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Abstract

Several authors have documented that the yield spread, defined as the difference between long-term and short-term interest rates, is a powerful leading indicator of real output growth in a number of OECD countries. This paper compares the predictive power of the yield spread and OECD forecasts for real output growth in the seven large industrialized countries. The results strongly suggest that combining the information in forecasts and the yield spread could result in significant improvements of predictive power for several countries including the U.S. and Germany.

Keywords: Yield spreads, leading indicators, band spectrum regressions, evaluation of forecasts.

1. Introduction

Financial market variables have traditionally been popular as leading indicators of output fluctuations in industrialized economies. Building on earlier empirical work by Sims (1980), a number of authors have recently studied the predictive power of interest rates for real economic activity in the U.S. (Harvey, 1988; Friedman and Kuttner, 1989; Stock and Watson, 1989; Bernanke, 1990; Estrella and Hardouvalis, 1991). One of the striking findings of these papers is that the slope of the yield curve or the yield spread -- that is, the difference between the long-term and the short-term interest rate -- provides a powerful leading indicator of fluctuations in U.S. real output growth. Extending the findings to the seven large (G-7) industrialized countries, Harvey (1991) reports that the yield spread accounts for a substantial portion of the variation in future real output growth in several G-7 countries.

In this paper I use time-domain and frequency-domain regressions to study the predictive power of macroeconomic forecasts and the yield spread for real output growth in the G-7 countries. The forecasts examined are semi-annual projections of real output growth published in the <u>OECD</u>

Economic Outlook over the time period 1968-1990. The OECD forecasts are likely to be representative of professional macroeconomic forecasts for the G-7 countries over the sample period under study. My purpose is to provide answers on two questions. First, does the yield spread contain information about future output movements not captured by macroeconomic forecasts? Second, is the information in macroeconomic forecasts and the yield spread relevant for predicting low-frequency as well as high-frequency movements in real output growth?

The impressive predictive power of the yield spread documented by several authors raises the question whether forecasts based on yield spread movements can provide substitutes for the more elaborate but also more expensive forecasts derived from structural econometric models. Harvey (1989), for example, shows that forecasts of U.S. real GNP growth based on lagged movements in the yield spread are in general not inferior to the forecasts published by well-known U.S. forecasting services such as Data Resources, Inc., or Wharton Econometric Forecasting Associates, Inc. But if two forecasts exhibit similar accuracy in tracking real output growth, the information in the forecasts may still be partly independent and may therefore be usefully combined to provide more accurate forecasts. A first goal of this paper is to evaluate whether combining the information provided by the OECD forecasts and the yield spread could result in improved predictive power.

It is common practice in the time domain to evaluate the predictive power of forecasts over different sample periods. A conceptually similar forecasting evaluation procedure can be implemented in the frequency domain. Instead of evaluating the predictive power of a forecast series over different sample periods, predictive power is evaluated across different frequency ranges. From the point of view of frequency-domain analysis a time series is interpreted as the sum of cycles with different time lengths. Low-frequency movements in the series are usually interpreted as cycles taking more than two years to complete whereas high-frequency movements comprise the cycles taking less than two years to complete. Plausibly, forecast producers as well as forecast users are likely to be more interested in accurate predictions of low-frequency rather than high-frequency movements in macroeconomic times series. In fact, some types of high-frequency movements in the data, for example seasonal fluctuations, are sometimes removed by data construction agencies even before the data are released to forecast producers. To shed light on the predictability of real output growth across different frequency ranges, the paper applies the band spectrum regression approach proposed by Engle (1974).

The rest of the paper is organized as follows. Section 2 outlines the forecasting evaluation procedures. Section 3 describes the data, and section 4 reports the empirical findings. Section 5 draws the conclusions.

2. Evaluation procedures

The empirical analysis of the paper is organized around the following regression equation:

$$A_t = \alpha + \beta F_t + \delta S_{t-1} + u_t. \tag{1}$$

The dependent variable A_t in regression (1) stands for the actual value of the real output growth rate. F_t is the OECD forecast of A_t issued at time t-1. S_{t-1} denotes the lagged yield spread defined as the difference between the long-term and the short-term interest rate at time t-1, and u_t is a regression error.

In the time domain, regression (1) is used to evaluate the predictive power of OECD forecasts and the lagged yield spread based on two types of statistical evidence: First, the t-statistics for the null hypotheses H_1 $\beta=0$ and H_2 $\delta=0$ provide a test whether the information in the forecast and lagged yield spread is useful for tracking movements in real output growth. In particular, if the lagged yield spread contains information not captured by the OECD forecast, the parameter δ should be statistically different from zero. Fair and Shiller (1990) use a similar test set-up to study the predictive power of different forecast series. Second, running regression (1) imposing the restrictions $\beta=0$ and $\delta=0$, respectively, provides two coefficients of determination (R^2) which can be compared across the two restricted regressions as well as with the R^2 of the unrestricted regression. This comparison of R^2-measures supplements the evidence from the statistical significance tests with a readily interpreted measure of predictive power.

Regression (1) does not allow for the possibility of higher lags of the yield spread to predict future output growth. I found for the semi-annual data used in this paper that higher lags of the yield spread were individually insignificant at the 1 percent significance level for all G-7 countries. For some countries, additional lags of the yield spread increased the adjusted R^2-statistics by very small increments. Because none of the conclusions of the paper is affected by allowing for more lags of the yield spread, I only report empirical results for the restricted regression (1).

Engle (1974) proposed frequency-domain or band spectrum regressions as a useful supplement for time-domain regression analysis. In the frequency domain, a time series is perceived as the sum of cycles with different time lengths. For semi-annual data, the high frequencies may be defined as cycles which take less than two years to complete whereas the low frequencies comprise the cycles which take more than two years to complete. The low-frequency range therefore covers fluctuations in real output growth usually associated with business-cycle fluctuations.

Time series plots may be useful to illustrate the possible insights provided by band spectrum regressions. Figure 1a plots the semi-annual output growth rate and the OECD forecasts of the growth rate for Germany. Figure 1b shows the output growth rate and the yield spread for the same country.[1] While there appears to be a positive relationship between output growth on the one hand and OECD forecasts and the yield spread on the other hand, this relationship is obscured by high-frequency movements in real output growth. Band spectrum regressions

1 The construction and sources of the data are described in section 3.

allow to consider the relationship between data series with high- or low-frequency fluctuations in the series excluded.

The evaluation of the predictive power of the yield spread and the OECD forecasts in the frequency domain is based on a transformed version of regression (1) suggested by Harvey (1978). Assume T denotes the number of observations. The time series data are transformed to the frequency domain by using a real finite Fourier transform matrix (Z) with dimension TxT, whose elements are defined as follows:

$$z_{ts} = T^{-1/2} \qquad t=1; \qquad s=1,...,T;$$
$$z_{ts} = (2/T)^{1/2}\cos[\pi t(s)/T] \qquad t = 2,4,6,...,T-1; \qquad s=1,...,T;$$
$$z_{ts} = (2/T)^{1/2}\sin[\pi t(s)/T] \qquad t = 3,5,7,...,T; \qquad s=1,...,T;$$

Omitting the constant term, equation (1) can be written in the frequency domain as:

$$A^* = \beta F^* + \delta S^* + u^* \qquad (2)$$

where $A^* = ZA_t$, $F^* = ZF_t$, $S^* = ZS_{t-1}$, and $u^* = Zu_t$.[2] These transformations create real valued variables with T entries which are indexed not by time, but by frequency. Because the

2 These transformations assume that the number of observations T is odd, as is the case in this paper. For T even, a slightly modified transformation matrix has to be used (see Harvey, 1978, p. 509).

sampling interval of the data is semi-annual, the highest frequency corresponds to cycles of one year length. The frequencies corresponding to cycles taking less than two years to complete will therefore cover half of the total frequency range. Band spectrum regressions for the low-frequency range correspond to running ordinary least squares (OLS) regressions using only the first half of the transformed data. The regressions for the high-frequency range are based on the second half of the transformed data series. If regression (2) is run with all frequencies included, it is equivalent to regression (1) in the time domain.

All the usual statistical properties of parameter estimates known from time-domain regressions will hold for the frequency-domain regressions subject to one caveat. Band spectrum regressions assume that the right-hand side regressors in equation (2) are orthogonal to the error term at all leads and lags. This strong orthogonality assumption is unlikely to hold exactly. For example, forecasters may adapt their forecasts based on the forecast errors in previous periods. In fact, small but positive cross-correlations between current forecasts and past forecast errors do occur for several of the countries studied below.

3. The data

The empirical analysis is based on semi-annual data for the G-7 countries: the U.S., Japan, Germany, France, Italy, the U.K., and Canada. The forecasts of semi-annual real output growth are taken from various issues of the OECD publication OECD Economic Outlook. The forecasts are mid-of-year or end-of-year projections of seasonally adjusted real output growth for the next half-year. The OECD did not issue a forecast for the U.K. in the December 1972 issue of the Economic Outlook. The observation for the first half year of 1973 was therefore omitted in the analysis of the U.K. data. The forecasts of semi-annual real output growth for all countries except France start in 1968.II.

Realized values for the level of semi-annual real output are taken from the OECD Economic Outlook database. The series are seasonally adjusted. The semi-annual growth rates are expressed at annual rates, i.e. if X_t denotes the level of the output series in half year t, then the semi-annual growth rate at an annual rate is given by $100[(X_t/X_{t-1})^2-1]$.

The interest rate series are taken from the OECD Main Economic Indicator database. Semi-annual interest rates were calculated as arithmetic averages of monthly interest rates. The monthly rates themselves are partly averages of daily quotations and partly end-of-month quotations. The Italian short-term interest rate series does not start before 1971. More descriptive information on the output and interest rate series is provided by the data appendix.

4. Empirical results

Table 1 contains the results for the time-domain regression (1). The table reports for each country the parameter estimates, the adjusted R^2 of the regression, the Ljung-Box Q-statistic for general serial autocorrelation, and the two adjusted R^2's for the regressions excluding the lagged yield spread (δ=0) and excluding the OECD forecast (ß=0), respectively.

Turning first to the R^2-measures in the last two columns of the table, the results show that for four of the G-7 countries (the U.S., Germany, Italy, and Canada), the lagged yield spread tracks real output growth almost as well or even better than the OECD forecasts. For the U.K. and Japan, there is no statistical evidence that the yield spread is correlated with future output growth. For France, the OECD forecasts track output growth better than the lagged yield spread.

The significance tests for the parameter estimates of the lagged yield spread suggest that the spread contains significant information about future output movements not captured by the OECD forecasts for five of the G-7 countries. As one would expect from the size of the restricted R^2-measures, the data for the U.K. and Japan do not reject the null hypothesis that the parameter of the lagged yield spread is zero. Also, with the exception of the U.K. and Japan, the unrestricted R^2-statistics exceed the restricted R^2-statistics for all countries.

The results for the U.K. reflect the unusual behavior of the yield curve over the sample period. The average value of the U.K. yield spread is 4.1 percent for the subsample 1968.II-1978.II but this value drops to -0.4 percent for the subsample 1979.I-1990.II. Thus, the mean of the yield curve is apparently not stationary over the sample period and is therefore unlikely to explain movements in the real output growth rate on a priori grounds. Interestingly, substituting the lagged German yield spread for the lagged U.K. yield spread results in a significant relationship between U.K. output growth and the lagged German yield spread. Japanese output growth is apparently unpredictable both from the point of view of OECD forecasts and from the point of view of the lagged yield spread.

Table 2 reports the band spectrum regression results for the low- and high-frequency range of the series. The subscripts of the parameter estimates indicate the frequency range of the regression. To conserve space, the estimates of the constant term are not reported. The results suggest two conclusions. First, the predictive power of the lagged yield spread is primarily concentrated at the low-frequency range of real output growth. Thus, the spread is a powerful predictor of business-cycle movements but not for short-term movements in real output growth. Second, the predictive power of OECD forecasts is also mainly concentrated at the low-frequency range of the data.

The band spectrum regression results also reveal substantial differences in the predictability of low- and high-frequency variation in output growth across countries. Both low- and high-frequency variation in real output growth appears to be unpredictable in Japan. These results presumably reflect the exceptionally smooth behavior of Japan's real output measure after the oil price shock of 1973. In contrast, Canadian output growth is predictable at all frequencies by both OECD forecasts and the lagged yield spread. Similar results are obtained for the U.S. The European members of the G-7 countries are grouped between the two extreme cases of Japan and Canada.

The finding that high-frequency movements in real output growth are predictable in Canada, the U.K. and the U.S. but not in the remaining G-7 countries may indicate different data construction procedures for real output measures across countries. From a different perspective, work using structural time series decomposition methods for aggregate output data has pointed out that high-frequency movements in U.S. output data look much less irregular than high-frequency movements in typical European output series (Clark, 1989).

5. Conclusions

Time-domain and frequency-domain regressions show that the yield spread is a powerful leading indicator of real output growth in several G-7 countries even if the regressions control for the information contained in macroeconomic forecasts. Symmetrically, the regressions show that macroeconomic forecasts contain valuable information about future output growth not captured by the yield spread variable. These findings suggest that pooling the information in macroeconomic forecasts and the yield spread could significantly improve predictive power for several large OECD countries. As real economic activity and financial market developments in many small economies, in particular in Europe, are closely tied to developments in the large OECD economies, similar results are likely to be found for countries outside the G-7 group.

The pooling of information could be achieved within the confines of the widely used structural econometric models by including a specification of the term structure relationship between long-term and short-term interest rates that accounts for forward-looking bond market behavior (see, e.g., Taylor (1988)). As a side benefit, adding forward-looking bond market behavior to traditional structural econometric models may improve the simulation properties of the models (Fair, 1979).

A theoretical macroeconomic model describing the intriguing interactions between real activity and forward-looking financial markets is provided by Blanchard (1981). His theoretical model illustrates that current movements in yield spreads should not be mechanically interpreted as leading indicators of movements in future real output growth. For example, the lead-lag relationship between the yield spread and real output in Blanchard's model depends on whether shocks in the economy are anticipated or not. While a positive yield spread unequivocally signals an increase of future output in the case of an unanticipated monetary expansion, the model predicts that both a negative and a positive yield spread are consistent with a future increase of output in the case of an anticipated monetary expansion.

Does the empirical evidence reported in this paper suggest that forecasters ignored readily available information about future output growth? Macroeconomic forecasting is based on extrapolating established patterns and relationships in the data. The empirical evidence presented in this paper is based on an ex-post scrutiny of the data and may therefore reflect a structural change in the relationship between financial markets and real economic activity which is easily recognized from today's perspective but was difficult to detect for forecast producers over the sample period studied. Results from simple Granger-causality tests for data before and after 1970 indicate that the empirical evidence on this question is mixed. For some countries including the U.S., the yield spread was a powerful predictor of real output growth before and after 1970. For other countries including Germany, there is no statistical evidence for a lead-lag relationship between the two variables before 1970. Presumably, the breakdown of the Bretton Woods exchange rate regime at the beginning of the 1970s followed by increased liberalization of financial markets and changes in monetary policy operation procedures was an important reason for the emergence of the impressive predictive power of the yield spread after 1970 in at least some countries.

Data appendix

Country	Time range	Output series[a]	Interest rate series[b]	
			Long-term rate	Short-term rate
U.S.	1968.I-1990.II	Real GNP	Goverment bond yields ("Composite" over 10 years)	Treasury bill rate (3 months)
Japan	1968.I-1990.II	Real GNP	Goverment bond yields (Central goverment)	Call money rate
Germany	1968.I-1990.II	Real GNP	Government bond yields (7-15 years)	Bank loan rate (3 months)
France	1970.I-1990.II	Real GDP	Bond yields (Goverment guaranteed)	Call money rate
Italy	1971.I-1990.II	Real GDP	Treasury bond yields (6 years)	Interbank rate (Sight deposits)
U.K.	1968.I-1990.II	Real GDP	Government bond yields (20 years)	Call money rate
Canada	1968.I-1990.II	Real GNP	Government bond yields (More than 10 years)	Deposit rate (3 months)

[a] Source: OECD Economic Outlook database. Semi-annual series.

[b] Source: OECD Main Economic Indicator database. Averaged monthly series.

FIGURE 1a. GNP GROWTH AND OECD FORECASTS: GERMANY

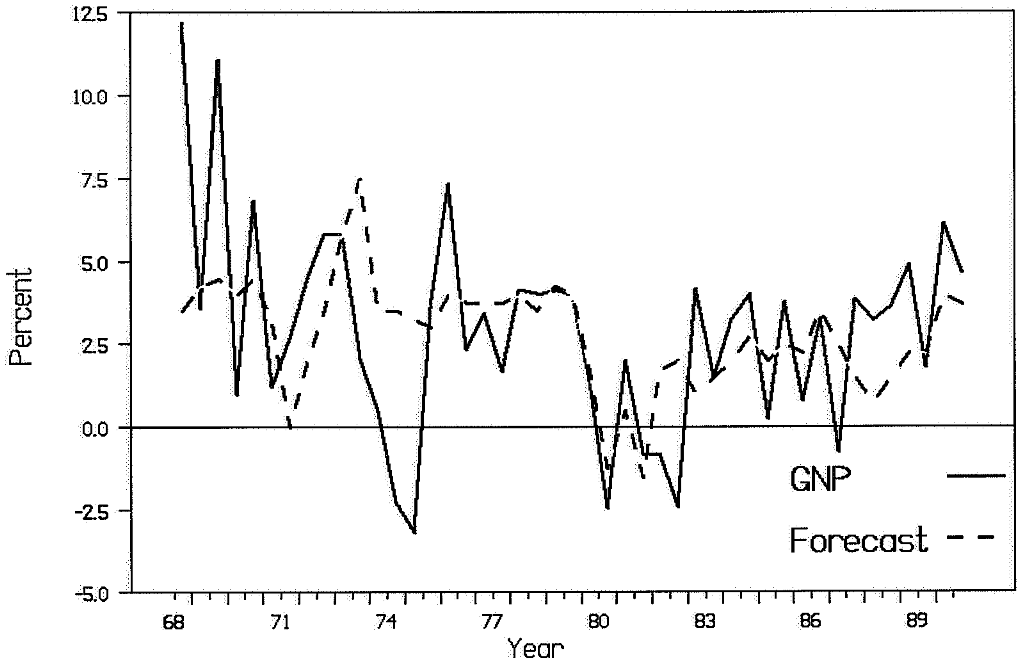

FIGURE 1b. GNP GROWTH AND YIELD SPREAD: GERMANY

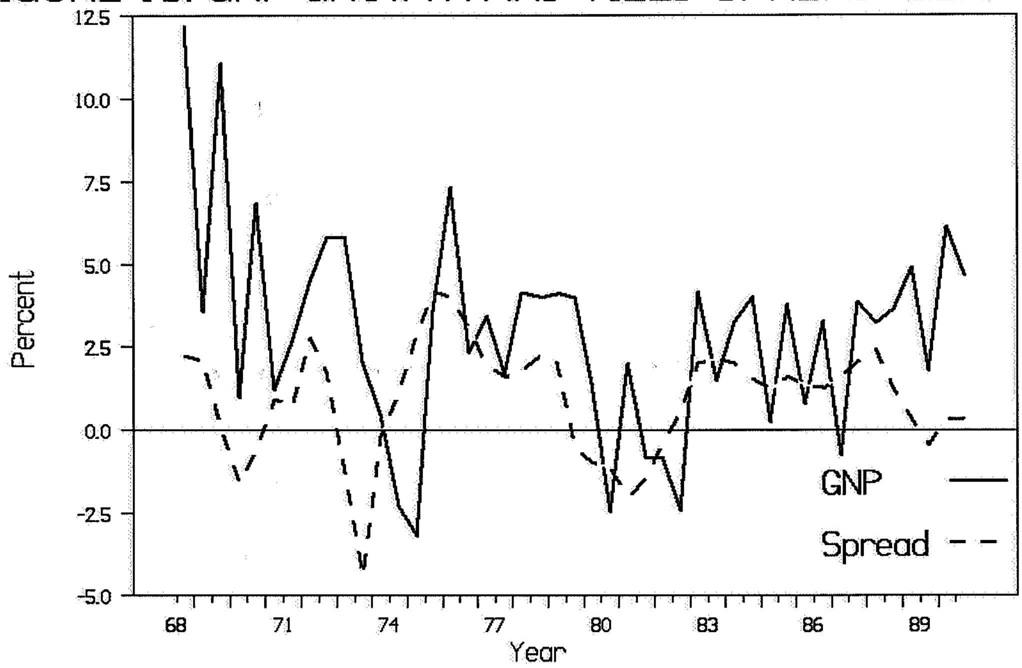

Table 1

The predictive power of OECD forecasts and the lagged yield spread.[a]

Country	α	β	δ	$\bar{R}^2$	Q^b	$\bar{R}^2$ (δ=0)	$\bar{R}^2$ (β=0)
U.S.	1.23* (0.47)	0.52** (0.15)	0.70** (0.18)	0.58	18.89 (0.53)	0.49	0.49
Japan	3.35** (0.23)	0.34 (0.23)	0.09 (0.32)	0.03	24.36 (0.14)	0.05	-0.02
Germany	0.58 (0.51)	0.57** (0.20)	0.74** (0.23)	0.26	20.25 (0.32)	0.12	0.18
France	0.29 (0.57)	0.63** (0.12)	0.52* (0.21)	0.41	19.61 (0.36)	0.28	0.07
Italy	2.99 (0.83)	0.27 (0.30)	0.75* (0.29)	0.24	28.96 (0.05)	0.14	0.23
U.K.	0.72 (0.44)	0.60** (0.12)	-0.01 (0.12)	0.21	16.27 (0.57)	0.23	-0.01
Canada	0.51 (0.72)	0.83** (0.20)	0.79** (0.14)	0.60	19.94 (0.34)	0.46	0.44

[a] Time range is 1968.II-1990.II (45 observations) except for France and Italy. Time range for France is 1970.II-1990.II; for Italy 1971.II-1990.II. Numbers in parentheses below parameter estimates are heteroscedasticity-consistent standard errors.

[b] Q is the Ljung-Box statistic for general serial autocorrelation. Numbers below Q-statistics give marginal significance levels.

* and ** indicate significance at the 5 percent and 1 percent level, respectively, in a two-tailed t-test.

Table 2

Band spectrum regression results.[a]

Country	β_{Low}	β_{High}	δ_{Low}	δ_{High}
U.S.	0.45* (0.20)	0.77* (0.30)	0.78** (0.26)	0.11 (0.62)
Japan	0.41 (0.26)	-0.46 (0.36)	0.16 (0.48)	-1.84 (1.06)
Germany	0.58* (0.27)	0.80 (0.77)	0.80** (0.26)	-0.30 (0.99)
France	0.64** (0.14)	0.36 (0.62)	0.57** (0.19)	0.05 (0.55)
Italy	0.29 (0.24)	0.00 (0.38)	0.82** (0.30)	-0.14 (0.58)
U.K.	0.77** (0.19)	0.84* (0.36)	-0.04 (0.14)	1.40* (0.66)
Canada	0.75** (0.21)	1.25* (0.45)	0.76** (0.20)	1.42* (0.56)

[a] The parameter subscript "Low" indicates that the estimates are based on data where all cycles taking less than two years to complete were removed. The parameter subscript "High" indicates that the estimates are based on data where all cycles taking more than two years to complete were removed. Numbers in parentheses below parameter estimates are standard errors.

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