quadratic probability score	Log probability score
Model 1	0.414	0.342	0.568
Model 2	0.455	0.413	0.675
Model 3	0.375	0.282	0.447

Note: Table 3 shows the root mean squared error, quadratic probability score, and log probability score. The forecast period included 22 periods from 2006: Q4 to 2012: Q1. Model 3 is estimated based on the DMD and MLD of the one-period lag.

4. Conclusions

Since 1999, when Japan employed the unconventional monetary policy, the recession-predicting power of Japan's term spread has declined. This study decomposes the term spread into two factors and shows that using a model that incorporates stock market information improves the accuracy of recession forecasts. In particular, the expected short-term interest rate and term premium, while having explanatory power for future recessions, have lost their predictive power for recessions since 2001. By contrast, stock market information is useful in predicting recessions. Future research should examine in detail the differences between Japan and the U.S. regarding the information reflected in stock market liquidity. Additionally, this study utilizes the future realized interest rate as a variable under the rational expectations hypothesis. However, despite limitations in data availability and rigorous calculations, future studies are expected to use only variables available at the present time as the expected short-term interest rate.

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Conflict of interest

The author declares that there are no relevant financial or non-financial competing interests to report.

Author contributions

All investigations, analysis, and writing for this study were done solely by Hokuto Ishii.

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