How Does the Yield Curve Influence Real Estate Markets and Vice Versa?*

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Abstract

The implicit information about discounting and about macroeconomic variables embedded in the term structure of interest rates can be used to extract the links between yield curve factors and real estate performance and to forecast real estate returns. This paper empirically studies the link between real estate returns and the yield curve. I find evidence that aggregate real estate returns and the slope of the yield curve Granger-cause the short rate with 1 quarter lag to 4 quarters lag. I also find that real estate returns and the short rate cause the slope of the yield curve with 1 quarter lag to 4 quarters lag. However, the short rate and the slope do not cause real state returns with 1 quarter lag. If I include 4 lags (4 quarters) to account for the seasonality of real estate markets, then the short rate and the slope of the yield curve Granger-cause real estate returns. The empirical analysis also documents the predictability of the NCREIF Property Index with values of R^2 above 0.55.

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1 Introduction

There is empirical evidence that some macroeconomic variables are related to the term structure of interest rates. For instance, it is well known that the the term structure usually moves from an increasing concave curve in periods where the economy is stable to a decreasing curve right before recessions. Therefore the link between the term structure and some macroeconomic variables could be used to forecast these variables. In this paper, I will focus on a specific macroeconomic variable: the performance of real estate markets.

Are the aggregated returns on real estate related to the term structure of interest rates? What information about real estate does the term structure provide? Academics and practitioners have recently focused on the study of how variation in real activity influences the term structure.[1] On one hand there is evidence that short rates and term spreads, understood as proxies for the "yield level" and the "yield slope" of the term structure, respectively, forecast macroeconomic variables. For example, Ang, Piazessi and Wei (2005) analyzes the link between GDP growth and the term structure. On the other hand, there is evidence that macroeconomic variables and real estate performance are related. Kaiser (1997), Wheaton (1999), and Leamer (2007) study the relationship between business cycles and real estate. If there is evidence that variables related to the term structure forecast macroeconomic variables and there is evidence that macroeconomic variables are related to returns on real estate, then we might ask ourselves the following questions: (i) is there evidence that the term structure and the real estate performance are related? and, (ii) do short rates and the term spreads forecast real estate returns?[2]

To answer these two questions, this paper uses a Vector Autoregression (VAR) model of real estate returns, the short interest rate and the slope of the yield curve to study the link between real estate markets and the yield curve. I find empirical evidence that the first two components of the term structure (i.e., the short interest rate and the slope of the yield curve) Granger-cause aggregate real estate returns. However, there is no evidence that real estate returns Granger-cause the first two components of the term structure. The empirical analysis also documents a that the NCREIF Property Index (NPI) can be predicted at a 4-quarter (i.e., one year) horizon using term

[1] For example, see Cooper and Priestley (2008); Ludvingson and Ng (2009); and Joslin, Priebsch and Singleton (2010)

[2] Note that there is both theoretical support (Poterba (1984)) and empirical evidence (Goodhart and Hofmann (2008)) of a direct relationship between interest rates and real estate prices.

structure data with values of R^2 above 0.55.

Figure 1 shows the dynamics of the short interest rate and the returns on the NPI. The shaded areas highlight the main recession periods in the U.S., except for the high-tech bubble period in the early 2000s. Three stylized facts arise from this plot. First, the returns on the real estate index (NPI) decrease and may become negative during recessions. Second, the short rate reaches a local maximum and starts to decrease right before any major recession. Third, the correlation between the short interest rate and the returns on the NPI is positive.

[INSERT FIGURE 1 HERE]

Figure 2 plots the dynamics of the slope of the yield curve and the returns on the NPI. The light shaded areas show the main recession periods in the U.S. The dark shaded areas highlight the periods in which the slope of the yield curve is negative. Two stylized facts arise from this figure. First, periods with negative slope precede economic recessions. Second, the correlation between the slope of the yield curve and the returns on the NPI is negative.

[INSERT FIGURE 2 HERE]

Figures 1 and 2 motivate the links between the yield curve and real estate. The empirical analysis of this paper rigorously shows the relationships between the term structure of interest rates and real estate returns. These links are important in different dimensions. First, it is important for investors in real estate markets. Second, it is important for policy makers. Third, it is important for pricing securities affected by both interest rates and the real estate markets such as mortgage-backed securities (MBS).[3]

The rest of this paper is organized as follows. Section 2 provides a detailed description of the modeling framework and relates it to the existing literature. Section 3 shows how vector autoregression techniques combined with variance decomposition and impulse response analysis

[3] Although most of the models used for pricing and hedging MBS are based solely on interest rates, recent models use two state variables: interest rates and house prices (see, for example, Downing, Stanton and Wallace, 2003.) Interest rates is used to count for prepayment, that is, the fact that borrowers are willing to prepay their mortgages when interest rates go down under certain levels. Models simplify the interest rate processes by typically just using short-term rated defined by the Vasicek (1997) or Cox, Ingersoll and Ross (1985) models. The other state variable used in those models, is a variable related to the real estate performance, typically the house prices. This variable is included to count for default, that is, the fact that borrowers might default on their obligations when the value of the collateral property (real estate) falls under certain levels. Most of the existing models do not take into account the joint dynamics of these state variables nor the dynamics of their variance and correlation.

can be used to study the joint dynamics of the term structure of interest rates and the aggregated real estate returns. Numerical results and their economical interpretation are shown in this section. Section 4 concludes this paper.

2 The Model

The aim of this paper is providing a new model to understand house prices and interest rates, rather than developing a new term structure model that improves the performance of previous models. The goal of this paper is to research on whether real estate returns forecast the yield curve and/or vice versa. This is why the present model is based on the Vector Autoregression (VAR) technique. In a VAR, many variables are tested as predictors all at once. Thus, many variables are put into the same autoregressive model and the choice of the variables that are more suitable to be include in the VAR is crucial to obtain an optimal empirical performance. As a general rule, the term structure must be described using the minimum number of variables or components.

The literature agrees on the fact that three principal components define the term structure. The first component is the level of the curve. The short term interest rate can be used to define the yield level. It is an instrument that the central bank uses to achieve its macroeconomic stabilization objectives and keep inflation close to its target.[4] The short rate is a very important instrument for estimating the bond yields of different maturities as risk-adjusted averages of expected future short rates. The second component is the slope of the curve. The difference of a long-term rate and the instant rate may be used to approximate the yield slope. The third component of the yield curve is the curvature, that is a parameter related to the change in the first derivative or, in a very simple way, an intermediate (medium-term) point that captures the shape of the term structure may be used to introduce the level of the curvature in the models.

The framework of the model is a factor approach to the forecast of real estate returns. The vector of state variables contains three variables. First, two variables that refer to a discretization of the term structure: the yield level or short rate at quarterly basis, $r_t^{(1)}$, and the yield slope or

[4] Central banks also play an important role linking the term structure to the performance of macroeconomic variables. Therefore, central banks determine the interest rates such that its targeted goals based on macroeconomic variables can be accomplished, as shown by the Taylor rules in Taylor (1993) and models to estimate these rules and identify monetary policy shocks using no-arbitrage pricing techniques (see for example Ang, Dong and Piazzesi (2005) and subsequent literature.)

5-year (i.e., 20 quarter) term spread at quarterly frequency, $r_t^{(20)} - r_t^{(1)}$. Then, a third variable that to the real estate returns, R_t^{RE}. Thus, the vector of state variables $X_t = [X_1, X_2, X_3]$ is defined as:

$$X_t = [r_t^{(1)}, r_t^{(20)} - r_t^{(1)}, R_t^{RE}]'. \tag{1}$$

The joint 3x1 vector of state variables X_t follows a VAR with one lag:

$$X_t = \mu + \Phi X_{t-1} + \Sigma \epsilon_t \tag{2}$$

where μ is a 3x1 vector, Φ and Σ are 3x3 matrixes, and ϵ_t is i.i.d. N(0,I).

I do not explicitly impose any structure for the market price of risk as in the affine term structure modeling literature. Instead, I use the findings in Duffee (2011) to be able to fit the dynamic model using linear techniques. Duffee (2011) evaluates the importance of the cross-sectional restrictions implied by no-arbitrage when using the term structure to forecast future bond yields. It concludes that no cross-sectional restrictions are needed, because cross-sectional properties of yields are easy to infer with high precision.[5] Following Duffee (2011), I do not calibrate an affine term structure model. Instead, I implement the following linear model:

$$\widetilde{r_t} = \widetilde{a} + \widetilde{B} X_t \tag{3}$$

$$X_t = \mu + \Phi X_{t-1} + \Sigma \epsilon_t \tag{4}$$

where equation (3) refers to:

$$\begin{bmatrix} r_t^{(1)} \\ r_t^{(2)} \\ \vdots \\ r_t^{(n)} \\ \vdots \\ r_t^{(20)} \end{bmatrix} = \begin{bmatrix} 0 \\ a^{(2)} \\ \vdots \\ a^{(n)} \\ \vdots \\ 0 \end{bmatrix} + \begin{bmatrix} 1 & 0 & 0 \\ b_1^{(2)} & b_2^{(2)} & 0 \\ \vdots & \vdots & \vdots \\ b_1^{(n)} & b_2^{(n)} & 0 \\ \vdots & \vdots & \vdots \\ 1 & 1 & 0 \end{bmatrix} \begin{bmatrix} X_{1,t} \\ X_{2,t} \\ X_{3,t} \end{bmatrix}. \tag{5}$$

[5] A similar argument was made in Pericoli and Taboga (2012). This paper finds that ordinary least squares (OLS) and non-linear least squares (NLS) fitted yields almost coincide.

Following a similar approach than Ang, Piazzesi and Wei (2005), and Duffee (2011), the dynamics of the short interest rate and term spread is linear on the state variable of the model. From the definition of R_t^{RE} as part of the vector of state variables in equation (1), it follows that:

$$R_{t\to t+k}^{RE} = \frac{1}{k} e_3' \sum_{j=1}^{k} X_{t+j} \tag{6}$$

where e_3 is the vector $e_3 = [0, 0, 1]'$. The expected value of the aggregated real estate returns in k quarters is:

$$E_t \left[R_{t\to t+k}^{RE} \right] = C + \frac{1}{k} e_3' \frac{\Phi(I - \Phi^k)}{(I - \Phi)} X_t \tag{7}$$

where C is a constant term that groups several constants. The important issue at this point is that equation (7) has the form of a regression. We can identify $\frac{1}{k} e_3' \frac{\Phi(I-\Phi^k)}{(i-\Phi)}$ as a regression coefficient, $\beta_k^{(n)}$. Consequently, we can forecast the returns on aggregate real estate investments at a k-period horizon, $R_{t\to t+k}^{RE}$, using the lagged two state variables of the yield curve and the lagged R_t^{RE} as variables in the following regression:

$$R_{t\to t+k}^{RE} = \beta_{k,0}^{(n)} + \beta_{k,1}^{(n)} \cdot r_t^{(1)} + \beta_{k,2}^{(n)} \cdot \left(r^{(n)} - r^{(1)} \right) + \beta_{k,3}^{(n)} \cdot R_t^{RE} + \epsilon_{t+k,k}^{(n)}. \tag{8}$$

After doing some algebra to (6), the coefficients of the regression (8) can be inferred from the following identification with (6):

$$R_{t\to t+k}^{RE} = \frac{1}{k} e_3' \sum_{j=1}^{k} \left[\sum_{m=0}^{j-1} \Phi^m \mu + \Phi^j X_t + \sum_{m=1}^{j} \Phi^{j-m} \Sigma \epsilon_{t+m} \right] \tag{9}$$

or, equivalently,

$$R_{t\to t+k}^{RE} = C + \frac{e_3' \Phi(I - \Phi^k)}{k(I - \Phi)} X_t + \frac{1}{k} e_3' \sum_{j=1}^{k} \sum_{m=1}^{j} \Phi^{j-m} \Sigma \epsilon_{t+m} \tag{10}$$

where the constant C is given by $C = e_3' \frac{I - \frac{1}{k} \Phi \frac{(I-\Phi^k)}{(I-\Phi)}}{(I-\Phi)} \mu$.

3 Empirical study

This section presents, in its first part, the study of the joint dynamics of the term structure of interest rates and the aggregated real estate returns. The term structure is defined by its first two principal components and the aggregated real estate returns are characterized by one single variable. This analysis is based on the model developed in section 3.1. The second part of this section shows the forecast of the aggregated returns on real using the approach presented in section 3.2. We use quarterly data through all the empirical study.

3.1 VAR analysis of the joint dynamics of the three components

A first approach leads us to a one lagged vector autoregression, VAR(1), defined by the two variables that count for the term structure of interest rates and a third variable that accounts for the macro real estate returns:

1. X_1: We use the 3-month (1 quarter) rate as a measure of the yield level in the short run.
2. X_2: Term spread (difference between the 5-year rate and the 1-year rate), as a proxy for the slope of the yield curve.
3. X_3: Returns on the National Council of Real Estate investment Fiduciaries (NCREIF) Property Index (NPI), as a measure of the aggregated real estate returns at a US national level.

Table 1 presents the summary statistics of the three state variables in the data. We use U.S. quarterly data from 1978 to 2011. The mean of the short rate is 5.41%. Its maximum value (15.05%) was in 1981Q3 and its minimum value (0.05%) was in 2011Q2. The mean of the slope of the yield curve is 0.80%. Its maximum value (2.43%) was in 1992Q2 and its minimum value (-1.66%) was in 1980Q1. The mean of the growth of the NPI is 2.20%. Its maximum value (6.19%) was in 1979Q4 and its minimum value (-8.29%) was in 2008Q4.

[INSERT TABLE 1 HERE]

Table 2 shows the results of the state dynamics VAR(1) analysis. These are the coefficients in the 3x1 vector μ and the 3x3 matrix Φ in equation (4). The R^2 that I obtain from this VAR(1) analysis are significant.

[INSERT TABLE 2 HERE]

First, this empirical analysis shows the autoregressive nature of the variables X_1, X_2, and X_3. There is a high influence of $X_1(t-1)$, $X_2(t-1)$, and $X_3(t-1)$ on $X_1(t)$, $X_2(t)$, and $X_3(t)$, respectively, with significant coefficients. Second, table 2 shows the ex ante influence of X_3 in X_1 with a coefficient of 0.09340. This means that the return on the real estate markets influences the short rate in the next quarter. Third, there is some relevant ex ante influence of X_3 on X_2 (-0.06178). Note that and increase in real estate prices anticipates a decrease in the demand for long term borrowing, since real estate is usually financed by long term borrowing. This means that long term borrowing must be cheaper, hence the long rate will be lower, and the slope of the term structure will decrease.

So far, this analysis has referred to the cross-influence in terms of mean values. Let's focus now on the analysis of the influence of shocks in any of the 3 variables on the other ones. Specifically, an impulse response analysis shows information on how a shock in the volatility of one standard deviation in one of the parameters affects the three of them along the next 12 periods (next year). I proceed to decompose the responses of yield factor and real estate return "shocks" based on their contributions to expected future changes in themselves and the other two respective variables. Figure 3 shows a graphical summary of the results of this analysis.

[INSERT FIGURE 3 HERE]

The top-left, middle-center and bottom-right graphs in Figure 3 respectively show the response of the NPI real estate index, the short rate, and the slope of the yield curve to a shock to themselves of one standard deviation of magnitude. Notice that shocks on the short rate are more persistent than shocks on the NPI and the slope. The response of the short rate X_1 to a one standard deviation shock on the NPI X_3 (top-center graph) is increasing and persistent. The response of the slope X_2 to a one standard deviation shock on the NPI X_3 (top-righ graph) is slightly decreasing and persistent. Finally, note that the response of the NPI X_3 to a shock on the slope X_2 (bottom-left graph) is diffuse and persistent. Specifically, one standard deviation impulses on X_1 and X_2 have a lower response on X_3 than one standard deviation impulse on X_3 itself. These responses are more persistent and higher in magnitude than the responses of shocks on X_2.

But, does the time series X_3 Granger-causes X_1 and/or X_2? Or does X_1 and/or X_2 Granger-cause X_3? In order to answer this question, I implement Granger Causality and Block Exogeneity Wald Tests through a series of F-tests on lagged values of A (and with lagged values of B also known). Table 3 shows the Granger Causality and Block Exogeneity Wald Tests for the VAR(1) analysis.[6]

[INSERT TABLE 3 HERE]

These tests show that there exists causality: (i) X_2 and X_3 do Granger-cause X_1, (ii) X_1 and X_3 do Granger-cause X_2, and (iii) X_1 and X_2 do not Granger-cause X_3 (with probability 0.4173). This implies that aggregate real estate returns influence the future the term structure of interest rates. However, this first analysis do not find evidence that the term structure influences future aggregate real estate returns. Therefore, table 3 shows empirical evidence that aggregate real estate returns and the slope of the yield curve Granger-cause the short rate with 1 quarter lag. It also shows that real estate returns and the short rate cause the slope of the yield curve with 1 quarter lag. However, the short rate and the slope do not cause real state returns with 1 quarter lag. If I include 4 lags (4 quarters) to account for the seasonality of real estate markets, then the short rate and the slope of the yield curve Granger-cause real estate returns.

Next question that might arise at this point is referred to the number of lags that are necessary for this analysis. So far, I have used VAR with just one lag, that is, VAR(1). However, there is evidence in the data of some 4 quarters (12 month) seasonality. To see this, note the peak in the autocorrelation graph for different NPI indexes in Figure 4.

[INSERT FIGURE 4 HERE]

First, I will study the extension of the VAR(1) analysis to a VAR(4) analysis, which is the maximum backward extension that we can do while keeping the evidence of Granger-causality from the first to components of the yield curve to the real estate returns. Table 4 shows the results the results for the VAR(4) analysis. All the VAR tables on the paper show the Akaike information criterion (AIC), Hannan-Quinn information criterion (HQIC) and the Schwarz Bayesian information criterion (SBIC) to be able to assess the optimal lag selection of the model.

[6] I test the null hypothesis on no Granger-causality from two of the state variables to the other one. If the probability is lower than 10%, then we reject the no causality null at a statistical significance higher than 90%.

[INSERT TABLE 4 HERE]

An impulse response analysis shows information on how a shock in the volatility of one standard deviation in one of the parameters affects the three of them along the next 12 periods (next year). I proceed to decompose the responses of yield factor and real estate return "shocks" based on their contributions to expected future changes in themselves and the other two respective variables. Figure 5 shows a graphical summary of the results of an impulse response analysis under a VAR(4) framework. The results do not change from the VAR(1) and VAR(2) analysis.

[INSERT FIGURE 5 HERE]

Table 5 shows the results for the VAR analysis using 3 and 4 lags. The results in the VAR(3) framework should be compared to the ones on table 3 for VAR(1) and we would find out that they are quite similar. I still find that X_2 and X_3 cause X_1, X_1 and X_3 cause X_2, and X_1 and X_2 do not cause X_3 (but now with probability 0.7396) in a VAR(3) framework. Table 5 also shows that the inclusion of a fourth lag drives to a different pattern of results. When a VAR(4) approach is implemented, the evidence of Granger-causality from X_2 and X_3 to X_1, as well as causality from X_1 and X_3 to X_2 applies as it did for the the VAR(1), VAR(2), and VAR(3) analysis. However, adding a fourth lag provides a new and interesting result: X_1 and X_2 do Granger-cause X_3, that is, the short rate and the slope of the yield curve Granger-cause real estate returns.

[INSERT TABLE 5 HERE]

All these results together suggest that there might be seasonality that does not show up until the fourth lag is included or, alternatively, that there is severe collinearity. To explore the existence of collinearity, I implemented a VAR with lags 1, 2, and 4, leaving the third lag out and I test whether we would obtain the same results than when a VAR(3) with 1, 2, and 3 lags is implemented. If yes, the difference in the results given by the addition of the fourth lag could be due to collinearity; if no, then we might have a seasonality issue. The results obtained from these two additional VAR analyses are quite different. Therefore, we can conclude that there is strong evidence of annual seasonality, in particular for lags of k=4 quarters.

3.2 Forecasting aggregate real estate returns (3rd component) from the lagged three components

Based on the analytical results obtained in section 3.2, Figure 6 shows a graphic representation of the coefficients $\beta_{k,0}^{(n)}$, $\beta_{k,1}^{(n)}$, $\beta_{k,2}^{(n)}$ and $\beta_{k,3}^{(n)}$ on the forecast of the aggregated returns on real estate, that is X_3 or $R_{t\to t+k}^{RE}$, using the regression defined in (8).

[INSERT FIGURE 6 HERE]

Figure 7 shows a graphic representation of the values of R^2 for these forecast estimations. Note, once again, the relevance of the case k=4. When we calibrate (8) for the case k=4, the highest values of R^2 are obtained for all the studied maturities of the term spread.

[INSERT FIGURE 7 HERE]

Table 6 shows these results for a particular case with 5 years maturity of the term spread (n=12 quarters). Note that the values of R2 decrease with k, except for an increase for k=4, which gets the maximum value of R^2 (R^2=0.56) and confirms our prior findings about the singularity of k=4. Note also that the coefficients of the regression for k=4 also confirm our intuition. An increase in the short rate one year ago (k=4 quarters) decreases the returns in real estate today (with a coefficient of -0.3407), while an increase in the slope (usually due to a decrease in the short rate, as it is suggested by the negative correlation sign between them in Table 4 leads to increasing real estate returns due to this possible decrease in the yield level.

[INSERT TABLE 6 HERE]

Finally, Figure 8 shows the comparison between the real data on the returns on the real estate index NPI National and the forecasted returns for a lag k=4 and a maturity of the term spread of 5 years (n=20 quarters). The forecasted NPI has been plotted using the coefficients in Table 6 for k=4. Note that the model capture most of the peaks of the graph and the trend observed on the real data.

[INSERT FIGURE 8 HERE]

4 Conclusions

The joint dynamics of real estate returns (from an aggregate macroeconomic point of view) and the term structure of interest rates must be studied in order to price securities that depend both on macro real estate dynamics and interest rates, such as Mortgage-Backed Securities. This paper shows evidence that the implicit information about discounting variables and about macro real estate returns embedded in the term structure can be used not just to extract the relations between yield curve factors and real estate performance but also to forecast returns on the real estate NCREIF Property Index (NPI). I use a model based on vector autoregression (VAR) techniques to extract these relations.

There is evidence from VAR analyses that aggregate real estate returns and the slope of the yield curve Granger-cause the short rate with 1 lag (1 quarter). The analysis also shows that real estate returns and the short rate the slope. However, the short rate and the slope do not cause real state returns. If I include 4 lags (4 quarters) to account for the seasonality of real estate markets, then the short rate and the slope of the yield curve Granger-cause real estate returns. The interpretations about the impulse-response analysis and about the VAR coefficients are also consistent with these causalities. The results reflect the seasonality effect of the aggregate real estates market. We must consider that lots of lease contracts (specially apartments) are renegotiated at an annual basis. In this paper, I have used the National NPI, which is an aggregated index that captures the aggregate of commercial, industrial, and residential activity in the U.S.

With this joint analysis, we were able to go one step further and study the predictability of macro real estate returns. The seasonality of 4 quarters (k=4) that was found in the data of the NCREIF Property Index drives the predictability of this macro real estate index to values of R^2 above 0.55.

This model is totally different from the recent approaches in the real estate literature that forecast real estate returns and future growth rents by assuming the rent-price ratio as capitalized rates. This different approach to the macroeconomics of the real estate markets opens a new field of research in real estate, in particular, in the improvement of real estate valuation models.

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Table 1: **Summary statistics**. U.S. quarterly data from 1978 to 2011.

Variable	Mean	Std. Dev.	Min	Max
Short interest rate, $X_1(t)$	5.41%	3.40%	0.05%	15.05%
Slope of the yield curve, $X_2(t)$	0.80%	0.88 %	-1.66%	2.43%
Real estate index (NPI), $X_3(t)$	2.20%	2.26 %	-8.29%	6.19%

Table 2: **VAR(1) analysis**. $X_1(t)$ is the variable short rate, $X_2(t)$ is the variable yield slope, and $X_3(t)$ is the variable growth of the NPI index. The root mean square error (RMSE), Akaike information criterion (AIC), Hannan-Quinn information criterion (HQIC) and the Schwarz Bayesian information criterion (SBIC) are also provided.

		Coef.	Std. Err.	z	$P > \|z\|$
$X_1(t)$					
	$X_1(t-1)$	0.96408	0.02675	36.04	0.000
	$X_2(t-1)$	0.06734	0.10996	0.61	0.540
	$X_3(t-1)$	0.09340	0.03687	2.53	0.011
	constant	-0.0011	0.00236	-0.46	0.642
$X_2(t)$					
	$X_1(t-1)$	0.00976	0.01185	0.82	0.410
	$X_2(t-1)$	0.84528	0.04873	17.35	0.000
	$X_3(t-1)$	-0.06178	0.01634	-3.78	0.000
	constant	0.00213	0.00105	2.04	0.042
$X_3(t)$					
	$X_1(t-1)$	0.01042	0.04616	0.23	0.821
	$X_2(t-1)$	-0.00146	0.18975	-0.01	0.994
	$X_3(t-1)$	0.77564	0.06362	12.19	0.000
	constant	0.00443	0.00407	1.09	0.277

	Parameters	RMSE	R^2	chi^2	$P >chi^2$
$X_1(t)$	4	0.00831	0.942	2164.17	0.000
$X_2(t)$	4	0.00368	0.830	648.39	0.000
$X_3(t)$	4	0.01433	0.609	207.62	0.000
Log likelihood	1455.20				
AIC	-21.70				
HQIC	-21.60				
SBIC	-21.44				

Table 3: **VAR(1) Granger Causality and Block Exogeneity Wald Tests**. $X_1(t)$ is the variable short rate, $X_2(t)$ is the variable yield slope, and $X_3(t)$ is the variable returns on the NPI index.

Dependent variable: X_1

Excluded	Chi-sq	df	Prob.
X_2	16.76651	1	0.0000
X_3	11.74081	1	0.0006
All	23.25407	2	0.0000

Dependent variable: X_2

Excluded	Chi-sq	df	Prob.
X_1	5.464162	1	0.0194
X_3	15.15590	1	0.0001
All	15.84215	2	0.0004

Dependent variable: X_3

Excluded	Chi-sq	df	Prob.
X_1	1.130860	1	0.2876
X_2	0.231303	1	0.6306
All	1.748125	2	0.4173

Table 4: **VAR(4) analysis**. $X_1(t)$ is the variable short rate, $X_2(t)$ is the variable yield slope, and $X_3(t)$ is the variable growth of the NPI index. The root mean square error (RMSE), Akaike information criterion (AIC), Hannan-Quinn information criterion (HQIC) and the Schwarz Bayesian information criterion (SBIC) are also provided.

		Coef.	Std. Err.	z	$P > \|z\|$
$X_1(t)$					
	$X_1(t-1)$	1.41701	0.13538	10.47	0.000
	$X_1(t-2)$	-0.79945	0.21791	-3.67	0.000
	$X_1(t-3)$	0.80586	0.21744	3.71	0.000
	$X_1(t-4)$	-0.46250	0.13587	-3.40	0.001
	$X_2(t-1)$	0.44867	0.29168	1.54	0.124
	$X_2(t-2)$	-0.49343	0.44166	-1.12	0.264
	$X_2(t-3)$	0.63355	0.45122	1.40	0.160
	$X_2(t-4)$	-0.48217	0.28572	-1.69	0.091
	$X_3(t-1)$	0.11655	0.04850	2.40	0.016
	$X_3(t-2)$	-0.10430	0.05680	-1.84	0.066
	$X_3(t-3)$	0.07199	0.05795	1.24	0.214
	$X_3(t-4)$	-0.02294	0.05200	-0.44	0.659
	constant	-0.00048	0.00230	-0.21	0.835
$X_2(t)$					
	$X_1(t-1)$	-0.06298	0.06158	-1.02	0.306
	$X_1(t-2)$	0.12467	0.09912	1.26	0.208
	$X_1(t-3)$	-0.18445	0.09890	-1.86	0.062
	$X_1(t-4)$	0.13089	0.06180	2.12	0.034
	$X_2(t-1)$	0.91373	0.13267	6.89	0.000
	$X_2(t-2)$	-0.18004	0.20089	-0.90	0.370
	$X_2(t-3)$	0.05971	0.20524	0.29	0.771
	$X_2(t-4)$	0.01434	0.12996	0.11	0.912
	$X_3(t-1)$	-0.06010	0.02206	-2.72	0.006
	$X_3(t-2)$	0.02208	0.02586	0.85	0.393
	$X_3(t-3)$	-0.00824	0.02636	-0.31	0.754
	$X_3(t-4)$	-0.00528	0.02365	-0.22	0.823
	constant	0.00233	0.00105	2.23	0.026
$X_3(t)$					
	$X_1(t-1)$	0.46400	0.23759	1.95	0.051
	$X_1(t-2)$	-0.72193	0.38242	-1.89	0.059
	$X_1(t-3)$	0.88639	0.38159	2.32	0.020
	$X_1(t-4)$	-0.61448	0.23845	-2.58	0.010
	$X_2(t-1)$	0.97493	0.51189	1.90	0.057
	$X_2(t-2)$	-1.58036	0.77509	-2.04	0.041
	$X_2(t-3)$	1.17007	0.79187	1.48	0.140
	$X_2(t-4)$	-0.19540	0.50142	-0.39	0.697
	$X_3(t-1)$	0.65468	0.08512	7.69	0.000
	$X_3(t-2)$	0.25271	0.09968	2.54	0.011
	$X_3(t-3)$	-0.22452	0.10169	-2.21	0.027
	$X_3(t-4)$	0.13912	0.09126	1.52	0.127
	constant	0.00036	0.00404	0.09	0.929

	Parameters	RMSE	R^2	chi^2	$P > chi^2$
$X_1(t)$	13	0.00763	0.9553	2778.31	0.000
$X_2(t)$	13	0.00347	0.8574	781.38	0.000
$X_3(t)$	13	0.01338	0.6838	281.13	0.000
Log likelihood	1460.68				
AIC	-21.87				
HQIC	-21.52				
SBIC	-21.01				

Table 5: **Granger Causality and Block Exogeneity Wald Tests**. $X_1(t)$ is the variable short rate, $X_2(t)$ is the variable yield slope, and $X_3(t)$ is the variable returns on the NPI index.

Dependent variable: X_1	VAR(3)			VAR(4)		
Excluded	Chi-sq	df	Prob.	Chi-sq	df	Prob.
X_2	3.364747	1	0.3387	4.057219	4	0.3983
X_3	8.119300	1	0.0436	9.680092	4	0.0462
All	11.11854	2	0.0848	14.11925	8	0.0787

Dependent variable: X_2	VAR(3)			VAR(4)		
Excluded	Chi-sq	df	Prob.	Chi-sq	df	Prob.
X_1	10.96587	1	0.0119	9.878924	4	0.0425
X_3	11.20634	1	0.0107	11.27784	4	0.0236
All	18.55750	2	0.0050	18.36094	8	0.0187

Dependent variable: X_3	VAR(3)			VAR(4)		
Excluded	Chi-sq	df	Prob.	Chi-sq	df	Prob.
X_1	2.848938	1	0.4155	8.101157	4	0.0879
X_2	2.906886	1	0.4062	4.747587	4	0.3142
All	3.532695	2	0.7396	14.59063	8	0.0676

Table 6: **Forecast for maturity of the term spread n=20 and different lags (k).**

k=1			R^2= 0.478
	Coefficients (β)	Standard Error	t-Stat
Intercept	0.02492	0.01619	1.53985
X_1	0.205748	0.193478	1.06342
X_2	-0.20002	0.41590	-0.48094
X_3	0.62379	0.08597	7.25553

k=2			R^2= 0.471
	Coefficients (β)	Standard Error	t-Stat
Intercept	0.03235	0.01654	1.95605
X_1	0.02986	0.19917	0.14992
X_2	-0.22868	0.42069	-0.54359
X_3	0.65993	0.08715	7.57233

k=3			R^2= 0.370
	Coefficients (β)	Standard Error	t-Stat
Intercept	0.04330	0.01835	2.35886
X_1	0.04415	0.22264	0.19830
X_2	-0.42253	0.46086	-0.91683
X_3	0.55943	0.09561	5.85085

k=4			R^2= 0.565
	Coefficients (β)	Standard Error	t-Stat
Intercept	0.02864	0.01519	1.88533
X_1	-0.34069	0.18505	-1.84107
X_2	0.39056	0.37652	1.03729
X_3	0.81790	0.07812	10.46984

k=5			R^2= 0.241
	Coefficients (β)	Standard Error	t-Stat
Intercept	0.04384	0.02042	2.14684
X_1	-0.09504	0.24932	-0.38119
X_2	0.20895	0.49883	0.41887
X_3	0.50855	0.10338	4.91897

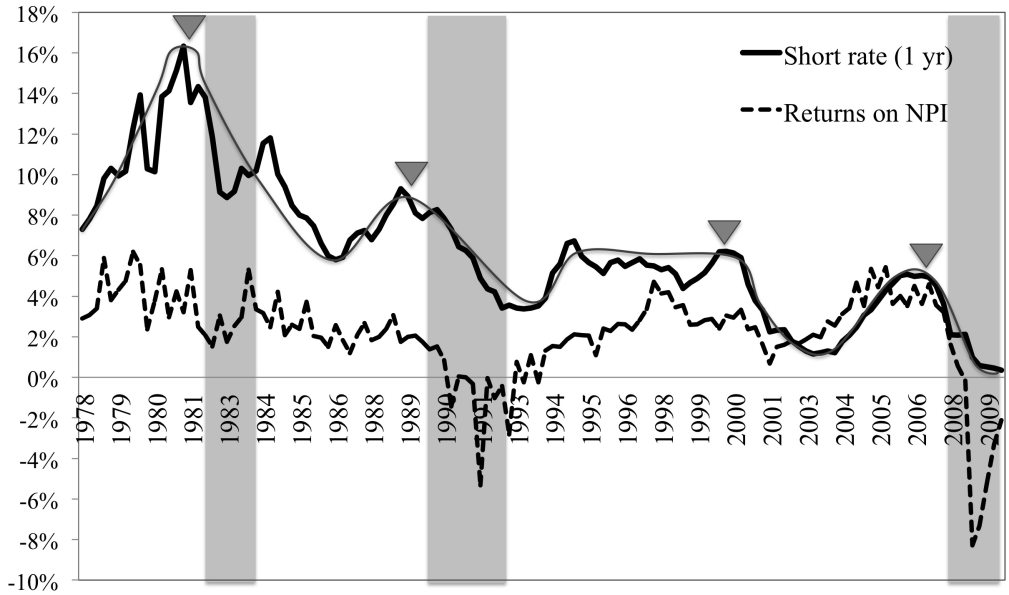

Figure 1: **Short rate versus the returns on the NPI index.** Short interest rate (1 year rate) versus the returns on the NCREIF Property Index. The shaded areas represent the NBER recessions. The triangle marks highlight the end of the periods of high short interest rates, which precede all the recessions. The light line shows the trend of the short rate.

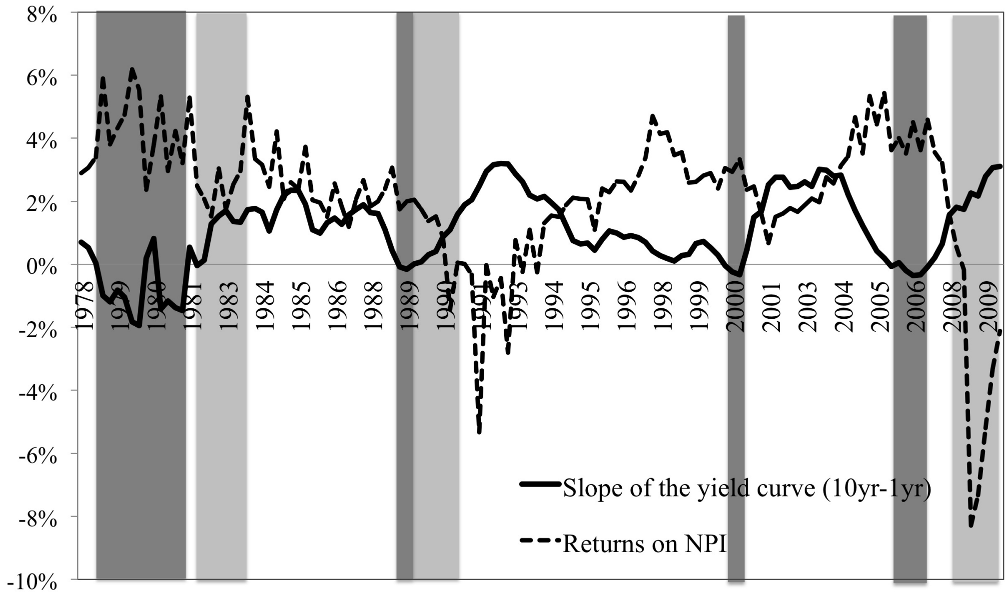

Figure 2: **Slope of the term structure versus the returns on the NPI index.** Slope of the term structure (10 year minus 1 year rates) and the returns on the NCREIF Property Index for the US economy. The light shaded areas represent the NBER recessions. The dark shaded areas highlight the periods in which the slope of the term structure is negative. Note that periods of negative slope precede recessions and the periods in which the returns on the NPI index is growing (decreasing) coincide with periods of economic expansion (recession.)

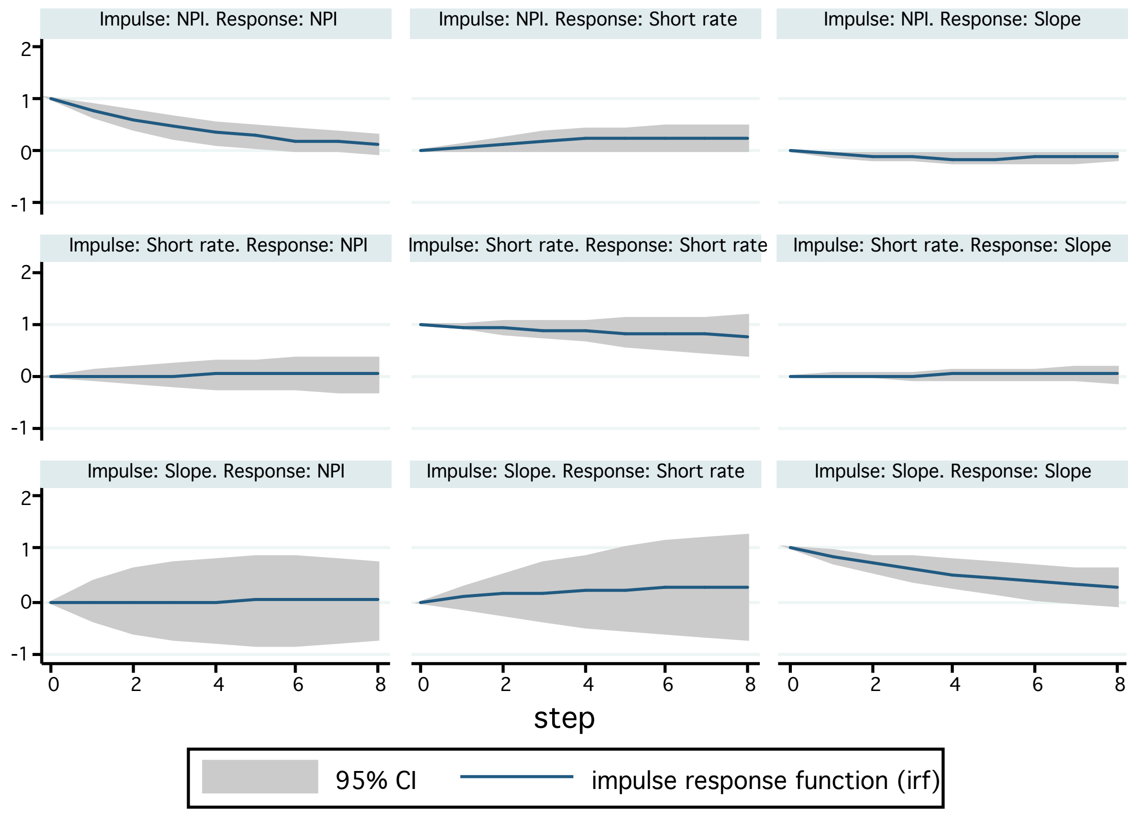

Figure 3: **Impulse response analysis for the VAR(1) analysis.** Short rate is X_1. Slope is the variable yield slope, X_2. NPI is the variable returns on the NPI index, X_3. The 9 figures show all the possible combinations of impulse in one variable and response on another (or the same) variable using a VAR(1) framework.

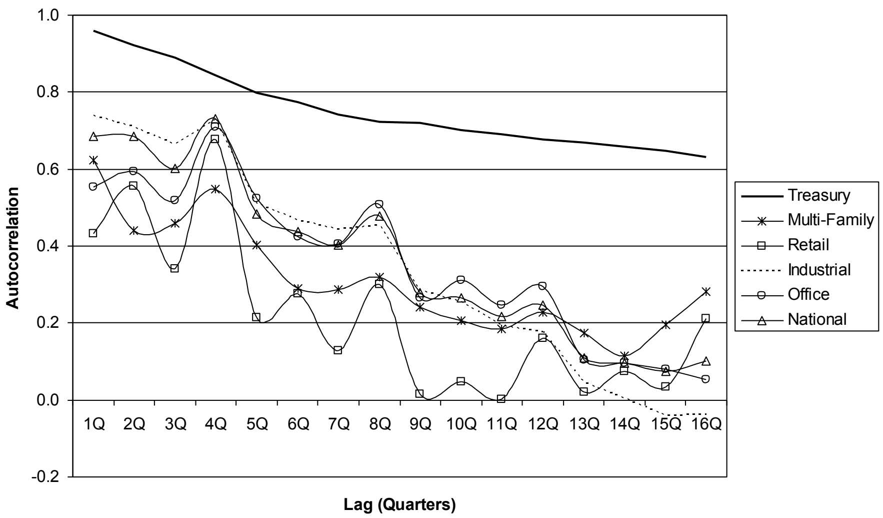

Figure 4: **Autocorrelation of the different NPI Indexes.** Autocorrelation up to 16 quarters of the short interest rate (Treasury) and 5 NPI Indexes.

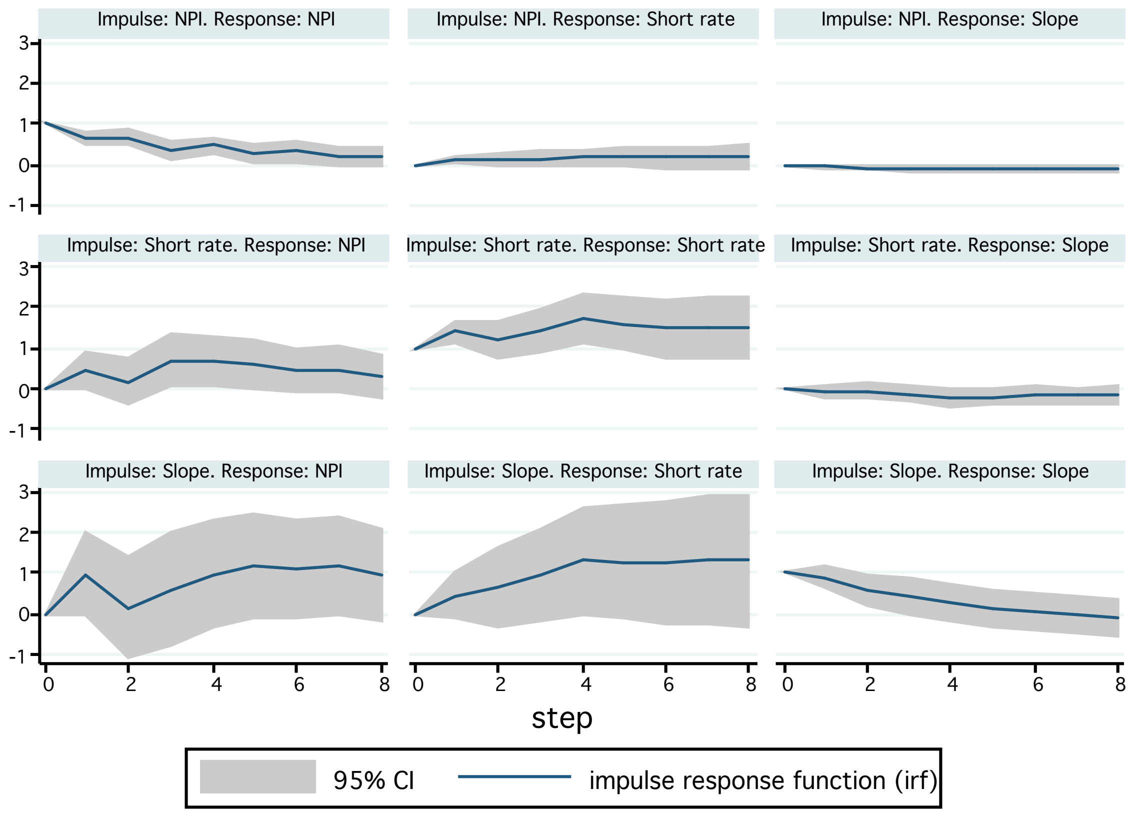

Figure 5: **Impulse response analysis for the VAR(4) analysis.** Short rate is X_1. Slope is the variable yield slope, X_2. NPI is the variable returns on the NPI index, X_3. The 9 figures show all the possible combinations of impulse in one variable and response on another (or the same) variable using a VAR(4) framework.

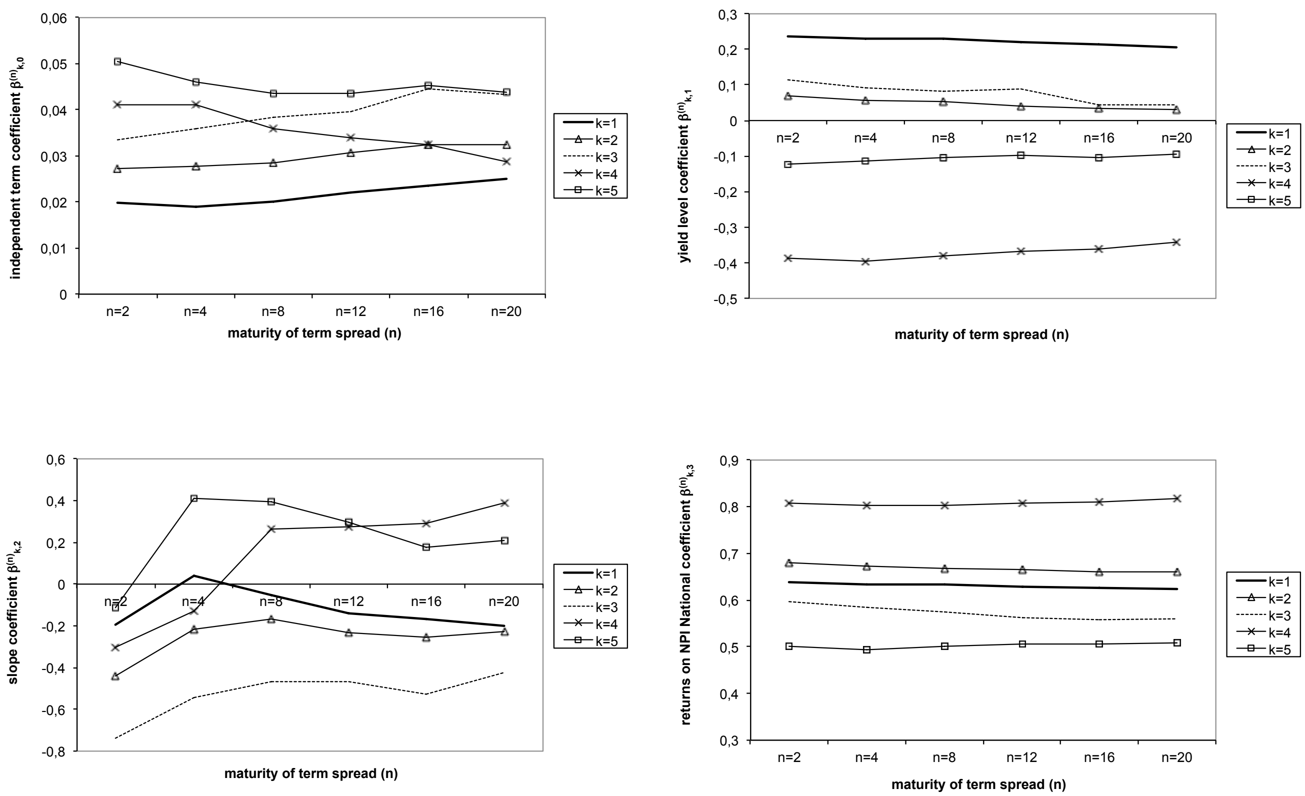

Figure 6: **Values of the four coefficients (betas) of the forecasting equation for different lags (k) and different maturities of the term spread (n, in quarters).** Coefficients of the following forecasting equation: $R^{RE}_{t\to t+k} = \beta^{(n)}_{k,0} + \beta^{(n)}_{k,1} \cdot r^{(1)}_t + \beta^{(n)}_{k,2} \cdot \left(r^{(n)} - r^{(1)}\right) + \beta^{(n)}_{k,3} \cdot R^{RE}_t + \epsilon^{(n)}_{t+k,k}$. The top left graph shows the coefficients $\beta^{(n)}_{k,0}$, the top right graph shows the coefficients $\beta^{(n)}_{k,1}$, the bottom left graph shows the coefficients $\beta^{(n)}_{k,2}$, and the bottom right graph shows the coefficients $\beta^{(n)}_{k,3}$ for different values of k and n.

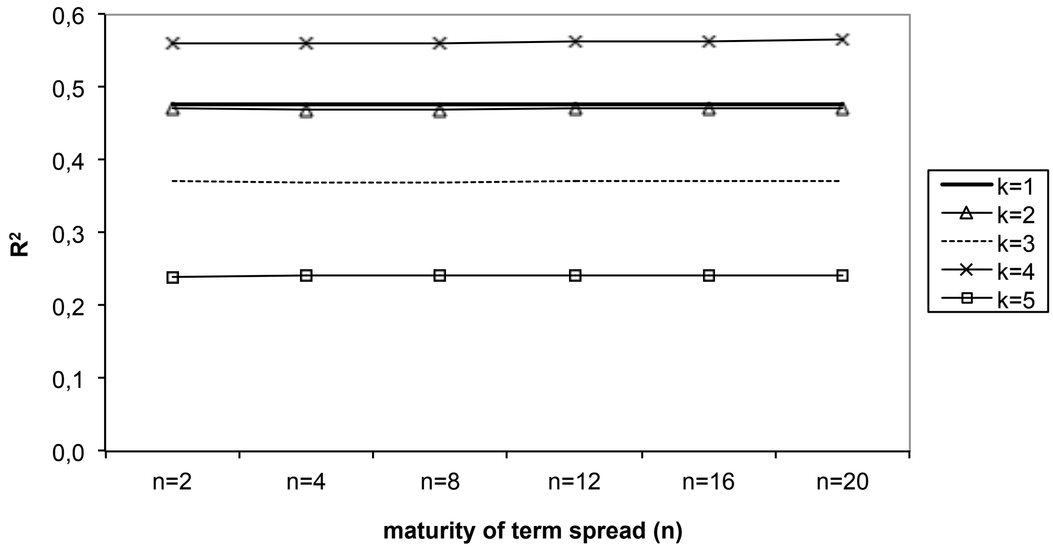

Figure 7: **Values of R^2 of the forecasting equation for different lags (k) and different maturities of the term spread (n).** This figure shows that R^2 does not change when we increase the number of quarters n of the term spread, but it changes when we increase the number of lags k.

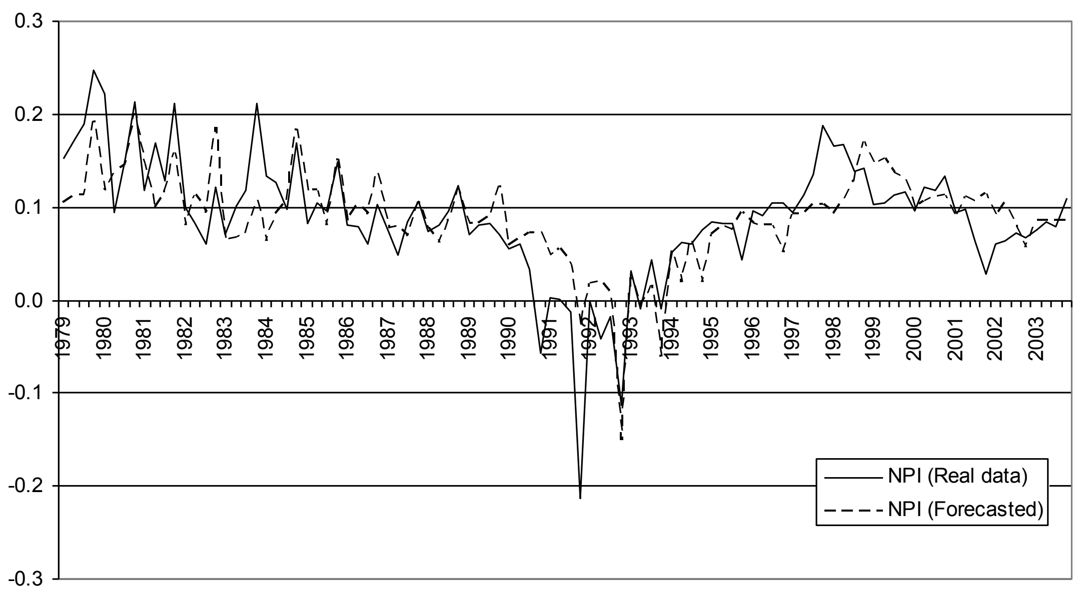

Figure 8: **Return on NPI National vs. Return on predicted NPI National.** Period 1978-2004 (prior to the recent real estate bubble).