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**Morgan Stanley Investment Management**
Quantitative GTAA

# Macro Finance

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# Table of Contents

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Section 1

# Executive Summary

# Main Results

This article illustrates that the model introduced by Cochrane and Piazzesi (2005) can be used to develop profitable trading strategies.

While Cochrane and Piazzesi (2005) use their model in the US market, we are the first to test its application in international fixed income markets. Their model is stable in a range of different market environments across the globe.

Unlike Cochrane and Piazzesi (2005), our strategies deliver the best results when implemented with a relatively short forecasting horizon of 1 month. An alternative forecasting specification developed in this article also delivers a high forecasting power for international fixed income returns. We arrive at strategies with an information ratio in excess of 1.5.

The performance of the trading strategies is found to be influenced by the shape of the yield curve.

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**Section 2**

# Literature Review

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# Bond Market Forecasts

Selected References

Among others, Stambaugh (1988), Ilamen (1997), Cochrane and Piazzesi (2005), and Ludvigson and Ng (2006) analyze models for the forecasting of bond returns. However, most of this research is performed for the US market. Furthermore, no study focuses on the profitability of these models in trading strategies. **Cochrane and Piazzesi (2005)** use forward rates to forecast future bond returns. This is in contrast to macroeconomic approaches which attempt to explain future bond returns on the basis of economic principles. **Kim and Moon (2005)** find that a single macro index consisting of inflation, real activity, and money market figures can forecast up to 37% in the variation of bond excess returns on an annual basis. **Ludvigson and Ng (2006)** uses a large range of macroeconomic variables and tests for their bond excess return forecasting ability. They find a strong impact of macroeconomic variables on future expected bond excess returns. The forecasting power of these macroeconomic variables is above and in excess of the predictive power found in the forward and yield curves.

# Yield Curve Forecasts

Selected References

Another strand of research deals with the forecasting of the yield curve as a whole. Since the shape of the yield curve determines bond prices, this is another route to forecast future bond returns.

**Diebold and Li (2006)** use a variation of the yield curve model introduced by Nelson and Siegel (1987, 1988) to derive a smooth yield curve from the yields observed in the USA. Diebold and Li find that the three factors of their model correspond to the level, slope, and curvature of the yield curve. These factors appear to be mean-reverting. Their model delivers encouraging results for the forecasting of the yield curve. **Diebold et al. (2007)** link the factors of the model by Nelson and Siegel (1987, 1988) with macroeconomic factors. They find a strong forecasting ability of macroeconomic factors for the factors and shape of the yield curve. Therefore, macroeconomic factors also have an impact on future bond returns**. Ang and Piazzesi (2003)** study VAR models for the yield curve. In a variance decomposition the authors show that macroeconomic factors can explain up to 85% of the volatility in bond yields, where the explanatory power is best at the short and middle section of the yield curve. They find that the inclusion of macroeconomic variables can improve the forecasting ability of the VAR model considerably

**Section 3**

# Cochrane/Piazessi (CP)-Model

# Some Notation

Let $P_t^n$ denote the price of a zero bond with a maturity of $n$ years at time $t$. Its one period return can then be determined as

(1) $$R_t^n = \ln(P_t^n) - \ln\left(P_{t-1}^{n+1}\right)$$

The forward rate at time $t$ for a loan between $t+n-1$ and $t+n$ is expressed and calculated as

(2) $$F_t^{(i-1)\rightarrow i} = \ln\left(P_t^i\right) - \ln\left(P_t^{i-1}\right)$$

For example for $i=1$ equation (2) becomes the 1 year spot rate. The bond return in excess of the risk free rate, $c_t$, is given by

(3) $$RX_t^n = R_t^n - c_t$$

As the strategies analyzed in this article are implemented using zero coupon swaps with a monthly reset of the floating we have reflected this in our notation. While (3) essentially describes the return of such a swap agreement, the average bond return across different maturities is calculated as

(4) $$\overline{RX}_t^N = \frac{1}{N}\sum_{n=1}^{N} RX_t^n$$

where $N=5$ for the purpose of this paper, i.e. w focus on the short end of the yield curve using a set of tenors ranging from 1 to 5 years.

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# The Basic Model

As in Cochrane/Piazessi we express future bond returns as a linear regression of realized excess returns versus on month lagged forward rates.

(5) $$RX_{t+1}^{n} = \gamma_o + \sum_{i=1}^{N} \gamma_i F_t^{(i-1)\to i} + \varepsilon_{t+1}$$

with $\varepsilon_{t+1} \sim N(0,\sigma)$ . We also run regressions with the average period return as dependent variable, i.e.

(6) $$\begin{aligned} \overline{RX}_{t+1}^{N} &= \gamma_o + \sum_{i=1}^{N} \gamma_i F_t^{(i-1)\to i} + \varepsilon_{t+1} \\ &= \gamma_o + \gamma^T f_t + \varepsilon_{t+1} \end{aligned}$$

where $f_t = \left[ F_t^{0\to 1}, F_t^{1\to 2}, \ldots, F_t^{4\to 5} \right]^T$ . Let us define a single (state) variable that summarizes the information stored in current forward rates as $\Gamma_t = \gamma^T f_t$ . We can now rerun a restricted version of (5). The parameters of this specification are estimated from

(7) $$RX_{t+1}^{n} = \gamma_o + \eta \Gamma_t + \zeta_{t+1}$$

This second, restricted specification is used by Cochrane and Piazzesi (2005) to show that the single factor model's restrictions have only a minor impact on the forecasting ability of future bond returns.

**Section 4**

# Statistical Significance

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# Annual (Overlapping) Excess Returns

**Table 1. International Forecasting Power of the Cochrane / Piazzesi (2005) specification.** We use equation (5), where the dependent variable is the one year bond return on a 5 year zero bond. The numbers below the parameter values denotes denotes the respective t-values.

| Parameter | AUS | CAN | GER | JAP | CH | UK | USA |
|---|---|---|---|---|---|---|---|
| $\gamma_o$ | -0.29 | -0.16 | -0.12 | -0.03 | -0.11 | -0.13 | -0.26 |
| | *-6.99* | *-7.28* | *-6.80* | *-6.22* | *-5.45* | *-6.19* | *-8.26* |
| $\gamma_1$ | -19.45 | -19.41 | -46.18 | 37.67 | -36.38 | -60.99 | -22.73 |
| | *-1.89* | *-2.89* | *-2.52* | *2.50* | *-3.14* | *-6.50* | *-2.83* |
| $\gamma_2$ | 80.44 | -5.02 | 18.91 | -24.48 | 22.99 | 149.05 | -51.80 |
| | *2.41* | *-0.56* | *0.36* | *-1.68* | *1.09* | *5.35* | *-2.33* |
| $\gamma_3$ | 28.44 | 72.00 | 33.55 | -28.58 | 47.24 | -100.94 | 91.14 |
| | *0.52* | *4.44* | *0.58* | *-1.81* | *2.53* | *-2.73* | *2.56* |
| $\gamma_4$ | -145.05 | -68.22 | 54.75 | 22.16 | -41.97 | -34.14 | 65.20 |
| | *-2.34* | *-1.75* | *2.65* | *2.10* | *-1.38* | *-0.79* | *4.28* |
| $\gamma_5$ | 121.48 | 59.79 | -28.58 | 37.25 | 49.09 | 78.50 | -27.11 |
| | *3.25* | *2.01* | *-1.00* | *4.06* | *2.05* | *3.00* | *-1.08* |
| $R^2$ | 67% | 69% | 51% | 55% | 38% | 55% | 65% |

# Monthly (Non-overlapping) Excess Returns

**Table 2: International Forecasting Power of the Cochrane / Piazzesi (2005) specification.** We use equation (5), where the dependent variable is the one month bond return on a 5 year zero bond. The numbers below the parameter values denotes the respective t-values.

| Parameter | AUS | CAN | GER | JAP | CH | UK | USA |
|---|---|---|---|---|---|---|---|
| $\gamma_o$ | -0.03 | -0.02 | -0.01 | -0.01 | -0.01 | -0.02 | -0.04 |
| | *-1.60* | *-1.79* | *-1.77* | *-2.52* | *-2.26* | *-3.32* | *-3.14* |
| $\gamma_1$ | 9.06 | -2.24 | 4.43 | 11.58 | -4.50 | 3.34 | -5.98 |
| | *1.85* | *-0.59* | *0.80* | *1.76* | *-1.33* | *0.99* | *-1.90* |
| $\gamma_2$ | -35.91 | -2.59 | -12.03 | -6.95 | 8.14 | -11.19 | 12.88 |
| | *-2.27* | *-0.51* | *-0.74* | *-1.00* | *1.34* | *-1.13* | *1.43* |
| $\gamma_3$ | 53.21 | 22.12 | 4.77 | -8.97 | -10.54 | -4.53 | -21.39 |
| | *2.13* | *2.36* | *0.27* | *-1.19* | *-1.92* | *-0.34* | *-1.47* |
| $\gamma_4$ | -41.68 | -27.41 | 9.03 | 3.46 | 4.39 | 18.69 | 18.10 |
| | *-1.55* | *-1.26* | *1.40* | *0.77* | *0.49* | *1.21* | *2.91* |
| $\gamma_5$ | 21.06 | 14.65 | -3.57 | 8.47 | 6.04 | -0.64 | 4.42 |
| | *1.27* | *0.92* | *-0.41* | *2.15* | *0.87* | *-0.07* | *0.43* |
| $R^2$ | 12% | 12% | 7% | 10% | 11% | 10% | 16% |

**Section 5**

# Economic Significance

# Monthly Excess Returns

Alternative portfolio construction rules matter little

**Table 5. Lehman weightings.** The table contains the results of the standard Cochrane/Piazzesi specification implemented with a Lehman weights portfolio. The forecasting horizon for the bond returns is 1 month. The parameter $\mu$ stands for the monthly mean return, $\sigma$ for the volatility, $IR$ for the information ratio, $TO$ for the turnover, and $T$ for the total number of periods the strategy is analyzed.

| Universe | Total | No Japan | Total | No Japan |
|---|---|---|---|---|
| | 60 | 60 | 36 | 36 |
| $\mu$ | 0.06% | 0.07% | 0.06% | 0.06% |
| $\sigma$ | 0.27% | 0.27% | 0.29% | 0.29% |
| $t-value$ | 1.72 | 2.07 | 1.80 | 1.96 |
| $IR$ | 0.74 | 0.90 | 0.66 | 0.72 |
| $TO$ | 0.50 | 0.55 | 0.70 | 0.72 |
| $T$ | 64 | 64 | 88 | 88 |

**Table 1. Results using Equally Weighted Cash-Neutral Portfolios.** The table contains the results of the standard Cochrane/Piazzesi specification implemented with equally weighted portfolios of different wing sizes. The forecasting horizon for the bond returns is 1 month. The estimation period is 60 months. The parameter $\mu$ stands for the monthly mean return, $\sigma$ for the volatility, $IR$ for the information ratio, $TO$ for the turnover, and $T$ for the total number of periods the strategy is analyzed.

| Universe | Total | No Japan | Total | No Japan | Total | No Japan |
|---|---|---|---|---|---|---|
| Wing Size | 1 | 1 | 2 | 2 | 3 | 3 |
| $\mu$ | 0.05% | 0.05% | 0.06% | 0.08% | 0.05% | 0.08% |
| $\sigma$ | 0.29% | 0.29% | 0.28% | 0.26% | 0.26% | 0.26% |
| $t-value$ | 1.35 | 1.51 | 1.80 | 2.34 | 1.53 | 2.43 |
| $IR$ | 0.58 | 0.65 | 0.78 | 1.01 | 0.66 | 1.05 |
| $TO$ | 0.57 | 0.55 | 0.54 | 0.48 | 0.50 | 0.45 |
| $T$ | 64 | 64 | 64 | 64 | 64 | 64 |

# Variation in Internationalizing the CP Model

So far we tested straightforward variations of the US centric version of the Cochrane/Piazesssi model. However, the US financial markets are well known to lead other national financial markets. This spill-over effect from US forward rates motivates us to try another specification (we term this specification “Cochrane/Piazzesi Modified”) using the US forward rate for all countries in the sample. The modified specification for the US is

(11) $$RX^{n}_{t+1,US} = \gamma_o + \sum_{i=1}^{N} \gamma_i F^{(i-1)\to i}_{t,US} + \varepsilon_{t+1}$$

while the specification for all other countries follows

(12) $$RX^{n}_{t+1,j} = \gamma_o + \sum_{i=1}^{N} \gamma_i F^{(i-1)\to i}_{t,j} + \kappa F^{4\to 5}_{t,US} + \varepsilon_{t+1}$$

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# Performance of the International CP Model

**Table 7. Results Using Specification (11) and (12) for the Return Forecasting.** The strategy applies Lehman weights and equally weighted portfolios with a wing size of 3. The forecasting horizon for the bond returns is 1 month. The strategy is implemented by using zero coupon bonds with a tenor of 60 months. The estimation period is 60 months

| Weighting | Lehmann | | Equal Weighting Wing Size of 3 | |
|---|---|---|---|---|
| Universe | Total | No Japan | Total | No Japan |
| $\mu$ | 0.11% | 0.12% | 0.05% | 0.07% |
| $\sigma$ | 0.26% | 0.28% | 0.27% | 0.28% |
| $t-value$ | 3.25 | 3.47 | 1.50 | 2.03 |
| $IR$ | 1.41 | 1.50 | 0.65 | 0.88 |
| $TO$ | 0.58 | 0.60 | 0.55 | 0.42 |
| $T$ | 64 | 64 | 64 | 64 |

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# Country by Country Analysis

**Table 15. Performance of Different Strategies Implemented in Each Country Separately. The** table contains the results when trading on a range of forecasting methodologies. The forecasts are for the next month. We implement the strategies in each month separately, going long in an index if positive returns are forecasted and short otherwise. Forecasting specification (5) is the standard Cochrane / Piazzesi approach, specification (7) uses the restricted Cochrane / Piazzesi factor with a rolling update, and specification (12) uses the US 5 year forward rate in the forecasting equation for all countries. The estimation period is 60 months. The equally weighted portfolio is the return obtained when investing an equal amount of money in the single country strategies.

| Forecasting Specification | | AUS | CAN | GER | JAP | CH | UK | USA | Equally Weighted Portfolio |
|---|---|---|---|---|---|---|---|---|---|
| CP (5) | $\mu$ | 0.07% | 0.07% | -0.25% | 0.06% | -0.17% | -0.19% | 0.43% | -0.02% |
| | $\sigma$ | 0.77% | 0.92% | 0.94% | 0.62% | 0.83% | 0.92% | 1.53% | 0.43% |
| | $IR$ | 0.30 | 0.28 | -0.91 | 0.34 | -0.71 | -0.72 | 0.97 | -0.19 |
| Restricted CP (7) | $\mu$ | 0.13% | -0.06% | -0.10% | -0.05% | 0.20% | -0.07% | 0.32% | 0.07% |
| | $\sigma$ | 0.76% | 0.92% | 0.97% | 0.62% | 0.82% | 0.94% | 1.55% | 0.43% |
| | $IR$ | 0.61 | -0.22 | -0.35 | -0.28 | 0.84 | -0.26 | 0.72 | 0.56 |
| International CP (12) | $\mu$ | 0.07% | -0.04% | 0.12% | 0.13% | 0.15% | 0.12% | 0.56% | 0.23% |
| | $\sigma$ | 0.77% | 0.93% | 0.97% | 0.61% | 0.83% | 0.94% | 1.47% | 0.64% |
| | $IR$ | 0.31 | -0.16 | 0.43 | 0.76 | 0.65 | 0.43 | 1.33 | 1.24 |

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**Section 6**

# Performance Decomposition

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# Methodology

We analyze the impact of the yield curve shape on the performance of the strategies in more detail by regressing the strategy returns on different components of the US yield curve. To be more precise, we estimate the parameters of the following specifications:

(1) $$RS_t = \beta_0^{RS} + \beta_l^{RS} level_{t,US} + \beta_s^{RS} slope_{t,US} + \beta_c^{RS} curvature_{t,US} + \varepsilon_t ,$$

(2) $$RS_t = \beta_0^{RS} + \beta_l^{RS} level_{t,US} + \varepsilon_t ,$$

(3) $$RS_t = \beta_0^{RS} + \beta_s^{RS} slope_{t,US} + \varepsilon_t ,$$

(4) $$RS_t = \beta_0^{RS} + \beta_c^{RS} curvature_{t,US} + \varepsilon_t ,$$

where $RS_t$ is the return of the analyzed trading strategy at time $t$. The returns are obtained from the performance of the base case using equation (5) for the return forecasting. We start with univariate regressions to filter out the most important factors.

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# Univariate Regressions

**Table 16: Impact of the Yield Curve Components on the Performance of the Base Strategy Using Forecasting Equation (5).** This table contains the results of forecasting the future bond returns using specification **(5)** and investing with Lehmann weights. The rolling period refers to the aggregation of the strategy returns. A value of 1 (6) indicates that the regression is performed with monthly (6-monthly) returns. The table gives the adjusted $R^2$ of the regressions.

| Rolling Return Period | 1 | 6 | 1 | 6 | 1 | 6 | 1 | 6 |
|---|---|---|---|---|---|---|---|---|
| $\beta_0^{RS}$ | 0.0010 | 0.0009 | 0.0002 | 0.0003 | 0.0000 | 0.0004 | 0.0034 | 0.0058 |
| | *1.2517* | *4.1184* | *0.2993* | *2.1600* | *0.1096* | *2.7970* | *0.6060* | *3.7048* |
| $\beta_l^{RS}$ | -0.1438 | -0.1471 | | | | | -0.5332 | -1.2291 |
| | *-0.5537* | *-2.0521* | | | | | *-0.4242* | *-3.4421* |
| $\beta_s^{RS}$ | | | 0.2994 | 0.1343 | | | -3.2466 | -2.2208 |
| | | | *1.0370* | *1.5921* | | | *-1.3407* | *-3.3764* |
| $\beta_c^{RS}$ | | | | | 2.0677 | 0.6581 | 12.4357 | 4.2705 |
| | | | | | *1.8204* | *1.8250* | *2.3602* | *2.7482* |
| $R^2$ | 0.0049 | 0.0688 | 0.0170 | 0.0426 | 0.0507 | 0.0552 | 0.1385 | 0.2289 |

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**Section 6**

# Bayesian Model Averaging

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# Model Error

Its is well known that searching for the best specification (for a given set of variables) will expose the researcher to inflated t-values and little guidance for choosing between models with almost equal likelihood. In other words there is significant model uncertainty. One of the methods suggested in the literature has been Bayesian Model averaging. Suppose there is a set of $i = 1, \ldots, k, \ldots, q$ models $M_i$ .For every moment in time we calculate the posterior probability that model $k$ is the correct model, $p(M_k | data)$.

(1) $$p(M_k | data) = \frac{p(data | M_k) p(M_k)}{\sum_i p(data | M_i) p(M_i)}$$

where $p(data | M_k)$ is the probability of the data given that $M_k$ is the correct model and $p(M_k)$ is the prior probability for model $k$. Assuming that $p(M_i) = \frac{1}{q}$ we can rewrite (1) as

$$p(M_k | data) = \frac{p(data | M_k)}{\sum_i p(data | M_i)} = \frac{1}{\sum_i B_{ik}}$$

where the Bayes-factor, $B_{ik}$ can be approximated by the so called BIC approximation

(2) $$B_{ik} \approx \exp\left(\frac{BIC_k - BIC_i}{2}\right)$$

As the $BIC$ value is readily available regression output for most software packages this allows us to calculate (1) without much computational effort.

# Model Combination

Indexing an individual country by $j$ we get at any point in time an $n \times 1$ vector assigning probabilities to each of the $q$ regression models, $\mathbf{P}_{j,t}$ as well as a $n \times (m+1)$ matrix of OLS regression coefficients ($m$ regressors plus one constant), $\mathbf{\Theta}_{j,t}$. Combined with our knowledge of forward rates at time $t$, represented by $\mathbf{F}_{j,t}$ we can now generate a forecast for country $j$

(1) $$\widehat{RX}_{t+1,j}^{bma} = \sum_{i=1}^{q} p_t \left( M_{i,j} \,|\, data \right) E_t \left( \widehat{RX}_{t+1,j} \,\middle|\, M_{i,j} \right) = \mathbf{P}_{t,j}^{T} \mathbf{\Theta}_{t,j} \begin{bmatrix} 1 \\ \mathbf{F}_{t,j} \end{bmatrix}$$

These forecasts are now taken as inputs into our portfolio construction rules. We can now compare our previous approach (use a specification that seems intuitive and worked well) with Bayesian model averaging.

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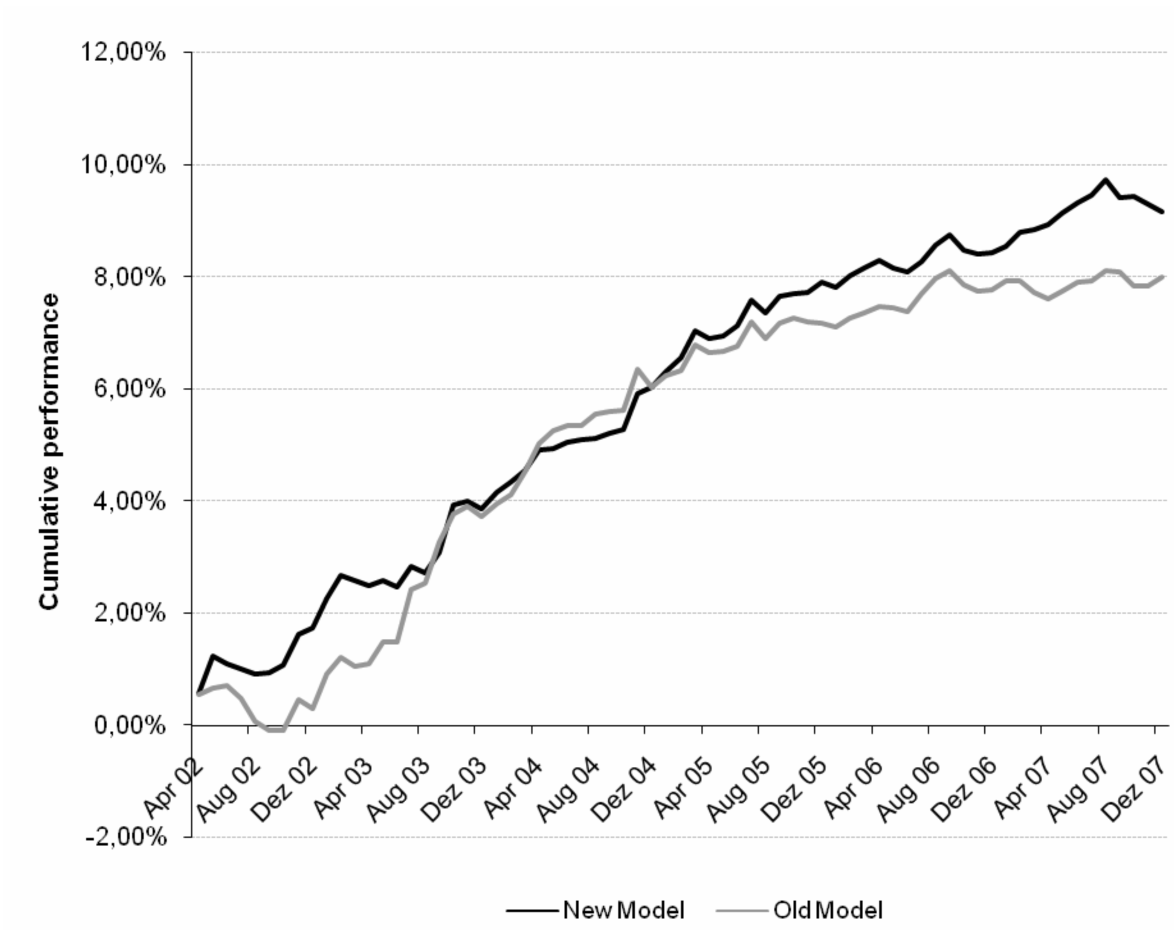
# Improved Performance



**Section 8**

# Literature

# Summary

This article illustrates that the model introduced by Cochrane and Piazzesi (2005) can be used to develop profitable trading strategies.

While Cochrane and Piazzesi (2005) use their model in the US market, we are the first to test its application in international fixed income markets. Their model is stable in a range of different market environments across the globe.

Unlike Cochrane and Piazzesi (2005), our strategies deliver the best results when implemented with a relatively short forecasting horizon of 1 month. An alternative forecasting specification developed in this article also delivers a high forecasting power for international fixed income returns. We arrive at strategies with an information ratio in excess of 1.5.

The performance of the trading strategies is found to be influenced by the shape of the yield curve.

# Selected References

Ang, A., M. Piazzesi (2003): "A No-Arbitrage Vector Autoregression of Term Structure Dynamics with Macroeconomic and Latent Variables," Journal of Monetary Economics, 50, 4, 745-787.

Cochrane , J. H., and M. Piazzesi (2005): "Bond Risk Premia," American Economic Review, 95(1), 138-160.

Diebold, F., C. Li, and V. Yue (2007): "Global Yield Curve Dynamics and Interactions: A Dynamic Nelson-Siegel Approach," PIER Working Paper No. 07-030

Ilmanen, A. (1997): “Forecasting US Bond Returns,” Journal of Fixed Income, June 1997

Kim, H., J. Moon (2005): “Do Macroeconomic Variables Forecast Bond Returns?,” Working Paper

Ludvigson, Sydney C. and Ng, Serena (2005): "Macro Factors in Bond Risk Premia," NBER Working Paper No. W11703, October 2005.

Nelson, C.R. and Siegel, A.F. (1987), “Parsimonious Modeling of Yield Curves,” Journal of Business, 60, 473-489.

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