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THE MACROECONOMIC FACTORS AND THE YIELD CURVE IN THE GERMAN ECONOMY

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งานวิจัยนี้ คือ การศึกษาการพยากรณ์เส้นอัตราผลตอบแทนของพันธบัตรรัฐบาลในประเทศเยอรมันโดยใช้แบบจำลองเชิงพลวัตรของ Nelson-Siegel และ Svensson ซึ่งเป็นการศึกษาต่อจากงานวิจัยของ Diebold และ Li โดยพยายามพัฒนาแบบจำลองด้วยการใช้ความสัมพันธ์ระหว่างเศรษฐกิจมหภาคกับเส้นอัตราผลตอบแทน และเพิ่มความยืดหยุ่นของแบบจำลอง Nelson-Siegel นอกจากนี้ยังศึกษาผลของวิธีการเลือกปัจจัยทางเศรษฐกิจมหภาคที่มีต่อการพยากรณ์เส้นอัตราผลตอบแทน

จากการศึกษา พบว่าปัจจัยทางเศรษฐกิจมหภาคช่วยเพิ่มความแม่นยำของการพยากรณ์เส้นอัตราผลตอบแทนในระยะกลาง (6-12 เดือน) สำหรับการพยากรณ์ระยะสั้น (1 เดือน) และระยะยาว (60 เดือน) ปัจจัยทางเศรษฐกิจมหภาคไม่สามารถเพิ่มความแม่นยำของการพยากรณ์เส้นอัตราผลตอบแทนได้ เนื่องจากผลกระทบของการเปลี่ยนแปลงทางเศรษฐกิจต่อเส้นอัตราผลตอบแทนต้องใช้ระยะเวลาและผลนี้จะคงอยู่เพียงช่วงระยะเวลาหนึ่งเท่านั้น สำหรับการพยากรณ์ระยะกลาง (6-12 เดือน) พบว่าวิธีการเลือกปัจจัยทางเศรษฐกิจมหภาคมีบทบาทสำคัญ กล่าวคือสำหรับแบบจำลอง Nelson-Siegel วิธีการเลือกปัจจัยทางเศรษฐกิจมหภาคโดยใช้เหตุผลทางเศรษฐศาสตร์ให้ผลการพยากรณ์ที่ดีกว่า แต่สำหรับแบบจำลอง Svensson วิธีการเลือกปัจจัยทางเศรษฐกิจมหภาคโดยใช้หลักการทางสถิติให้ผลการพยากรณ์ที่ดีกว่า และเมื่อทำการเปรียบเทียบผลของการพยากรณ์จากแบบจำลองทั้งสองดังกล่าวแล้ว พบว่าความยืดหยุ่นของแบบจำลอง Svensson เมื่อใช้ร่วมกับวิธีการเลือกปัจจัยทางเศรษฐกิจมหภาคโดยใช้หลักการทางสถิติให้ผลการพยากรณ์ที่ดีกว่า

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We study the prediction of the German Treasury bond yields by using the dynamic Nelson-Siegel and dynamic Svensson models by extending Diebold and Li (2006) work. We try to improve the prediction by (i) using the relationship between macroeconomic and yield curve factors to explain the movement of the yield curve, and (ii) including an extra curvature factor (i.e. Svensson model) to provide higher flexibility for fitting the yield curve. The effect of the macroeconomic selection methods to the prediction is also studied.

From this study, the cross relationship between macroeconomic and latent factors helps improve yield curve forecasts for medium horizons (6-12 months) at most maturities. At very short (1 month) and very long (60 months) forecast horizons, however, the models without macro variables are better. This indicates the time required for the changes in the macroeconomic variables to reflect in the yield curve movements, and how long the effect lasts. Focusing on the medium forecast horizons (6-12 months) where macroeconomic variables improve the forecast performance, we find that the method of selecting the macroeconomic variables is important and model dependent: the Nelson-Siegel model is better with the traditional approach and the Svensson model is better with the correlation-based approach. Comparing the two models, we find that the flexibility and statistical support from the Svensson model with the correlation-based approach leads to better forecasting results.

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CHAPTER 1

INTRODUCTION

A yield curve is a graph that presents relationship between the yield and maturity of fixed income securities at a certain moment in time. The treasury yield curve is focused by the market and used as the benchmark for pricing other fixed income securities because treasury bonds have no credit risk. In addition, investors and economists use the yield curve to forecast interest rates and economic conditions as well as create fixed income securities.

From these benefits of the yield curve and the fact that the shape of the yield curve changes over time, we can say that interest rate forecasting is crucial for financial business. Hence, during the last decades, there have been a lot of advances in the field of financial economics about the yield curve. The recent literatures try to discover and improve the model in order to forecast yield curves as good as possible.

1.1 Literature review

The significant progress in modeling the term structure is the literature on the affine models[1]. It was started by seminal papers of Vasicek (1977) and Cox et al. (1985). Their models are classified as one factor models. They use only one factor, which is the short rate, to explain the yield curve.

Another approach for curve fitting was proposed by Nelson and Siegel (1985) whose method was used and modified by many researchers. Their idea was based on parsimonious modeling in which few parameters can capture the whole yield curve. Other variations of Nelson and Siegel curves extended by subsequent researchers introduced some sophistication by increasing the number of parameters to be estimated. Svensson (1994) extended the work of Nelson and Siegel (1985) by adding an exponential decay term resulting in two extra parameters to capture the humped

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[1] Affine model explains yield movements by a small number of latent factors that can be extracted from the panel of yields for different maturities and impose cross-equation restrictions that rule out arbitrage opportunities.

characteristic of the yield curve.

Other researchers consider models that use the multi factors to explain the entire set of yields. For example, Litterman and Scheinkman (1991) call their factors as "level", "slope", and "curvature". Similarly, Dai and Singleton (2000) use the words "level", "slope", and "butterfly" to describe their factors.

Diebold and Li (2006) use the parsimonious three factors (exponential components) yield curve model proposed by Nelson and Siegel (1987). They study the term structure modeling by using dynamic Nelson-Siegel factor autoregressive of order 1, AR(1), and use a simple two-step approach. They first estimate the three factors, then model and forecast them. They forecast term structure at both short and long horizons. They find that the forecasted results are more accurate at long horizons than several standard benchmark forecasts.

There are many researchers that study the relationship between the yield curve and the macroeconomic variables. For example, Jagjit S. Chadha and Sean Holly (2006) trace the response of the yield curve to macroeconomic shocks and conclude that macroeconomic persistence seems to be priced into the yield curve. Marie Briere and Florian Ielpo (2007) analyses the response of the Euro yield curve to macroeconomic and monetary policy announcements and they find that the impact of economic announcements on the yield curve shows different patterns according to the news and we provide a hierarchy of the economic figures that have the strongest impact on the different maturities. Ang, Bekaert and Wei (2007) study the term structure of real rate and inflation. They find that variation in inflation compensation (expected inflation and inflation risk premia) explains about 80% of the variation in nominal rates at both short and long maturities.

To improve the yield curve prediction, there are many papers that use the relationship between macroeconomic and interest rate to improve the yield curve forecasting. Andrew Ang and Monika Piazzesi (2002) study the term structure by using the joint dynamics of bond yields and macroeconomic variables in a vector autoregression. They find that forecasting performance of a VAR improves when macro factors are included.

Some researchers do not incorporate latent yield curve factors but instead use the common components of a large number of macroeconomic variables and the short rates as explanatory factors. For example, Emanuel Mönch (2005) says that central banks reach to economic information by monitoring a variety of economic time series variables beyond output and inflation. Hence, he suggests the term structure model which parsimoniously exploits a broad macroeconomic information set.

Diebold, Rudebusch, and Aruoba (2006) use latent factors and three observable macroeconomic variables (real activity, inflation, and monetary policy instrument) to explain the yield curve. They propose a one-step approach that uses the state-space model to do factor estimation, modeling, and forecasting simultaneously. They argue that the one-step state-space approach provides a unified framework and should improve out-of-sample forecasts. They also find strong evidence of the effects of macro variables on the future movements in the yield curve.

Marco Morales (2008) and Wei-Choun Yu and Eric Zivot (2008) extend Diebold and Li (2006) and Diebold, Rudebusch, and Aruoba (2006) work. They examine both one- and two-step approaches and include the macroeconomic variables to model estimation. They find that the state-space approach cannot improve out-of-sample forecasts for Treasury yield.

From the literature described previously, there are some research questions need be answered. For example, most of them study only the term structure of the US government Treasury bond yields and they do not study the detail and the effect of macro selection methods. So it is interesting to see how the results will be like for a non-US economy and how the choices of macroeconomic variables affect the yield forecasts. To answer the questions, we apply the dynamic Nelson-Siegel with macroeconomic variables to the German economy and propose two methods of selecting macroeconomic variables.

1.2 Objective

The purpose of this paper is to extend Diebold and Li (2006) work and apply the model to forecast the German government bond yields. In particular, our first contribution is that we include a set of macroeconomic variables into the model and use a vector autoregression of order 1, VAR (1) to model the dynamic of the latent and macroeconomic factors because we anticipate that the relationship between the yield curve and the macroeconomic variables will improve the yield curve prediction. The model is estimated using a simple two-step approach. Specifically, we first estimate the latent factors by fitting the Nelson-Siegel factor model to the yield at each time period. Then a set of three macroeconomic factors is chosen. We have two macro selection methods. First is the traditional approach that selects macroeconomic factors by using economic intuition. Second is the correlation-based approach that selects macroeconomic factors that have high correlation with the *future* latent factors. The underlying assumption of this approach is that the correlation between the macroeconomic factors and the future latent factors should provide useful information in predicting the movement of the yield curve. Finally we find the relationship among latent and macroeconomic factors by using a VAR (1) process. The second contribution is that we add one more latent factor into the model by using the Svensson model. The Svensson model is similar to the Nelson-Siegel model but Svensson adds one more factor in his model in order to reduce the drawback in the Nelson-Siegel model and increase flexibility to the model. We forecast the term structure at various forecast horizons and evaluate the forecasted results using root mean square error-RMSE.

To summarize, the contribution of this paper is twofold and consists of

(i) The term structure of government bond yields in Germany is forecasted by using both Nelson-Siegel method and Svensson method and (ii) we include a set of macroeconomic variables into the model (We have two methods of macroeconomic selection, that is, traditional and correlation-based approaches).

We proceed as follow. In chapter 2 we introduce the basic concept of Nelson-Siegel and Svensson models and the detail of the estimation process of the yield curve factors, macroeconomic variables and vector autoregression. In chapter 3 we examine the out-of-sample forecasting performance and interpret the impulse response. In chapter 4 we offer concluding remarks.

CHAPTER 2
METHODOLOGY

2.1 Introduction of yield curve models

2.1.1 Nelson and Siegel model

Nelson and Siegel (1987) function form is a convenient and parsimonious three-component exponential approximation. Denote the set of yield at time t from Bundesbank (Bank of Germany) as $y_t(\tau)$, where τ denotes maturity and $\varepsilon_t(\tau)$ denotes the maturity τ error term at time t.

$$y_t(\tau) = \beta_{1t} + \beta_{2t}\left(\frac{1-e^{-\lambda_{1t}\tau}}{\lambda_{1t}\tau}\right) + \beta_{3t}\left(\frac{1-e^{-\lambda_{1t}\tau}}{\lambda_{1t}\tau} - e^{-\lambda_{1t}\tau}\right) + \varepsilon_t(\tau) \qquad (1)$$

Parameter λ_{1t} determines the rate of exponential decay. Three latent dynamic factors are β_{1t}, β_{2t} and β_{3t}. Factor loading on β_{1t} is 1, a constant that does not decay to zero. It loads equally at all maturities. In other word, a change in β_{1t} changes all yield uniformly. Therefore, it is called a level factor. When the maturity becomes larger, β_{1t} plays more important role in forming yields with respect to smaller factor loading on β_{2t} and β_{3t}. Hence, β_{1t} may be viewed as a long-term factor. Factor loading on β_{2t} is $\left(1-e^{-\lambda_{1t}\tau}\right)/\lambda_{1t}\tau$, which starts at 1 but decays fast and monotonically to zero. An increase in β_{2t} increases short yields more than long yields because the short rates load on β_{2t} more heavily; consequently, it changes the slope of the yield curve. β_{2t} may be viewed as a slope or short-term factor. Factor loading on β_{3t} is $\left(\left(1-e^{-\lambda_{1t}\tau}\right)/\lambda_{1t}\tau\right)-e^{-\lambda_{1t}\tau}$, which starts at zero, increases, and then decays to zero; hence it may be viewed as a medium-term factor. It is also called a curvature factor because an increase in β_{3t} will increase the yield curve curvature. (Illustrated in Figure 1)

2.1.2 Svensson model

One major drawback of the Nelson-Siegel model is that the fitted curve can have at most one hump. Svensson (1994) proposes an extension of the Nelson-Siegel model (1987) by adding flexibility to the model in order to potentially have an extra hump in the curve.

$$y_t(\tau) = \beta_{1t} + \beta_{2t}\left(\frac{1-e^{-\lambda_{1t}\tau}}{\lambda_{1t}\tau}\right) + \beta_{3t}\left(\frac{1-e^{-\lambda_{1t}\tau}}{\lambda_{1t}\tau} - e^{-\lambda_{1t}\tau}\right) + \beta_{4t}\left(\frac{1-e^{-\lambda_{2t}\tau}}{\lambda_{2t}\tau} - e^{-\lambda_{2t}\tau}\right) + \varepsilon_t(\tau) \quad (2)$$

where β_{1t}, β_{2t}, β_{3t}, β_{4t}, λ_{1t}, and λ_{2t} are parameters to be estimated. The Svensson curve is thus modeled using six parameters, with the additional input β_{4t} and λ_{2t}. The additional parameters will capture an extra hump for the curve.

2.2 Dynamic factor model

To estimate yield curve, there are two basic approaches. First, as in Diebold, Rudebusch, and Aruoba (2006), they use a one-step estimation of the dynamic model by the Kalman Filter method. The second approach is a simple two-step method as proposed by Diebold and Li (2006). As mention above, this paper implements the two-step approach. We start with the yield curve factors estimation and then we forecast and model the term structure by fitting the VAR(1) that explains the relationship among factors.

For the Nelson-Siegel model, we fit the yield curve using the three-factor model given by equation (1). We have to estimate the parameters β_{1t}, β_{2t}, β_{3t} and λ_{1t} by nonlinear least squares, for each month t.

For the Svensson model, we fit the yield curve using the four-factor model given by equation (2). We have to estimate the parameters β_{1t}, β_{2t}, β_{3t}, β_{4t}, λ_{1t}, and λ_{2t} by nonlinear least squares, for each month t.

Following standard practice tracing to Nelson and Siegel (1987), however, we instead assume that λ_{1t} for the Nelson-Siegel method and λ_{1t} and λ_{2t} for the Svensson method are constants.

Consequently, the Nelson-Siegel model can be re-written as:

$$y_t(\tau) = \beta_{1t} + \beta_{2t}\left(\frac{1-e^{-\lambda_1\tau}}{\lambda_1\tau}\right) + \beta_{3t}\left(\frac{1-e^{-\lambda_1\tau}}{\lambda_1\tau} - e^{-\lambda_1\tau}\right) + \varepsilon_t(\tau)$$

and the Svensson model can be re-written as:

$$y_t(\tau) = \beta_{1t} + \beta_{2t}\left(\frac{1-e^{-\lambda_1\tau}}{\lambda_1\tau}\right) + \beta_{3t}\left(\frac{1-e^{-\lambda_1\tau}}{\lambda_1\tau} - e^{-\lambda_1\tau}\right) + \beta_{4t}\left(\frac{1-e^{-\lambda_2\tau}}{\lambda_2\tau} - e^{-\lambda_2\tau}\right) + \varepsilon_t(\tau)$$

The method for estimating the parameters under the constant λ assumption is given in section 2.4.1.

Next, we choose the macroeconomic variables. In this paper, we use two macro selection methods: the traditional approach and the correlation-based approach. (See section 2.4.2 for the detail of the selection method) After we get the time series of all factors (latent and macroeconomic factors), we use vector autoregression of order 1, VAR(1), to find the relationship among factors (latent and macroeconomic factors). For example, in the Svensson yield only model, the equation system can be written as:

$$\begin{pmatrix} \beta_{1t} \\ \beta_{2t} \\ \beta_{3t} \\ \beta_{4t} \end{pmatrix} = \begin{pmatrix} c_{\beta_1} \\ c_{\beta_2} \\ c_{\beta_3} \\ c_{\beta_4} \end{pmatrix} + \begin{pmatrix} a_{11} & a_{12} & a_{13} & a_{14} \\ a_{21} & a_{22} & a_{23} & a_{24} \\ a_{31} & a_{32} & a_{33} & a_{34} \\ a_{41} & a_{42} & a_{43} & a_{44} \end{pmatrix} \begin{pmatrix} \beta_{1,t-1} \\ \beta_{2,t-1} \\ \beta_{3,t-1} \\ \beta_{4,t-1} \end{pmatrix} + \begin{pmatrix} \varepsilon_{\beta_1} \\ \varepsilon_{\beta_2} \\ \varepsilon_{\beta_3} \\ \varepsilon_{\beta_4} \end{pmatrix} \quad (3)$$

Where β_{1t} is the level factor of the Svensson model at time t

β_{2t} is the slope factor of the Svensson model at time t

β_{3t} is the first curvature factor of the Svensson model at time t

β_{4t} is the second curvature factor of the Svensson model at time t

c_i is the estimated constant for factor i from VAR(1)

a_{ij} is the estimated coefficient of factor j for factor i from VAR(1)

We consider four variants of VAR(1) system:

- Nelson-Siegel yield-only model
- Svensson yield-only model
- Nelson-Siegel yield-macro model
- Svensson yield-macro model

In general, we can write

$$f_t = C + A(f_{t-1}) \tag{4}$$

Where A is the matrix of coefficients

C is the vector of constants

$f_t = (\beta_{1t}, \beta_{2t}, \beta_{3t})$; for Nelson-Siegel yield-only model

$f_t = (\beta_{1t}, \beta_{2t}, \beta_{3t}, \beta_{4t})$; for Svensson yield-only model

$f_t = (\beta_{1t}, \beta_{2t}, \beta_{3t}, M1_t, M2_t, M3_t)$; for Nelson-Siegel yield-macro model

$f_t = (\beta_{1t}, \beta_{2t}, \beta_{3t}, \beta_{4t}, M1_t, M2_t, M3_t)$; for Svensson yield-macro model

2.3 Data

Zero-coupon yields for German Treasury bonds are collected from Deutsche Bundesbank (Bank of Germany). Our sample period covers January 1992 until December 2008 for a total of 204 monthly observations (See Figure 2). We examine fixed maturities of 12, 24, 36, 48, 60, 72, 84, 96, 108, 120, 132, 144, 156, 168 and 180 months. The descriptive statistics of the yield curve are shown in Table 1. The in-sample period covers January 1992 until December 2002 while the out-of-sample period covers January 2003 to December 2008.

We collect the Germany's macroeconomic indicators from Deutsche Bundesbank. Then we adjust and analyze data to obtain the appropriate indicators (See Section 2.4.2.2 for more details).

2.4 Estimation method

2.4.1 Latent factors estimation

Since the Nelson-Siegel model requires estimating a non-linear equation which complicates the algorithm considerably, we try to fix the λ in order to convert the non-linear equation to a linear equation. The value of this parameter determines the maturity at which the loading on the curvature factor achieves it maximum. As two or three year maturities are commonly used for this purpose, Diebold and Li (2006) set λ = 0.0609 which is the value that maximizes the loading on the curvature factor at 30 months.

However, Hurn et al (2005) study the effect of fixing λ and show that although this approach has the advantage of simplicity in terms of implementation; it is likely to be suboptimal if the fit of the yield curve is sensitive to the choice of the time-scale parameter. They apply the Nelson-Siegel model to the UK Gilts data during 1985-2004. They find that the yield curve constructed from λ = 0.0609 has a poor fit to the true yield curve of UK. Similarly, for the German yield curve, we believe the λ should be different from the one used in the US market. Consequently, we decide not to use λ = 0.0609 as suggested by Diebold and Li (2006).

What is the appropriate value for λ? In this paper, we simply use the average of the time series of λ obtained from the non-linear least square. Although this choice of λ could be debatable, we leave this issue for future study. More precisely, to estimate the value of λ, we use solver in Microsoft Excel to solve for the in-sample value of latent factors (β_{it}'s) and λ_t that minimize the root mean square error (RMSE) at each month t.

$$RMSE = \sqrt{\frac{1}{N}\sum_{\tau=1}^{N}(y_t(\tau) - \hat{y}_t(\tau))^2}$$

Where N is number of maturities

$y_t(\tau)$ is the actual yield at maturity of τ year(s) at time t from Bundesbank

$\hat{y}_t(\tau)$ is the predicted yield at maturity of τ year(s) at time t from the models (given by equations (1) and (2))

Then we fix λ_t by taking the average of the time series. That is, we fix

$$\lambda_i = \sum_{t=1}^{T} \frac{\hat{\lambda}_{it}}{T}$$

where $\hat{\lambda}_{it}$ is the estimated rate of exponential decay i from nonlinear lease square (based on equations (1) and (2))

T is a number of months in the in-sample period

We get λ_1 equal to 0.460 for the Nelson-Siegel model, and λ_1 and λ_2 equal to 0.452 and 0.194 respectively for the Svensson model. After we fix λ_1 (and λ_2), we re-run solver to discover the values of β_{1t}, β_{2t}, β_{3t} and β_{4t} that minimize RMSE at each time t.

Note that the estimated results of the non-linear least squares are very sensitive to the initial value of the inputs before running the program. In this study, we try to minimize the RMSE in the following manner. We first minimize the RMSE by changing only the cells of β_{1t} while other parameters are fixed. Then we minimize RMSE by changing only β_{2t} while β_{1t} are fixed at the values obtained in the previous step. We repeat the same process for the remaining parameters. Finally, we minimize the RMSE by changing all parameters. The reason we have to use these steps is that if we minimize the RMSE for each month as usual, the resulting factors tend to considerably fluctuate. In reality, such rapid changes in those factors during short period of one month are not sensible. Hence, we try to smooth the changes of the yield curve factors by aforementioned process.

2.4.2 Selection of macroeconomic factors

We propose two methods of macroeconomic variables selection which are traditional and correlation-based approaches. In the traditional approach, we select the macroeconomic variables that should have useful information to explain the trend of each latent factor according to economic theory or intuition. For example, the inflation rate should explain the movement of the level factor according to the Fisher equation. In the correlation-based approach, we select the macroeconomic variables that are highly correlated with the latent factors.

We confirm our estimated yield factors by computing the correlation between the yield curve factors and its proxy. If the correlations are high, it implies that the estimated yield curve factors are acceptable since they match their definition.

2.4.2.1 Traditional approach

In Figure 3-4, we show the estimated level and two comparison series:

- A common empirical proxy for level is an average of short-, medium- and long term yields, ($y_t(12) + y_t(96) + y_t(180)) / 3$). The correlation between β_{1t} and the proxy is 0.71 and 0.54 for the Nelson-Siegel and the Svensson model respectively. This supports our explanation that β_{1t} is a level factor.

- A measure of inflation (the 12-month percent change in the price deflator for personal consumption expenditures, $100 * (P_t – P_{t-12}) / P_{t-12}$, where P_t is the price deflator for personal consumption expenditures at time t and P_{t-12} is the price deflator for personal consumption expenditures at time t-12). The correlation between β_{1t} and the actual inflation is 0.35 for the Nelson-Siegel model and 0.14 for the Svensson model. We choose inflation as one of our macroeconomic variables because there is a link between the level of yield curve and inflationary expectation suggested by the Fisher equation.

In Figure 5-6 we show the estimated slope and two comparison series:

- A standard empirical slope proxy is the difference between the short-maturity and long-maturity yield given by $y_t(12)$ - $y_t(180)$. The correlation between

β_{2t} and the proxy is 0.99 and 0.95 for the Nelson-Siegel and the Svensson model respectively. This supports our explanation that β_{2t} is a slope factor.

- The consumer goods production index. The correlation between β_{2t} and the index is 0.83 for the Nelson-Siegel model and 0.78 for the Svensson model. The consumer goods production index could represent economic activity because when economy is bad, there will be less consumer goods produced. As a result, the production of consumer goods index will decrease. At the same time, the central bank will have to decrease the short term policy rate to stimulate the economy. Then the slope factor of the yield curve will decrease. This explains the relationship between the slope factor and the production index.

In Figure 7-9, we show the estimated curvature and two comparison series:

- A common empirical proxy for curvature is the difference between the twice the medium-maturity yield and the sum of the short- and long-maturity. In the Nelson-Siegel model and the first curvature of Svensson model, 2 * $y_t(48)$ - $y_t(12)$ - y_t (180). The correlation between β_{3t} and this proxy is 0.99 and 0.91 for Nelson-Siegel and the first curvature of Svensson model respectively. For the Svensson model, we use 2 * $y_t(96)$ - $y_t(12)$ - $y_t(180)$ as a proxy for the second curvature factor. The correlation between β_{4t} and this proxy is 0.45. This supports our explanation that β_{3t} and β_{4t} are curvature factors.

- The change of unemployment. We select the change of unemployment as suggested by Modena (2008) who studies the yield curve of the US market and found that the curvature factor reflects the cyclical behavior of the economy which can be represented by the dynamics of industrial production and unemployment. He found a sharp reduction of the curvature factor immediately before recessions. This result suggests that the curvature of the term structure seems to be informative for predicting evolution of the economy. Hence, in this paper we use change of unemployment as a macroeconomic factor to explain the dynamics of the curvature factors. The correlation between β_{3t} and the index is -0.34 and -0.42 for

Nelson-Siegel and Svensson model and the correlation between β_{4t} and the index is 0.29.

2.4.2.2 Correlation based approach

In this approach macroeconomic factors are chosen based on their correlations with the latent factors. To do that, we first select the main economic indicators for each group by choosing indicators that reflect the whole character for each group. For example, we choose total GDP instead of GDP from construction sector. Then we adjust data in order to remove the seasonal effect and focus on the portion extracted from macroeconomic variables that potentially affect the yield curve. Figure 10 shows all selected indicators and their adjusting approaches. After that we compute the correlation between each of these variables at time t-1 and each of the latent factors at time t[2]. Then, for each latent factor, we choose the macroeconomic variable that has the highest correlation with the latent factor. We expect that these macroeconomic indicators will improve yield curve forecasting. Our selected measures of the economy include: number of employee (EMP_t) for the level factor, production of consumer goods ($PROD_t$) for the slope factor, and orders received in manufacturing sector (MN_t) for the curvature factor. The correlations are given in Figure 11.

Note that for the curvature factor we choose the macro variable that has the highest value of the sum of the absolute correlations. That is the absolute values of correlation from Nelson-Siegel model and Svensson model are calculated. Next, we find the summation of them and choose the macro variable that has the highest value. The correlation between the latent factors and the macro variables are shown in Figure 12-18.

[2] We use the correlation between the macroeconomic variables at time t-1 and the latent factors at time t because we want to choose the macro factors that are able to forecast the future values of the latent factors.

2.4.3 Estimation of vector autoregression (VAR)

Vector autoregression (VAR) is commonly used for forecasting systems of interrelated time series and for analyzing the dynamic impact of random disturbance on the system of variables. The VAR approach models by treating every endogenous variable in the system as the function of the lagged values of all of the endogenous variables in the system.

From equation (4), we have two sets of macro variables. In the traditional approach, M1, M2, and M3 are inflation rate, production of consumer goods index and change in unemployment rate respectively. In the correlation-based approach, M1, M2, and M3 are number of employees, production of consumer goods index and order received in manufacturing sector.

Figure 19-22 show the estimated matrices of coefficients of the Nelson-Siegel and Svensson with macro factors models for both traditional and correlation-based approaches. Bold entries in Figure 19-22 denote parameter estimates that are significant at the 5 percent level. Most diagonal coefficients are significantly different from zero at 5 percent level. This implies the latent factors can be explained by themselves in the past. In addition, we find the effect of the macroeconomic in the previous month to the current latent factors through some coefficients that significantly different from zero at 5 percent level. This supports our expectation that macro variables have useful information and could improve the yield curve forecasting.

Table 2 provides the correlation between the macroeconomic variables at time t and the yield curve factors at time t. We find that the correlation between the latent factors and their macro factor is high. Hence, these macro variables do not give much of new information provided that the latent factors are already included. This result is consistent with the estimated matrices of coefficients that only most of the diagonal coefficients are significantly different from zero.

CHAPTER 3
FORECASTS EVALUATION

3.1 Out-of-sample forecast

For this step, we use data from 1992:1 to 2002:12 as in-sample and 2003:1 through 2008:12 as out-of-sample. To evaluate the forecasting performance, we compare the Root Mean Square Error (RMSE) from all the models. The smaller the RMSE, the better the model forecasts. The RMSE is calculated from

$$RMSE_{\tau} = \sqrt{\frac{1}{N}\sum_{t=1}^{N}(y_t(\tau) - \hat{y}_t(\tau))^2}$$

Where $RMSE_{\tau}$ is the root mean square error of yield at maturity of τ year(s)

N is a number of months in the out-of-sample period

$y_t(\tau)$ is the actual yield at maturity of τ year(s) from Bundesbank at time t

$\hat{y}_t(\tau)$ is the predicted yield at maturity of τ year(s) from the models at time t

In Table 3-8 we compare forecasting results by using the root mean square error (RMSE) from the 6 models;

- Nelson-Siegel yield only model
- Nelson-Siegel yield macro model (traditional approach)
- Nelson-Siegel yield macro model (correlation-based approach)
- Svensson yield only model
- Svensson yield macro model (traditional approach)
- Svensson yield macro model (correlation-based approach)

for maturities 1 to 15 years and forecast horizon of 1, 3, 6, 12, 24 and 60 months.

From Table 3, the result shows that in case of the forecast horizon that is very short (1 month), the yield only of the Nelson-Siegel model provides the best forecasts of the yield curve for short maturities. However, for long maturities the yield-only of the Svensson model provides better forecasts. When comparing between two macro selection approaches, traditional approach is better.

From Table 4, the result shows that at forecast horizon of 3 months macroeconomic variables from correlation-based approach improve the prediction for short maturities. However, for the long maturities the macroeconomic variables and the flexibility of Svensson do not improve the yield curve prediction.

From Table 5-6, the result shows that at forecast horizon of 6 and 12 months the macroeconomic factors and the flexibility of Svensson model improve yield curve prediction.

From Table 7, the result shows that at forecast horizon of 24 months the flexibility of Svensson model can reduce the RMSE at all maturity while the macroeconomic factors can improve the yield curve forecasting only at short and medium maturities.

From Table 8, the result shows that at forecast horizon of 60 months the yield-only Nelson-Siegel model is the best model for most of maturities, that is the flexibility of the Svensson model and macroeconomic cannot improve the prediction of yield curve.

In conclusion, the results give support to the dynamic interaction between the yield curve latent factors and macroeconomic variables; that is, we find strong evidence of macroeconomic effects on the future yield curve leading to the improvement in yield curve forecasting in medium forecast horizons (6-12 months) at most maturities. At 1 and 60 months forecast horizon, however, the models without macro variables are better. At 1 month forecast horizon, the effects of macroeconomic variables are not yet reflected in the yield curve since market participants and policy makers require time to digest the information in order to react properly. Hence, adding them to the model will not improve the prediction. Moreover, at 60 months horizons, we cannot accurately predict the macroeconomic variables since the economic condition has been changed considerably from the current condition.

When we compare the Nelson-Siegel and the Svensson models, we find that if we exclude the macro variables, the Nelson-Siegel model gives better forecasting in some forecast horizons (3,6 and 60 months) but in other forecast horizons the results are mixed. The reason is that the factors in Nelson-Siegel model cover all useful information. Then, if we include unnecessary information from macro variables, the model will suffer from noise. If we include the macro variables to the model, we find that for the traditional approach the results are not obvious; that is at 1, 12 and 24 forecast horizons, the Svensson model is better but at 3, 6 and 60 months the results are mixed. However, for the correlation-based approach the results show that the Svensson model is better for almost all forecast horizons. Therefore, we can conclude that the flexibility of the Svensson model and the information of macroeconomic variables together have some useful interaction and can improve the yield curve prediction.

When we compare the results between the Nelson-Siegel model and Svensson model without macro variables, we find that the results are mixed. Moreover, when we compare between traditional and correlation-based approaches, at short forecast horizons (1-12 months) for the Nelson-Siegel model, the traditional approach gives better prediction but for the Svensson model, the correlation-based approach gives better prediction except at the forecast horizon of 1 month. However, at long forecast horizons (24-60 months) the tradition approach gives better prediction.

To examine the sources of error, we compute the forecasting errors in term of RMSE for the forecasts of latent factors. The results are given in Table 9. We find that most of the RMSE of forecasted latent factors is consistent with the RMSE of the forecasted yield curve. For example, at 1 month forecast horizon the RMSE of forecasted latent factors and yield curve of Nelson-Siegel yield-only model is lowest and at 12 months forecast horizon the RMSE of forecasted latent factors and yield curve of Svensson yield-macro model is lowest. Hence, a part of the error of yield curve forecasting comes from latent factor forecasting.

Now we compare our models with the following standard models:

(1) Random walk : $\hat{y}_{t+1}(\tau) = y_t(\tau)$

Where $\hat{y}_{t+1}(\tau)$ is the predicted yield at maturity of τ year(s) at time t+1

$y_t(\tau)$ is the actual yield at maturity of τ year(s) from Bundesbank at time t

(2) AR(1) on yield level : $\hat{y}_{t+1}(\tau) = \hat{c}(\tau) + \hat{\gamma}(\tau) y_t(\tau)$

Where $\hat{y}_{t+1}(\tau)$ is the predicted yield at maturity of τ year(s) at time t+1

$y_t(\tau)$ is the actual yield at maturity of τ year(s) from Bundesbank at time t

$\hat{c}(\tau)$ and $\hat{\gamma}(\tau)$ are the coefficients estimated from AR(1) model at maturity of τ year(s)

(3) VAR(1) on yield level : $\hat{y}_{t+1} = \hat{c} + \hat{\Gamma} y_t$

Where $\hat{y}_{t+1}$ is the vector of predicted yield for all maturities at time t+1

y_t is the vector of actual yield for all maturities from Bundesbank at time t

$\hat{c}$ and $\hat{\Gamma}$ are the matrixes of coefficients estimated from VAR(1) model

(4) AR(1) on Nelson-Siegel factors :

$$\widehat{\beta}_{1,t+1} = \hat{c}_1 + \hat{\Gamma}_1 \beta_{1,t}$$

$$\widehat{\beta}_{2,t+1} = \hat{c}_2 + \hat{\Gamma}_2 \beta_{2,t}$$

$$\widehat{\beta}_{3,t+1} = \hat{c}_3 + \hat{\Gamma}_3 \beta_{3,t}$$

Where $\widehat{\beta}_{1,t+1}$, $\widehat{\beta}_{2,t+1}$ and $\widehat{\beta}_{3,t+1}$ are the predicted level, slope, and curvature factor of Nelson-Siegel model at time t+1

$\beta_{1,t}$, $\beta_{2,t}$, and $\beta_{3,t}$ are the level, slope, and curvature factor of Nelson-Siegel model at time t from fitting of the yield curve to actual data from Bundesbank

$\hat{c}_1$, $\hat{c}_2$, $\hat{c}_3$, $\hat{\Gamma}_1$, $\hat{\Gamma}_2$ and $\hat{\Gamma}_3$ are the coefficients estimated from AR(1)

(5) AR(1) on Svensson factors :

$$\widehat{\beta}_{1,t+1} = \hat{c}_1 + \hat{\Gamma}_1 \beta_{1,t}$$

$$\widehat{\beta}_{2,t+1} = \hat{c}_2 + \hat{\Gamma}_2 \beta_{2,t}$$

$$\widehat{\beta}_{3,t+1} = \hat{c}_3 + \hat{\Gamma}_3 \beta_{3,t}$$

$$\widehat{\beta}_{4,t+1} = \hat{c}_4 + \hat{\Gamma}_4 \beta_{4,t}$$

Where $\widehat{\beta}_{1,t+1}$, $\widehat{\beta}_{2,t+1}$, $\widehat{\beta}_{3,t+1}$ and $\widehat{\beta}_{4,t+1}$ are the predicted level, slope, the first curvature, and the second curvature factors of the Svensson model at time t+1

$\beta_{1,t}$, $\beta_{2,t}$, $\beta_{3,t}$, and $\beta_{4,t}$ are the level, slope, the first curvature, and the second curvature factors of the Svensson model at time t from fitting of the yield curve to actual data from Bundesbank

$\hat{c}_1$, $\hat{c}_2$, $\hat{c}_3$, $\hat{c}_4$, $\hat{\Gamma}_1$, $\hat{\Gamma}_2$, $\hat{\Gamma}_3$, and $\hat{\Gamma}_4$ are the coefficients estimated from AR(1)

The equations described previously make forecasts for one period. To do multiperiod forecasts, we use the chain rule of forecasting. Using the chain rule forecasting, we substitute the predicted value of factor at time t+1 into the equation to get the factor's value at time t+2, and substitute the predicted value of factor at time t+2 into the equation to get the factor's value at time t+3, and so on.

The result in Table 10 indicates VAR(1) models (the Nelson-Siegel yield-only and yield-macro model and the Svensson yield-only and yield-macro model) are the best approaches to forecast the yield curve for most of all forecast horizons since they outperform other competitor models in most cases. The reason is that VAR(1) model incorporates highest level of information compared to random walk and AR(1). For example, VAR(1) also considers the cross relationship between the variables at time t+1 and other variables at time t. In addition, we also found that VAR(1) on the latent factors of the yield curve outperform VAR(1) on yield level.

3.2 Impulse response

The most intuitive tool to analyze the interaction among variables in the system is the impulse response function for each of the series.

We will consider four groups of impulse responses as follows:

- Macro responses to macro shocks
- Macro responses to yield curve shocks
- Yield curve responses to macro shocks
- Yield curve responses to yield curve shocks

3.2.1 Traditional approach

The macroeconomic variables for traditional approach are as follows:

- M1: Inflation rate
- M2: Production of consumer goods index
- M3: Change in unemployment rate

From the impulse response, we find that most of the yield curve responses to yield curve shocks and some of the other types of responses are statistically significant. Moreover, the impulse response is consistent with the economy theory. For example, when there is unexpected increase in inflation, the slope factor (B2) will increase because central bank will have to increase the short term policy rate to reduce inflation.

a) Macro responses to macro shocks

The result for both the Nelson-Siegel and Svensson model is the same. A positive shock in inflation rate (M1) has no significant on consumer goods index (M2) and unemployment (M3). An increase in production index (M2) has no significant effect on unemployment (M3) but inflation rate (M1) will increase. In addition, when there is a positive shock in unemployment (M3), which means higher unemployment rate than expected, inflation rate (M1) and production of consumer goods index (M2) will increase but not significant.

b) Macro responses to yield curve shocks

An increase in the level factor (B1) will be followed by an increase in inflation rate (M1) but not statistically significant. When the level factor increases, production index (M2) will decrease with statistical significance. The reason is that when the interest rate increases, people will buy less consumer products and try to save more. Hence, the production index will decrease. In addition, an increase in the level factor will be followed by an increase in unemployment (M3). This effect is statistically significant. The reason is that when the level of interest rate increases, there will be less investment in real sectors and thereby unemployment will increase.

When the slope factor (B2) increases, inflation rate (M1) and production index (M2) will increase since when the central bank concerns about inflation, the short term policy rate and the slope factor will increase. However, the increase of interest rate will not prevent inflation completely. Hence, inflation rate will still going up but only to a small extent. An increase in the curvature factor (B3) will has the effect that is statistically significant on production index (M2) and unemployment (M3). When the curvature factor increases, production index will increase and unemployment rate will decrease since the curvature factor usually represent the state of economy. If the curvature factor is positive, the economy is during boom. Then the production index tends to increase while the unemployment tends to decrease.

For the Svensson model, the result is the same as the Nelson-Siegel model. In addition, there is no significant response of macroeconomic variable to the second curvature factor shock (B44).

c) Yield curve responses to macro shocks

The yield curve factors have negligible responses to shocks in inflation (M1) except the response of the slope factor (B2). The reason is that when there is an unexpected inflation, the central bank will increase the policy rate which is a short term rate. Hence, the slope factor will increase.

When the consumer goods production index (M2) increases, there is only the response of curvature factor that statistically significant. The reason is the increase in production index is the signal of good economy. This is consistent with the curvature that reflects the economic condition. However, the unemployment rate (M3) have no significant effect on the yield curve factors.

For Svensson model, the result is the same as the Nelson-Siegel model. In addition, there is no significant response of the second curvature factor (B44) to the macroeconomic variable shock.

d) Yield curve responses to yield curve shocks

For the Nelson-Siegel model, when the level factor increases, the slope factor and curvature factor will decrease. When the curvature factor increases, the slope factors will increase. For the Svensson model, when the level factor increases, the slope factor and the second curvature factor will decrease while the first curvature factor will increase. When the slope factor or the second curvature factor increase, there will be no significant effect on other factors. However, an increase in the first curvature factor will be followed by an increase in the slope factor and a decrease in the second curvature factor.

3.2.2 Correlation-based approach

The macroeconomic variables for traditional approach are as follows:

- M1: Number of employees
- M2: Production of consumer goods index
- M3: Order received in manufacturing sector

Similar to the traditional approach, we find that most of the yield curve responses to yield curve shocks and some of the other types of responses are statistically significant. Moreover, the impulse response is consistent with the economy theory.

a) Macro responses to macro shocks

The responses of the macro variables to macro shocks for both Nelson-Siegel and Svensson models have the same trend. Most of them are not statistically significant. However, for the Svensson model, when production index (M2) increases, the number of employee (M1) will increase. This response is statistically significant. The reason is that when the production index increases, there will be more labor employed. Hence, number of employee will also increase.

b) Macro responses to yield curve shocks

Responses of macro to yield curve shocks are not statistically significant, except the responses of production index (M2) to shock of the slope factor (B2) and the curvature factor (B3) as well as response of order received (M3) to the shock of curvature factor (B3). In the case of positive shock to slope factor such as the situation when the long-term interest rates decrease compared to the short-term interest rates, the cost of capital for the firms will decrease and there will be more investment in manufacturing sector. Consequently, the production index will be increased. The increase in curvature can be interpreted as a sign of good economy. During the good economy, the demand of consumer goods is high. Hence, the order received in manufacturing sector will increase. In addition, the producers tend to increase their production and production index will increase.

c) Yield curve responses to macro shocks

For both Nelson-Siegel model and Svesson model, an increase in the production index (M2) will be followed by an increase in the level factor (B1). Moreover, when order received in manufacturing sector (M3) increases, the slope factor (B2) will increase. The reason is that when the production index unexpectedly increases, people will realize that the economy is during boom and they will increase their inflation expectation. This higher inflation expectation will raise all nominal interest rates. Hence, the level factor will increase. On the other hand, when the order received in manufacturing sector increases, investors who invest in long-term securities such as corporate bonds will require less risk premium since their counterparty, the manufacturers, can justify their requests for capital (To expand their production capacity in order to match the increasing demand). Hence, long-term interest rates tend to decreases compared to the short-term interest rates and the slope factor will decrease.

d) Yield curve responses to yield curve shocks

For the Nelson-Siegel model, when the level factor (B1) increases, the slope (B2) and curvature factor (B3) will decrease. When the slope factor increases, there will be no significant effect on the level factor and the curvature factor. An increase in the curvature factor (B3) will be followed by an increase in the slope factor (B2).

For the Svensson model, when the level factor increases, the slope factor (BB2) and the second curvature factor (BB4) will decrease while the first curvature factor (BB3) will increase. When the slope factor (BB2) increases, the first curvature factor (BB3) will decrease while the second curvature factor (BB4) will increase. An increase in the first curvature factor (BB3) will be followed by an increase in the slope factor (BB2) and a decrease in the second curvature factor (BB4).

CHAPTER 4

CONCLUSION

We extend Diebold and Li (2006) work in estimating a dynamic model for the yield curve forecasting that incorporates both yield factors (level, slope, and curvature) and macroeconomic variables. In particular, we study the prediction of the German Treasury bond yields by using the dynamic Nelson-Siegel and dynamic Svensson models. We try to improve the prediction by (i) using the relationship between macroeconomic and yield curve factors to explain the movement of the yield curve, and (ii) including an extra curvature factor (i.e. Svensson model) to provide higher flexibility for fitting the yield curve. The effect of the macroeconomic selection methods to the prediction is also studied.

The results give support to the existence of the interaction between the yield curve latent factors and macroeconomic variables, which can be seen from the coefficients in VAR(1) and the impulse response. That is each factor is mostly explained by its own previous (lag-1) value, while the previous (lag-1) values of other factors have smaller explanatory power. Nevertheless, the cross relationship between macroeconomic and latent factors helps improve yield curve forecasts for medium horizons (6-12 months) at most maturities. At very short (1 month) and very long (60 months) forecast horizons, however, the models without macro variables are better, and the results are mixed for somewhat short (3 months) and long (24 months) forecast horizons. The reason is market participants and policy makers require time to digest the information in order to react properly so macro variables give poor prediction in short horizons, and the economic condition can change considerably over time so macro variables give poor prediction in long horizons. Moreover, we find that the RMSE of the Nelson-Siegel yield-only is close to that of the Svensson yield-only model for the very short and very long forecast horizons. This implies that for the situation where the macro variables do not help, the flexibility from the Svensson model does not help either.

Focusing on the medium forecast horizons (6-12 months) where macroeconomic variables improve the forecast performance, we find that the method of selecting the macroeconomic variables is also significant and model dependent.

More precisely, for the Nelson-Siegel model, the traditional approach provides better yield curve prediction but for the Svensson model, the correlation-based approach provides better yield curve prediction. This is because the macro variables chosen in the traditional approach, which is used by many economists and researchers, are based on the Nelson-Siegel factors literature. On the other hand, for a different model like the Svensson, the statistical analysis adopted in the correlation-based approach helps select better macro variables. Moreover, when we compare the Nelson-Siegel with macro factors from the traditional approach and the Svensson with macro factors from the correlation-based approach, we find that the later model gives better forecasting result.

Finally, because the yield curve forecasting error comes from both the yield curve fitting and latent factors forecasting, to improve the yield curve forecasting, we need to improve either the yield curve fitting or latent factor forecasting. For example, we might use a new method of choosing macroeconomic variables to improve the latent factor forecasting, or we might use a dynamic λ instead of a fixed λ to improve the yield curve fitting. We, however, leave these ideas for future studies.

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APPENDICES

APPENDIX A

Maturity (Years)	Minimum (Percent per Year)	Maximum (Percent per Year)	Mean (Percent per Year)	Standard Deviation (Percent per Year)
1	1.61	9.47	4.016	1.628
2	1.83	9.11	4.188	1.524
3	2.04	8.88	4.382	1.451
4	2.26	8.66	4.567	1.401
5	2.46	8.47	4.734	1.367
6	2.66	8.32	4.879	1.344
7	2.83	8.2	5.006	1.327
8	3.00	8.1	5.115	1.314
9	3.12	8.02	5.209	1.302
10	3.21	7.96	5.291	1.293
11	3.29	7.9	5.362	1.283
12	3.36	7.9	5.424	1.275
13	3.42	7.94	5.479	1.268
14	3.48	7.97	5.528	1.261
15	3.52	7.99	5.572	1.255

Table 1 Descriptive statistics for monthly yields at different maturities (Full period).

	Nelson-Siegel model					
	Traditional approach			Correlation-based approach		
	M1	M2	M3	M1	M2	M3
Level	0.354	-0.259	0.329	0.830	-0.259	-0.158
Slope	0.641	0.836	-0.048	-0.125	0.836	-0.217
Curvature1	0.153	0.355	-0.317	0.058	0.355	0.365

	Svensson model					
	Traditional approach			Correlation-based approach		
	M1	M2	M3	M1	M2	M3
Level	0.123	-0.309	0.163	0.659	-0.309	0.005
Slope	0.755	0.782	0.069	0.055	0.782	-0.302
Curvature1	-0.083	0.297	-0.411	-0.185	0.297	0.439
Curvature2	0.454	-0.015	0.351	0.517	-0.015	-0.300

Note

Traditional approach
M1 inflation
M2 consumer goods production index
M3 change of unemployment

Correlation-based approach
M1 Number of employee
M2 Consumer goods production index
M3 Order received from manufacturing sector

Table 2 The correlation between the macroeconomic factors at time t and the yield curve factors at time t

maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
1	0.2350	0.2424	0.2361	**0.2315**	0.2390	0.3177
2	**0.2452**	0.2593	0.2604	0.2471	0.2600	0.3385
3	**0.2457**	0.2633	0.2747	0.2478	0.2640	0.3452
4	**0.2358**	0.2559	0.2791	0.2375	0.2556	0.3380
5	**0.2232**	0.2454	0.2819	0.2242	0.2434	0.3238
6	**0.2099**	0.2332	0.2838	0.2105	0.2295	0.3074
7	**0.1999**	0.2236	0.2891	0.2003	0.2188	0.2926
8	**0.1910**	0.2149	0.2938	0.1915	0.2095	0.2794
9	**0.1839**	0.2071	0.2994	0.1845	0.2016	0.2689
10	**0.1787**	0.2013	0.3050	0.1792	0.1960	0.2613
11	**0.1737**	0.1952	0.3104	0.1740	0.1904	0.2553
12	0.1703	0.1907	0.3156	**0.1697**	0.1862	0.2519
13	0.1684	0.1872	0.3209	**0.1670**	0.1836	0.2495
14	0.1659	0.1837	0.3250	**0.1637**	0.1813	0.2474
15	0.1649	0.1810	0.3287	**0.1618**	0.1800	0.2470

Table 3 RMSE of forecasted yield at 1 month horizon

maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
1	0.5376	0.5090	**0.4934**	0.5368	0.5073	0.5431
2	0.5334	0.5115	**0.5025**	0.5386	0.5132	0.5206
3	0.5088	0.4938	**0.4904**	0.5157	0.4965	0.4929
4	0.4761	0.4684	0.4686	0.4837	0.4707	**0.4625**
5	0.4436	0.4432	0.4469	0.4512	0.4439	**0.4337**
6	0.4116	0.4178	0.4250	0.4189	0.4165	**0.4058**
7	0.3852	0.3964	0.4087	0.3922	0.3932	**0.3825**
8	**0.3626**	0.3780	0.3961	0.3693	0.3735	0.3630
9	**0.3428**	0.3614	0.3861	0.3492	0.3561	0.3464
10	**0.3268**	0.3475	0.3794	0.3328	0.3422	0.3336
11	**0.3126**	0.3346	0.3753	0.3185	0.3303	0.3232
12	**0.3014**	0.3244	0.3716	0.3071	0.3215	0.3159
13	**0.2927**	0.3158	0.3707	0.2987	0.3154	0.3099
14	**0.2860**	0.3094	0.3711	0.2925	0.3124	0.3058
15	**0.2801**	0.3030	0.3710	0.2876	0.3102	0.3030

Table 4 RMSE of forecasted yield at 3 months horizon

maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
1	0.7140	0.6193	0.5990	0.7179	0.6223	**0.5938**
2	0.7029	0.6195	0.6029	0.7124	0.6233	**0.5434**
3	0.6647	0.5934	0.5837	0.6768	0.5987	**0.4938**
4	0.6201	0.5606	0.5559	0.6338	0.5669	**0.4484**
5	0.5783	0.5303	0.5301	0.5924	0.5361	**0.4106**
6	0.5396	0.5020	0.5063	0.5533	0.5062	**0.3785**
7	0.5072	0.4786	0.4884	0.5199	0.4806	**0.3538**
8	0.4798	0.4590	0.4755	0.4911	0.4587	**0.3364**
9	0.4566	0.4422	0.4664	0.4663	0.4398	**0.3236**
10	0.4379	0.4285	0.4612	0.4461	0.4247	**0.3156**
11	0.4216	0.4160	0.4591	0.4286	0.4118	**0.3113**
12	0.4095	0.4069	0.4582	0.4154	0.4030	**0.3093**
13	0.3996	0.3991	0.4597	0.4053	0.3970	**0.3095**
14	0.3919	0.3934	0.4623	0.3981	0.3940	**0.3111**
15	0.3856	0.3881	0.4651	0.3929	0.3925	**0.3139**

Table 5 RMSE of forecasted yield at 6 months horizon

maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
1	0.8239	**0.7582**	0.8090	0.8289	0.7610	0.7615
2	0.8216	0.7664	0.8244	0.8273	0.7650	**0.7159**
3	0.7803	0.7356	0.8036	0.7868	0.7343	**0.6455**
4	0.7323	0.6974	0.7737	0.7392	0.6964	**0.5769**
5	0.6875	0.6614	0.7468	0.6936	0.6594	**0.5187**
6	0.6478	0.6295	0.7240	0.6523	0.6252	**0.4701**
7	0.6145	0.6028	0.7077	0.6166	0.5955	**0.4329**
8	0.5879	0.5814	0.6978	0.5875	0.5712	**0.4064**
9	0.5661	0.5640	0.6922	0.5634	0.5514	**0.3875**
10	0.5483	0.5496	0.6905	0.5439	0.5357	**0.3761**
11	0.5335	0.5371	0.6921	0.5280	0.5231	**0.3698**
12	0.5225	0.5281	0.6940	0.5168	0.5152	**0.3667**
13	0.5134	0.5204	0.6987	0.5085	0.5099	**0.3671**
14	0.5067	0.5151	0.7033	0.5035	0.5082	**0.3693**
15	0.5012	0.5103	0.7085	0.5007	0.5082	**0.3727**

Table 6 RMSE of forecasted yield at 12 months horizon

maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
1	1.0543	0.9749	1.2048	1.0576	**0.9747**	1.1959
2	0.9805	0.9216	1.2558	0.9826	**0.9177**	1.1428
3	0.8945	0.8526	1.2592	0.8977	**0.8485**	1.0533
4	0.8207	0.7932	1.2464	0.8241	**0.7879**	0.9695
5	0.7625	0.7469	1.2310	0.7637	**0.7380**	0.9006
6	0.7184	0.7125	1.2162	0.7158	**0.6986**	0.8455
7	0.6867	0.6883	1.2052	0.6793	**0.6690**	0.8040
8	0.6649	0.6722	1.1983	0.6530	**0.6484**	0.7740
9	0.6491	0.6607	1.1939	**0.6335**	0.6338	0.7516
10	0.6393	0.6540	1.1927	**0.6215**	0.6259	0.7368
11	0.6319	0.6486	1.1941	**0.6134**	0.6213	0.7271
12	0.6288	0.6471	1.1952	**0.6112**	0.6221	0.7200
13	0.6260	0.6452	1.1987	**0.6107**	0.6242	0.7168
14	0.6250	0.6451	1.2018	**0.6131**	0.6293	0.7145
15	0.6253	0.6458	1.2057	**0.6180**	0.6363	0.7142

Table 7 RMSE of forecasted yield at 24 months horizon

maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
1	**0.9389**	0.9473	1.7954	0.9390	0.9430	1.7292
2	**0.8594**	0.8766	1.9653	0.8714	0.8831	1.7306
3	**0.7962**	0.8225	2.0534	0.8142	0.8329	1.6830
4	**0.7598**	0.7938	2.1010	0.7775	0.8016	1.6351
5	**0.7439**	0.7834	2.1289	0.7572	0.7849	1.5967
6	**0.7410**	0.7841	2.1456	0.7484	0.7786	1.5674
7	**0.7462**	0.7913	2.1579	0.7484	0.7800	1.5472
8	0.7555	0.8015	2.1681	**0.7544**	0.7867	1.5342
9	0.7659	0.8122	2.1765	**0.7637**	0.7963	1.5254
10	0.7767	0.8229	2.1847	**0.7755**	0.8081	1.5207
11	**0.7865**	0.8322	2.1935	0.7880	0.8206	1.5194
12	**0.7970**	0.8423	2.2003	0.8028	0.8354	1.5185
13	**0.8053**	0.8501	2.2078	0.8166	0.8491	1.5195
14	**0.8137**	0.8580	2.2136	0.8312	0.8637	1.5199
15	**0.8215**	0.8653	2.2200	0.8458	0.8783	1.5219

Table 8 RMSE of forecasted yield at 60 months horizon

1 month ahead						
maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
Beta 1	**0.1669**	0.1791	0.3967	0.3155	0.3498	0.2379
Beta 2	**0.3163**	0.3183	0.4623	0.3839	0.4164	0.5868
Beta 3	**0.6469**	0.6886	0.7788	0.9865	1.0222	1.2201
Beta 4				**1.2399**	1.2730	1.3522

3 months ahead						
	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
Beta 1	**0.2621**	0.2926	0.6563	0.4891	0.5430	0.3613
Beta 2	0.6017	**0.5768**	0.8369	0.6410	0.6968	0.9109
Beta 3	0.9820	**0.9605**	1.1052	1.3083	1.2669	1.2380
Beta 4				1.6204	1.6315	**1.5571**

6 months ahead						
maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
Beta 1	**0.3743**	0.4013	0.7490	0.6245	0.6690	0.4363
Beta 2	0.7083	**0.6749**	0.9146	0.8127	0.8792	1.0450
Beta 3	1.1501	**1.0941**	1.1478	1.4398	1.3528	1.2224
Beta 4				1.7935	**1.7709**	1.9263

12 months ahead						
maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
Beta 1	0.5336	0.5521	0.9660	0.7392	0.7800	**0.5053**
Beta 2	0.9203	**0.8744**	1.1803	1.0305	1.0713	1.2883
Beta 3	1.3025	1.2666	1.2497	1.4956	1.4547	**1.1425**
Beta 4				1.7284	1.7164	**1.5921**

24 months ahead						
maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
Beta 1	**0.7461**	0.7688	1.3840	0.9050	0.9444	0.7479
Beta 2	1.3598	1.2890	**1.2761**	1.4272	1.4033	1.5384
Beta 3	1.2068	1.2014	1.1604	1.3857	1.4178	**1.0892**
Beta 4				**1.4848**	1.4998	1.6890

60 months ahead						
maturity	Nelson-Siegel			Svensson		
	yield only	with macro		yield only	with macro	
		traditional	correlation-based		traditional	correlation-based
Beta 1	**1.0399**	1.0761	2.3517	1.1257	1.1566	1.1253
Beta 2	1.5299	1.5401	**1.4815**	1.4857	1.4963	1.7105
Beta 3	1.1636	**1.1589**	1.3501	1.4819	1.4868	1.8977
Beta 4				1.3604	**1.3483**	1.7817

Table 9 The RMSE of forecasted yield curve factors at

1, 3, 6, 12, 24, 36, 48 and 60 forecast horizons

1 month ahead					
Maturities	1	3	5	10	15
Random Walk	0.23128	0.24870	0.22271	0.17997	0.16359
AR(1) : Nelson-Seigel	0.24046	0.25035	0.22562	0.18189	0.16788
AR(1) : Svensson	0.28200	0.30454	0.29903	0.27542	0.27083
AR(1) : Yield Level	0.24057	0.26041	0.23584	0.19034	0.17271
VAR(1) : Yield Level	0.25704	0.32834	0.39251	0.36597	0.24235
VAR(1) : Nelson-Seigel ONLY	0.23500	0.24574	0.22320	0.17872	0.16492
VAR(1) : Svensson ONLY	0.23149	0.24776	0.22425	0.17923	0.16183
VAR(1) : Nelson-Seigel + Macro	0.24242	0.26330	0.24541	0.20133	0.18097
VAR(1) : Svensson + Macro	0.23903	0.26398	0.24338	0.19602	0.17997
VAR(1) : Nelson-Seigel + Macro*	0.23607	0.27469	0.28193	0.30503	0.32873
VAR(1) : Svensson + Macro*	0.31773	0.34519	0.32382	0.26126	0.24698

3 months ahead					
Maturities	1	3	5	10	15
Random Walk	0.55078	0.52477	0.45039	0.32775	0.28639
AR(1) : Nelson-Seigel	0.55340	0.51839	0.45049	0.33848	0.29461
AR(1) : Svensson	0.65335	0.68265	0.67890	0.65298	0.64416
AR(1) : Yield Level	0.57263	0.56073	0.49447	0.36568	0.32018
VAR(1) : Yield Level	0.57143	0.65537	0.76853	0.69890	0.44988
VAR(1) : Nelson-Seigel ONLY	0.53761	0.50878	0.44358	0.32678	0.28014
VAR(1) : Svensson ONLY	0.53678	0.51570	0.45116	0.33283	0.28763
VAR(1) : Nelson-Seigel + Macro	0.50899	0.49377	0.44317	0.34752	0.30304
VAR(1) : Svensson + Macro	0.50729	0.49649	0.44393	0.34224	0.31022
VAR(1) : Nelson-Seigel + Macro*	0.49335	0.49035	0.44688	0.37937	0.37100
VAR(1) : Svensson + Macro*	0.54310	0.49287	0.43367	0.33362	0.30304

6 months ahead					
Maturities	1	3	5	10	15
Random Walk	0.76633	0.70211	0.60398	0.44935	0.40241
AR(1) : Nelson-Seigel	0.75679	0.68403	0.59129	0.46065	0.41601
AR(1) : Svensson	0.90536	0.96987	0.99595	1.01078	1.01278
AR(1) : Yield Level	0.84579	0.82113	0.74175	0.56709	0.50698
VAR(1) : Yield Level	0.75420	0.75715	0.84955	0.75963	0.48624
VAR(1) : Nelson-Seigel ONLY	0.71397	0.66467	0.57832	0.43794	0.38562
VAR(1) : Svensson ONLY	0.71786	0.67684	0.59242	0.44613	0.39286
VAR(1) : Nelson-Seigel + Macro	0.61934	0.59339	0.53028	0.42848	0.38812
VAR(1) : Svensson + Macro	0.62235	0.59874	0.53614	0.42468	0.39250
VAR(1) : Nelson-Seigel + Macro*	0.59902	0.58371	0.53009	0.46124	0.46512
VAR(1) : Svensson + Macro*	0.59383	0.49378	0.41057	0.31558	0.31387

12 months ahead					
Maturities	1	3	5	10	15
Random Walk	0.92504	0.85219	0.75116	0.59308	0.55502
AR(1) : Nelson-Seigel	0.91968	0.80825	0.70616	0.59889	0.57568
AR(1) : Svensson	1.11241	1.22279	1.29604	1.38213	1.40892
AR(1) : Yield Level	1.20613	1.19107	1.11438	0.88838	0.81114
VAR(1) : Yield Level	1.03259	0.82031	0.74317	0.59960	0.51382
VAR(1) : Nelson-Seigel ONLY	0.82390	0.78032	0.68745	0.54830	0.50125
VAR(1) : Svensson ONLY	0.82891	0.78683	0.69360	0.54386	0.50066
VAR(1) : Nelson-Seigel + Macro	0.75825	0.73556	0.66141	0.54956	0.51029
VAR(1) : Svensson + Macro	0.76102	0.73431	0.65940	0.53567	0.50819
VAR(1) : Nelson-Seigel + Macro*	0.80898	0.80355	0.74683	0.69045	0.70853
VAR(1) : Svensson + Macro*	0.76146	0.64550	0.51872	0.37610	0.37268

Table 10 The comparison between our models to other competitors.

24 months ahead					
Maturities	1	3	5	10	15
Random Walk	1.38980	1.12082	0.91767	0.72710	0.73214
AR(1) : Nelson-Seigel	1.17183	0.94401	0.82038	0.77453	0.80074
AR(1) : Svensson	1.31568	1.41059	1.49935	1.63017	1.68061
AR(1) : Yield Level	1.81490	1.32298	0.94598	0.72571	0.83059
VAR(1) : Yield Level	1.71323	1.27502	0.99095	0.88580	1.09889
VAR(1) : Nelson-Seigel ONLY	1.05428	0.89445	0.76248	0.63933	0.62527
VAR(1) : Svensson ONLY	1.05760	0.89768	0.76372	0.62155	0.61802
VAR(1) : Nelson-Seigel + Macro	0.97489	0.85258	0.74691	0.65396	0.64579
VAR(1) : Svensson + Macro	0.97470	0.84853	0.73803	0.62591	0.63626
VAR(1) : Nelson-Seigel + Macro*	1.20482	1.25917	1.23097	1.19273	1.20566
VAR(1) : Svensson + Macro*	1.19589	1.05334	0.90064	0.73678	0.71416

36 months ahead					
Maturities	1	3	5	10	15
Random Walk	1.77408	1.45084	1.19482	0.92229	0.89010
AR(1) : Nelson-Seigel	1.14058	0.89332	0.80894	0.85800	0.92077
AR(1) : Svensson	1.35496	1.45052	1.54723	1.69075	1.74618
AR(1) : Yield Level	2.24867	1.68736	1.32195	1.18856	1.40181
VAR(1) : Yield Level	2.03994	1.63730	1.39988	1.41760	1.67847
VAR(1) : Nelson-Seigel ONLY	1.11725	0.92623	0.80072	0.72025	0.72666
VAR(1) : Svensson ONLY	1.11739	0.93805	0.81365	0.71742	0.74120
VAR(1) : Nelson-Seigel + Macro	1.04185	0.88570	0.78794	0.73951	0.75358
VAR(1) : Svensson + Macro	1.03801	0.88704	0.78343	0.71610	0.75452
VAR(1) : Nelson-Seigel + Macro*	1.55478	1.66554	1.66236	1.63606	1.64396
VAR(1) : Svensson + Macro*	1.53983	1.40609	1.26122	1.10593	1.07770

48 months ahead					
Maturities	1	3	5	10	15
Random Walk	1.67538	1.37147	1.15749	0.95639	0.95088
AR(1) : Nelson-Seigel	0.99252	0.82408	0.82201	0.95035	1.02649
AR(1) : Svensson	1.32293	1.43745	1.54599	1.70070	1.75923
AR(1) : Yield Level	2.36182	1.91307	1.67059	1.70802	1.96667
VAR(1) : Yield Level	2.20244	1.89611	1.75029	1.88855	2.17129
VAR(1) : Nelson-Seigel ONLY	1.00489	0.83393	0.75252	0.74591	0.77689
VAR(1) : Svensson ONLY	1.00374	0.85100	0.76695	0.74315	0.79857
VAR(1) : Nelson-Seigel + Macro	0.98778	0.84477	0.78274	0.79105	0.82212
VAR(1) : Svensson + Macro	0.98365	0.85398	0.78465	0.77463	0.83342
VAR(1) : Nelson-Seigel + Macro*	1.69447	1.89151	1.93167	1.94687	1.96731
VAR(1) : Svensson + Macro*	1.66887	1.58412	1.46938	1.35208	1.33641

60 months ahead					
Maturities	1	3	5	10	15
Random Walk	1.47160	1.33009	1.21754	1.08603	1.07297
AR(1) : Nelson-Seigel	0.89562	0.78534	0.82523	0.98531	1.06743
AR(1) : Svensson	1.31021	1.43359	1.54576	1.70298	1.76201
AR(1) : Yield Level	2.43534	2.15472	2.04546	2.22635	2.50682
VAR(1) : Yield Level	2.36023	2.16969	2.11662	2.35093	2.64167
VAR(1) : Nelson-Seigel ONLY	0.93890	0.79623	0.74392	0.77672	0.82148
VAR(1) : Svensson ONLY	0.93902	0.81423	0.75715	0.77548	0.84580
VAR(1) : Nelson-Seigel + Macro	0.94727	0.82245	0.78342	0.82290	0.86528
VAR(1) : Svensson + Macro	0.94298	0.83285	0.78491	0.80814	0.87826
VAR(1) : Nelson-Seigel + Macro*	1.79536	2.05340	2.12886	2.18471	2.22001
VAR(1) : Svensson + Macro*	1.72917	1.68302	1.59670	1.52073	1.52189

Table 10 The comparison between our models to other competitors. (Cont.)

APPENDIX B

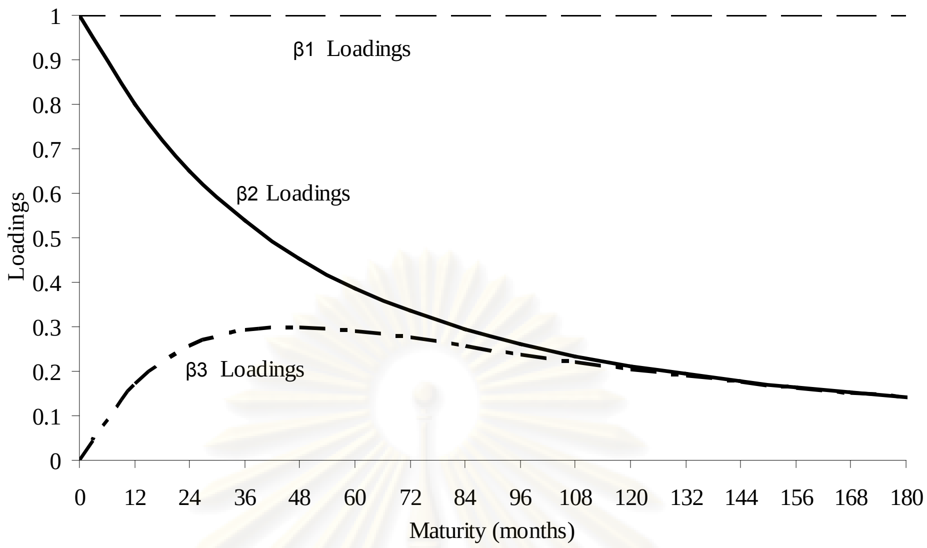

Figure 1 Factor loading of Nelson-Siegel model.

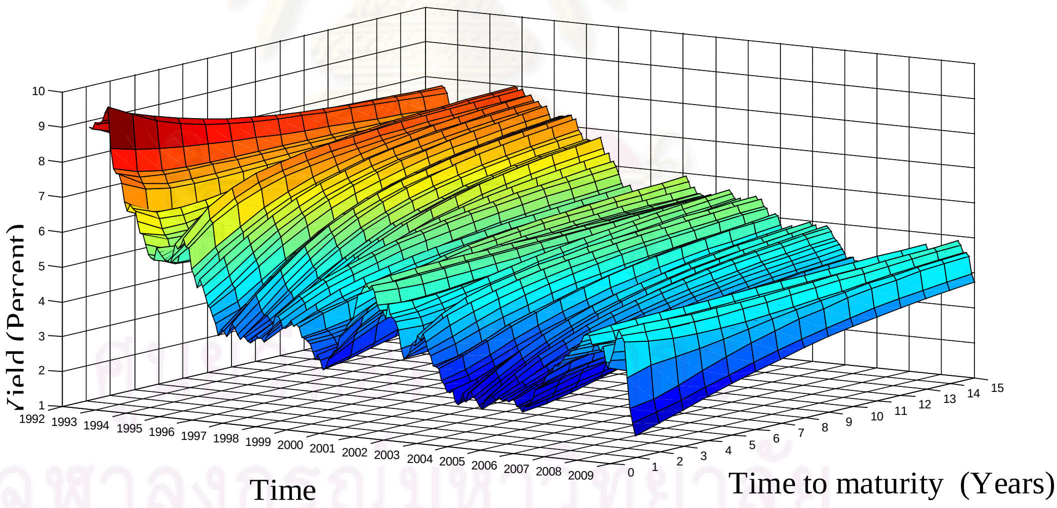

Figure 2 Yield curve, 1992:1-2008:12. The sample consists of monthly yield data from January 1992 to December 2008 at maturities of 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, and 15 years.

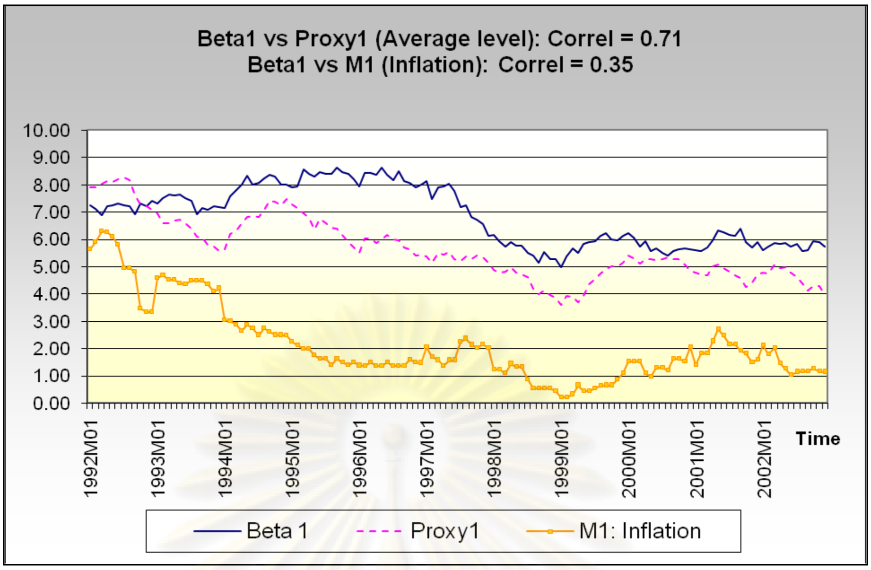

Figure 3 Nelson-Siegel model level factor and empirical counterparts (Traditional approach)

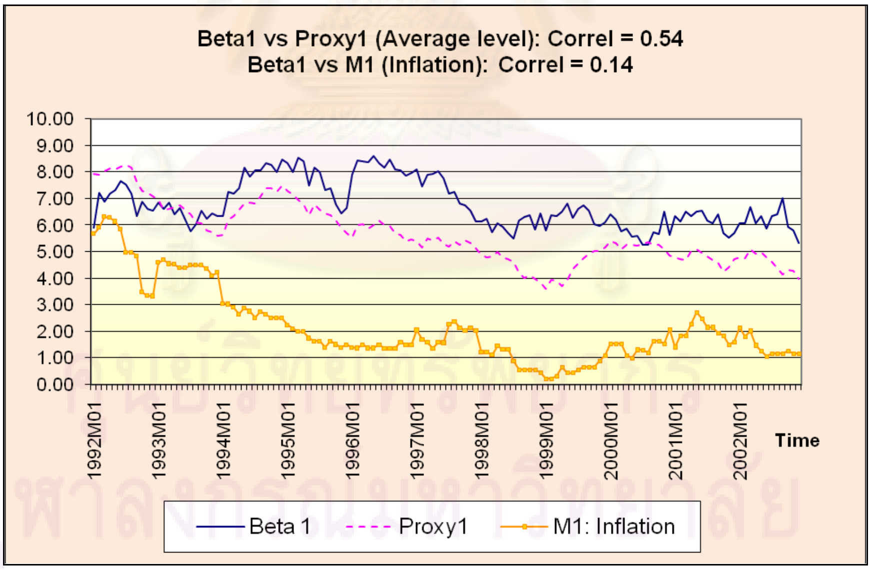

Figure 4 Svensson model level factor and empirical counterparts (Traditional approach)

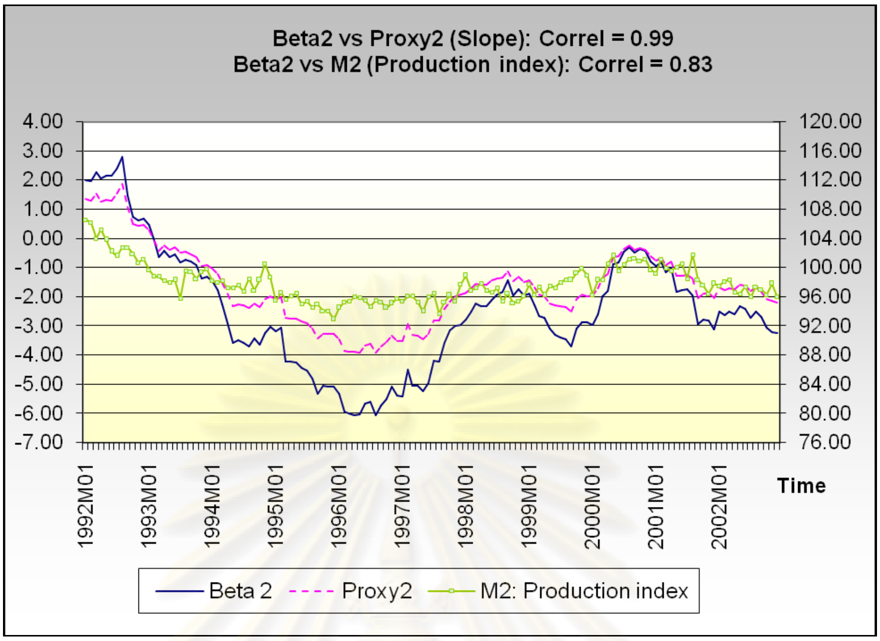

Figure 5 Nelson-Siegel model slope factor and empirical counterparts (Traditional approach)

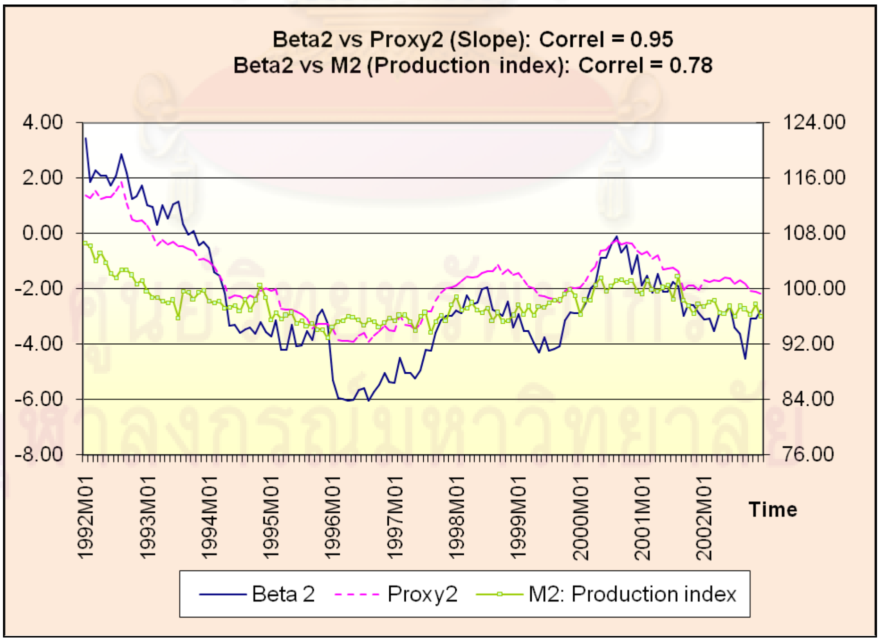

Figure 6 Svensson model slope factor and empirical counterparts (Traditional approach)

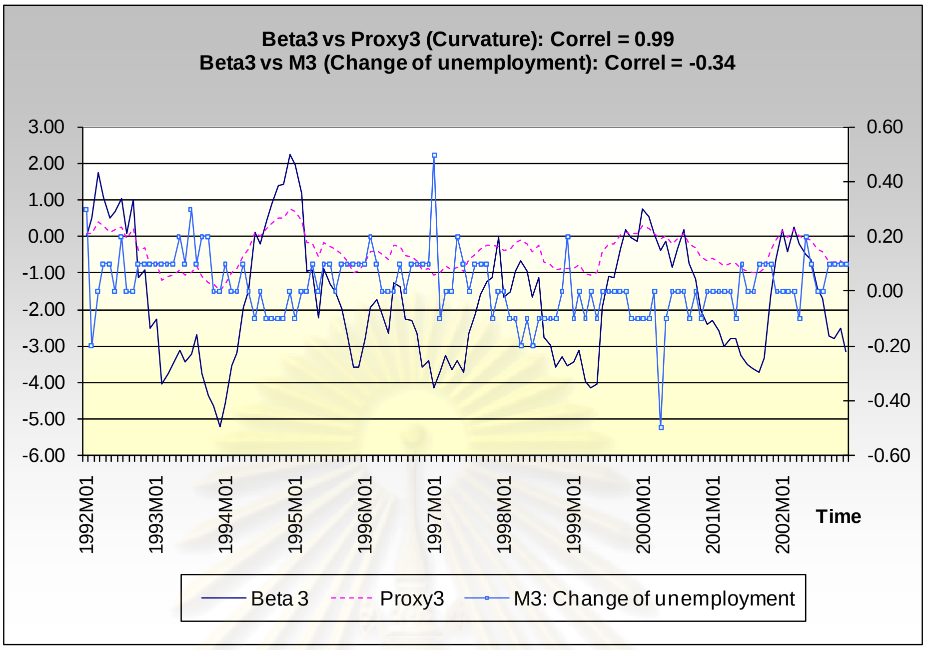

Figure 7 Nelson-Siegel model curvature factor and empirical counterparts (Traditional approach)

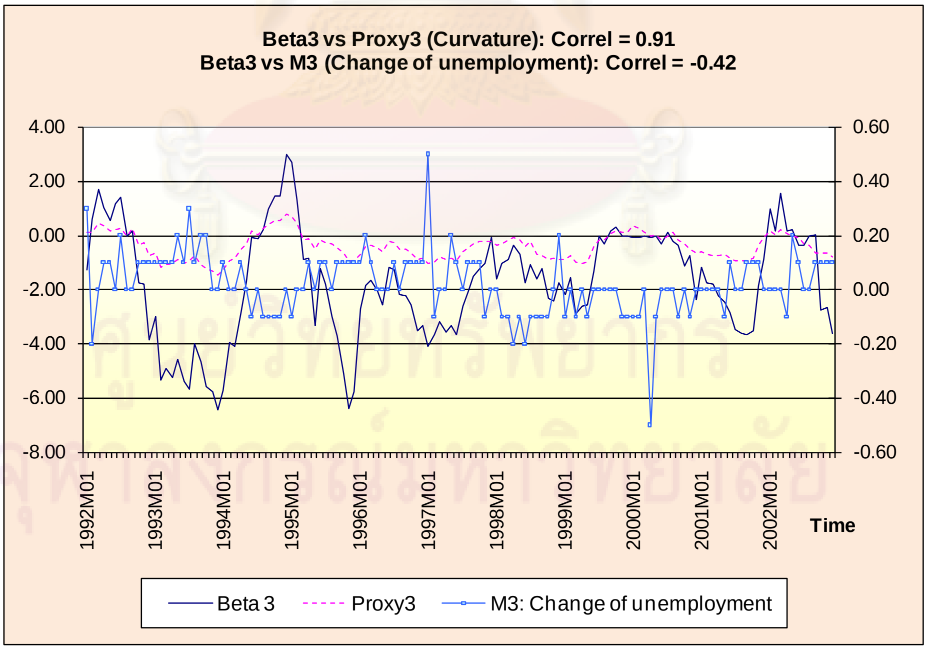

Figure 8 Svensson model first curvature factor and empirical counterparts (Traditional approach)

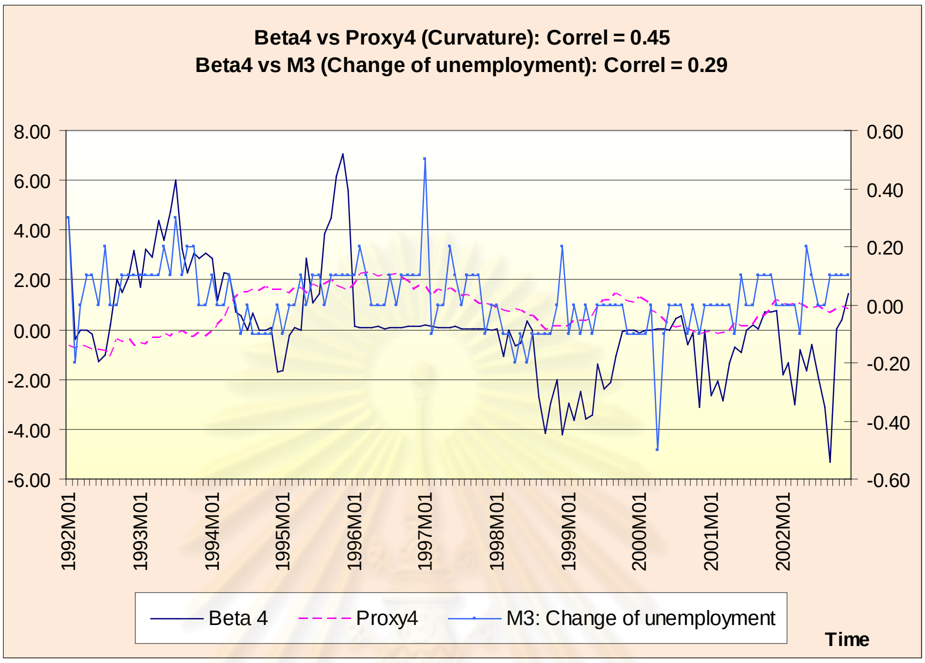

Figure 9 Svensson model second curvature factor and empirical counterparts (Traditional approach)

Code	Name	Type*
JQA036	National accounts/Households' income/Germany/ Net wages and salaries (residence concept)	1
UXDA01	Germany / Orders received / Value / Working-day adjusted / Construction sector	1
UXA001	Germany / Orders received / Value / Working-day adjusted / Total	1
UXA742	Germany / Orders received / Value / Working-day adjusted / Total / Consumer goods	1
JQC000	National accounts/Overall economic view/Price index/ GDP	1
JQB058	National accounts/Origin of GDP/Chain-linked index/ Wholesale/retail trade, hotel and restauran	1
UXNA01	Germany / Production / Working-day adjusted / Production sector / including construction	1
UXNA05	Germany / Production / Working-day adjusted / Capital goods	1
DU7504	Pay rates, overall economy, on a monthly basis, Germany	1
DU7802	Basic pay rates, overall economy, excluding ancillary benefits, excluding one-off payments, on a	1
UUFA01	Germany / Consumer price index / Original data / Total	2
UXHJ45	Retail turnover / Value / Total / Calendar adjusted	1
USCC02	Unemployment rate (unemployment as a percentage of the civilian labour force) / Germany / Sea	4
USMB01	Germany / Employees / Seasonally adjusted	4
US366C	Germany / Turnover / Value / Seasonally adjusted / Abroad / Industry	2
JBB000	Gross domestic product / chain index / Seasonally and working-day adjusted	3
JBA000	Gross domestic product / at current prices / Seasonally and working-day adjusted	3
JAA106	Government consumption / at current prices / Seasonally adjusted	3
JAB106	Government consumption / chain index / Seasonally adjusted	3
JBB152	Machinery and equipment / chain index / Seasonally and working-day adjusted	4
JAA034	Gross wages and salaries / Seasonally adjusted	3
JAA327	Saving ratio / Seasonally adjusted	1
JAA001	Gross national income (GNP) / at current prices / Seasonally adjusted	3
JAA025	National income / Seasonally adjusted	3
USA003	Germany / Orders received / Value / Seasonally adjusted / Abroad / Total	2
USC743	Germany / Orders received / Volume / Seasonally adjusted / Domestic market / Consumer goods	4
USA001	Germany / Orders received / Value / Seasonally adjusted / Total	4
USC742	Germany / Orders received / Volume / Seasonally adjusted / Total / Consumer goods	4
USDA01	Germany / Orders received / Value / Seasonally adjusted / Construction sector	1
US19DA	Western Germany / Orders received / Volume / Seasonally adjusted / Non-residential constructio	1
USNI67	Germany / Production / Seasonally adjusted / Consumer goods	4
USNA61	Germany / Production / Seasonally adjusted / Construction sector / Total	1
XSC400	Exports / Index of unit values / Total / Seasonally adjusted	4
USFB76	Consumer price index / Total, excluding energy / Seasonally adjusted	2
US0RB7	Eastern Germany / Wages and salaries per employee / Seasonally adjusted	2
JAB016	GDP per total hours worked / chain index / Seasonally adjusted	3
USHJ45	Retail turnover / Value / Total / Seasonally adjusted	1
USHK45	Retail turnover / Volume / Total / Seasonally adjusted	1
USHJ80	Retail turnover / Value / Retail of motor vehicles / Seasonally adjusted	1
US003A	Germany / Turnover / Value / Seasonally adjusted / Total / Capital goods	1
US004B	Germany / Turnover / Value / Seasonally adjusted / Domestic market / Durable goods	1
JAB938	Financial, real estate renting and business services / Seasonally adjusted	3
USBA14	Employment / Germany / Seasonally adjusted	4
USCC01	Unemployment / Germany / Seasonally adjusted	4
XS4204	German exports / special trade / values / Seasonally adjusted	1
USCX01	Orders received / volume / manufacturing sector / Seasonally adjusted	1
JB5001	National accounts - domestic demand (price adjusted) / Seasonally and working-day adjusted	3
USZF01	Producer prices for industrial products (domestic sales) / Seasonally adjusted	2

* Data adjustment tpye

1 Adjust bysubtracting previous year data from current data
2 Adjust bysubtracting previous month data from current data
3 Adjust bysubtracting previous quarter data from current data
4 No adjustment

Figure 10 Adjustment of yield curve data

		Nelson-Siegel			Svensson			
		beta1	beta2	beta3	beta1	beta2	beta3	beta4
JQA036	National accounts/Households' income/Germany/ Net wages and salaries (residence concept)	-0.418	0.741	0.109	-0.341	0.611	0.049	0.011
UXDA01	Germany / Orders received / Value / Working-day adjusted / Construction sector	0.213	0.483	0.136	0.284	0.504	-0.001	0.201
UXA001	Germany / Orders received / Value / Working-day adjusted / Total	-0.155	-0.126	0.372	-0.084	-0.153	0.425	-0.246
UXA742	Germany / Orders received / Value / Working-day adjusted / Total / Consumer goods	-0.118	-0.004	0.388	-0.005	-0.069	0.365	-0.107
JQC000	National accounts/Overall economic view/Price index/ GDP	0.385	0.484	0.096	0.362	0.550	-0.123	0.417
JQB058	National accounts/Origin of GDP/Chain-linked index/ Wholesale/retail trade, hotel and restaurant services, tr	-0.380	0.162	0.353	-0.306	0.064	0.404	-0.272
UXNA01	Germany / Production / Working-day adjusted / Production sector / including construction	-0.183	-0.126	0.379	-0.078	-0.198	0.357	-0.291
UXNA05	Germany / Production / Working-day adjusted / Capital goods	-0.314	-0.172	0.234	-0.186	-0.310	0.412	-0.405
DU7504	Pay rates, overall economy, on a monthly basis, Germany	0.273	0.534	0.059	0.244	0.584	-0.155	0.414
DU7802	Basic pay rates, overall economy, excluding ancillary benefits, excluding one-off payments, on a monthly bas	0.105	0.259	0.111	0.115	0.318	0.069	0.038
UUFA01	Germany / Consumer price index / Original data / Total	0.130	0.172	0.019	0.152	0.229	-0.027	0.064
UXHJ45	Retail turnover / Value / Total / Calendar adjusted	-0.096	0.189	-0.015	-0.076	0.124	-0.043	0.037
USCC02	Unemployment rate (unemployment as a percentage of the civilian labour force) / Germany / Seasonally adju	-0.194	-0.644	-0.256	-0.222	-0.625	-0.056	-0.298
USMB01	Germany / Employees / Seasonally adjusted	0.836	-0.153	0.045	0.809	-0.004	-0.189	0.514
US366C	Germany / Turnover / Value / Seasonally adjusted / Abroad / Industry	-0.068	-0.149	0.068	-0.127	-0.126	0.113	-0.095
JBB000	Gross domestic product / chain index / Seasonally and working-day adjusted	-0.019	-0.092	0.210	-0.005	-0.091	0.233	-0.127
JBA000	Gross domestic product / at current prices / Seasonally and working-day adjusted	0.098	0.160	0.214	0.130	0.159	0.156	0.037
JAA106	Government consumption / at current prices / Seasonally adjusted	0.053	0.168	0.163	0.068	0.164	0.060	0.133
JAB106	Government consumption / chain index / Seasonally adjusted	0.032	0.007	0.076	0.012	0.029	-0.002	0.123
JBB152	Machinery and equipment / chain index / Seasonally and working-day adjusted	-0.833	0.341	0.138	-0.729	0.156	0.334	-0.530
JAA034	Gross wages and salaries / Seasonally adjusted	-0.145	0.512	0.450	-0.069	0.471	0.382	-0.069
JAA327	Saving ratio / Seasonally adjusted	-0.120	0.026	0.255	-0.079	-0.018	0.277	-0.151
JAA001	Gross national income (GNP) / at current prices / Seasonally adjusted	0.064	0.128	0.143	0.117	0.099	0.133	-0.054
JAA025	National income / Seasonally adjusted	0.090	0.068	0.174	0.161	0.036	0.162	-0.061
USA003	Germany / Orders received / Value / Seasonally adjusted / Abroad / Total	-0.026	-0.120	0.042	-0.057	-0.069	0.056	-0.042
USC743	Germany / Orders received / Volume / Seasonally adjusted / Domestic market / Consumer goods	0.585	0.396	0.179	0.603	0.501	-0.079	0.475
USA001	Germany / Orders received / Value / Seasonally adjusted / Total	-0.751	0.082	0.153	-0.682	-0.081	0.364	-0.533
USC742	Germany / Orders received / Volume / Seasonally adjusted / Total / Consumer goods	-0.169	0.583	0.396	-0.069	0.522	0.305	0.005
USDA01	Germany / Orders received / Value / Seasonally adjusted / Construction sector	0.202	0.495	0.140	0.267	0.515	0.006	0.193
US19DA	Western Germany / Orders received / Volume / Seasonally adjusted / Non-residential construction	-0.201	0.148	0.009	-0.072	0.063	0.088	-0.215
USNI67	Germany / Production / Seasonally adjusted / Consumer goods	-0.237	0.831	0.350	-0.157	0.771	0.277	-0.041
USNA61	Germany / Production / Seasonally adjusted / Construction sector / Total	0.228	0.308	0.347	0.221	0.384	0.197	0.159
XSC400	Exports / Index of unit values / Total / Seasonally adjusted	0.232	0.573	0.162	0.273	0.564	-0.046	0.365
USFB76	Consumer price index / Total, excluding energy / Seasonally adjusted	0.249	0.217	-0.038	0.256	0.293	-0.133	0.218
US0RB7	Eastern Germany / Wages and salaries per employee / Seasonally adjusted	0.102	0.172	0.103	0.096	0.192	0.032	0.104
JAB016	GDP per total hours worked / chain index / Seasonally adjusted	0.121	-0.141	0.094	0.074	-0.106	0.082	0.018
USHJ45	Retail turnover / Value / Total / Seasonally adjusted	-0.097	0.183	0.033	-0.067	0.111	0.006	0.014
USHK45	Retail turnover / Volume / Total / Seasonally adjusted	-0.230	-0.105	-0.039	-0.206	-0.208	0.040	-0.166
USHJ80	Retail turnover / Value / Retail of motor vehicles / Seasonally adjusted	0.155	-0.304	-0.054	0.125	-0.301	-0.002	-0.055
US003A	Germany / Turnover / Value / Seasonally adjusted / Total / Capital goods	-0.281	-0.143	0.174	-0.156	-0.267	0.355	-0.465
US004B	Germany / Turnover / Value / Seasonally adjusted / Domestic market / Durable goods	0.010	0.297	0.274	0.083	0.268	0.155	0.123
JAB938	Financial, real estate renting and business services / Seasonally adjusted	-0.213	0.278	0.047	-0.248	0.290	0.073	-0.086
USBA14	Employment / Germany / Seasonally adjusted	-0.732	0.338	0.164	-0.663	0.164	0.306	-0.416
USCC01	Unemployment / Germany / Seasonally adjusted	-0.379	-0.585	-0.242	-0.404	-0.606	-0.001	-0.395
XS4204	German exports / special trade / values / Seasonally adjusted	0.236	-0.025	0.049	0.227	-0.002	-0.021	0.183
USCX01	Orders received / volume / manufacturing sector / Seasonally adjusted	-0.172	-0.176	0.353	-0.109	-0.194	0.431	-0.295
JB5001	National accounts - domestic demand (price adjusted) / Seasonally and working-day adjusted	0.682	0.327	0.168	0.654	0.455	-0.100	0.518
USZF01	Producer prices for industrial products (domestic sales) / Seasonally adjusted	-0.025	0.113	0.182	-0.020	0.162	0.147	-0.007

Figure 11 Correlation between latent factors and macroeconomic indicators

43

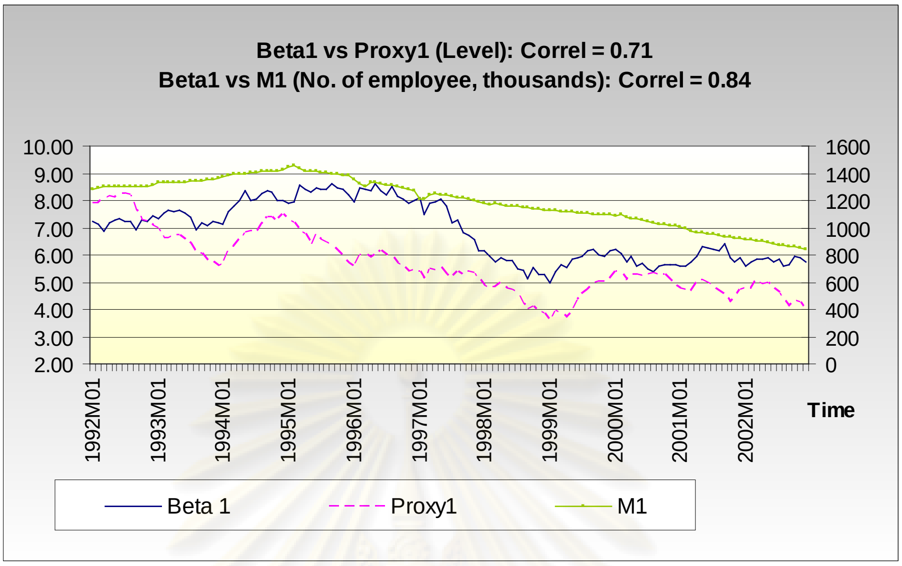

Figure 12 Nelson-Siegel model level factor and empirical counterparts (Correlation-based approach)

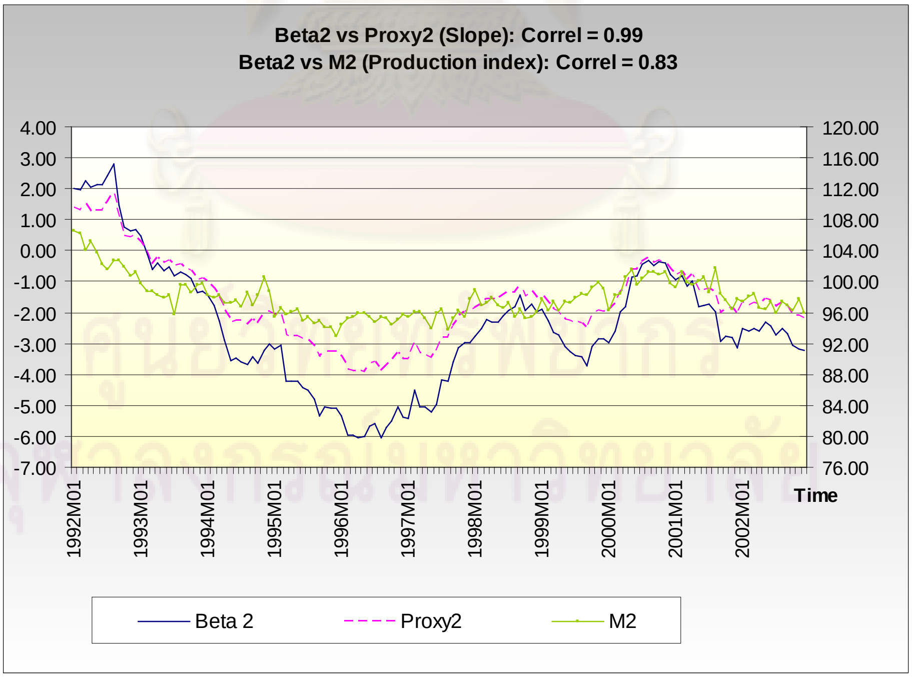

Figure 13 Nelson-Siegel model slope factor and empirical counterparts (Correlation-based approach)

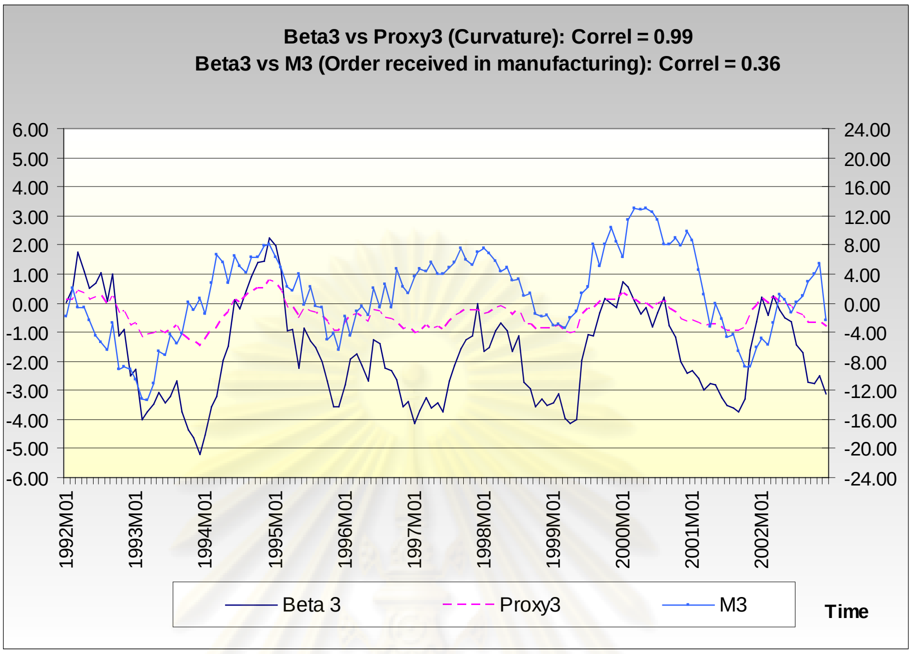

Figure 14 Nelson-Siegel model curvature factor and empirical counterparts (Correlation-based approach)

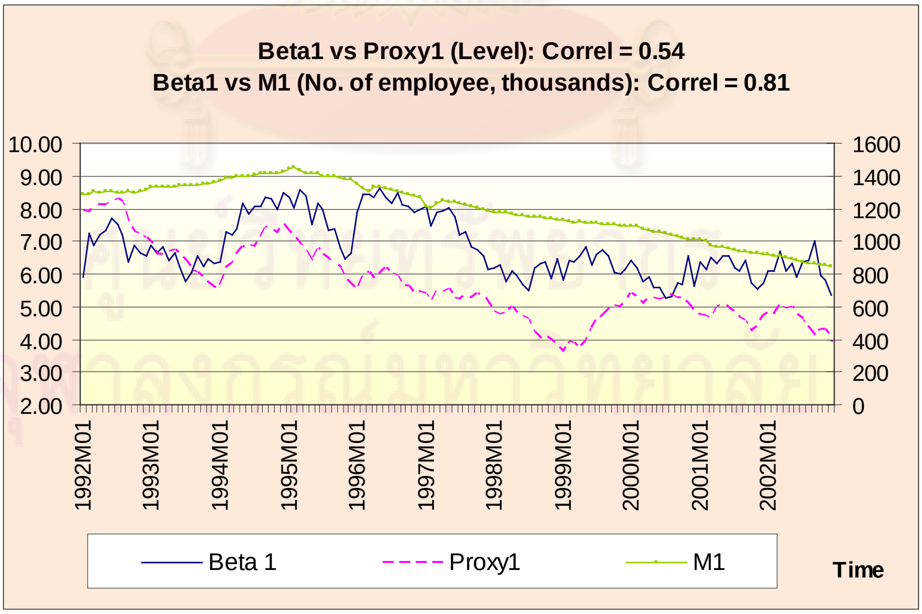

Figure 15 Svensson model level factor and empirical counterparts (Correlation-based approach)

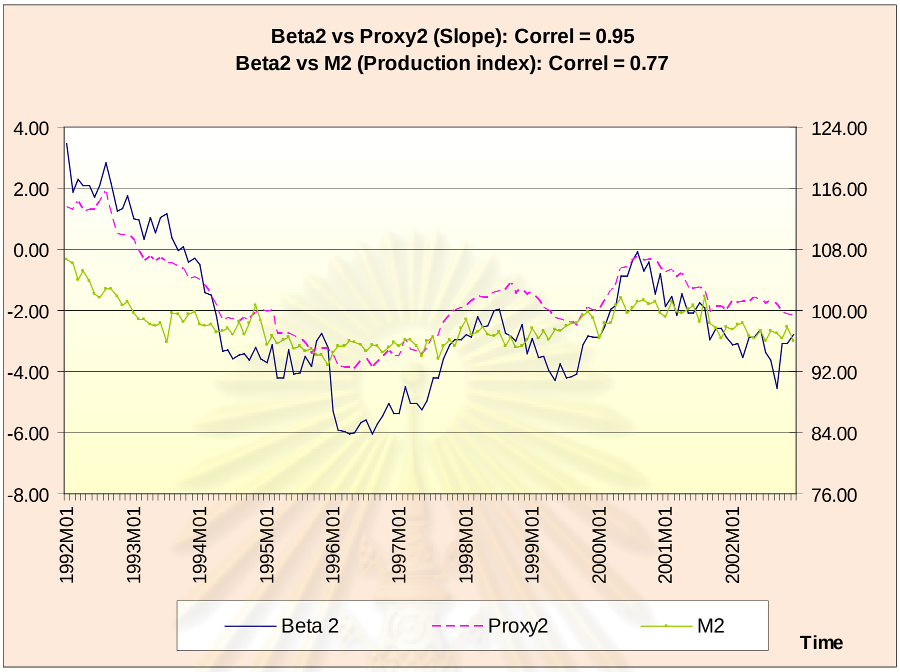

Figure 16 Svensson model slope factor and empirical counterparts (Correlation-based approach)

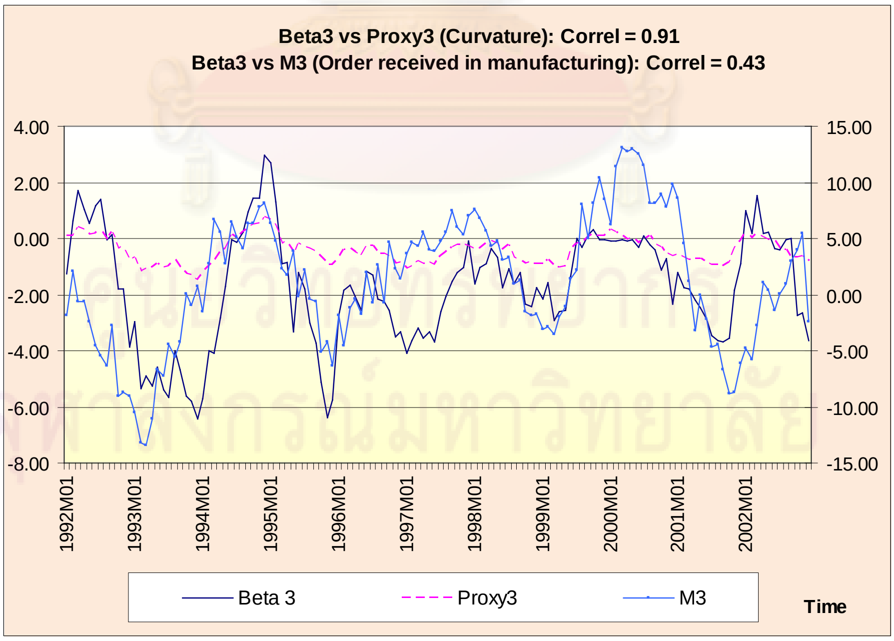

Figure 17 Svensson model first curvature factor and empirical counterparts (Correlation-based approach)

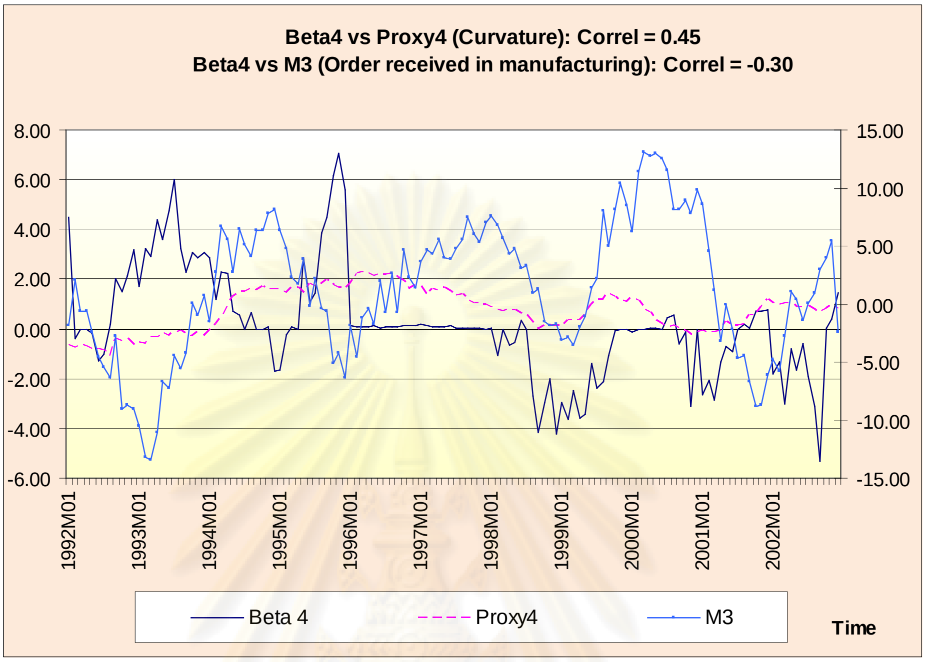

Figure 18 Svensson model second curvature factor and empirical counterparts (Correlation-based approach)

Standard errors in ( ) & t-statistics in [ ]

	B1	B2	B3	M1	M2	M3
B1(-1)	**1.023371**	**-0.160559**	-0.043672	**0.146206**	-0.222719	0.015438
	(0.04103)	**(0.06132)**	(0.12808)	**(0.05227)**	(0.20237)	(0.01767)
	[24.9394]	**[-2.61833]**	[-0.34099]	**[2.79690]**	[-1.10058]	[0.87381]
B2(-1)	0.019973	**0.86314**	-0.149067	0.061407	0.25578	-0.000898
	(0.02964)	**(0.04429)**	(0.09251)	(0.03776)	(0.14617)	(0.01276)
	[0.67384]	**[19.4867]**	[-1.61133]	[1.62628]	[1.74983]	[-0.07034]
B3(-1)	-0.007828	**0.050943**	**0.86222**	-0.025159	**0.175392**	**-0.020381**
	(0.01394)	**(0.02083)**	**(0.04350)**	(0.01775)	**(0.06873)**	**(0.00600)**
	[-0.56174]	**[2.44616]**	**[19.8228]**	[-1.41717]	**[2.55203]**	**[-3.39678]**
M1(-1)	-0.030845	**0.115632**	0.112504	**0.809352**	0.13445	0.025466
	(0.03832)	**(0.05726)**	(0.11960)	**(0.04881)**	(0.18897)	(0.01650)
	[-0.80496]	**[2.01932]**	[0.94068]	**[16.5801]**	[0.71148]	[1.54358]
M2(-1)	0.012558	0.009741	0.066343	**0.044034**	**0.563356**	-0.006692
	(0.01548)	(0.02313)	(0.04831)	**(0.01972)**	**(0.07633)**	(0.00666)
	[0.81141]	[0.42119]	[1.37342]	**[2.23342]**	**[7.38100]**	[-1.00427]
M3(-1)	-0.132615	0.055026	-1.164988	0.248118	1.317014	0.046526
	(0.20924)	(0.31269)	(0.65308)	(0.26656)	(1.03190)	(0.09009)
	[-0.63379]	[0.17598]	[-1.78384]	[0.93083]	[1.27630]	[0.51645]
C	-1.296598	-0.391022	-7.041442	**-4.835685**	**44.8137**	0.475961
	(1.56097)	(2.33269)	(4.87206)	**(1.98854)**	**(7.69813)**	(0.67207)
	[-0.83064]	[-0.16763]	[-1.44527]	**[-2.43177]**	**[5.82137]**	[0.70821]

Figure 19 Nelson-Siegel yield macro model parameter estimated: Traditional approach

Standard errors in ( ) & t-statistics in [ ]

	BB1	BB2	BB3	BB4	M1	M2	M3
BB1(-1)	**0.88641**	0.007451	-0.275251	**0.550136**	**0.142351**	-0.220151	0.015152
	(0.07637)	(0.09986)	(0.17610)	**(0.23396)**	**(0.05559)**	(0.21533)	(0.01885)
	[11.6070]	[0.07461]	[-1.56302]	**[2.35144]**	**[2.56089]**	[-1.02238]	[0.80385]
BB2(-1)	-0.035035	**0.927202**	-0.230011	0.206358	0.060712	0.257308	-0.001612
	(0.05247)	**(0.06861)**	(0.12099)	(0.16073)	(0.03819)	(0.14794)	(0.01295)
	[-0.66775]	**[13.5149]**	[-1.90113]	[1.28385]	[1.58978]	[1.73929]	[-0.12448]
BB3(-1)	0.01631	0.021	**0.907942**	-0.098989	-0.024487	**0.172483**	**-0.020072**
	(0.02527)	(0.03304)	**(0.05826)**	(0.07740)	(0.01839)	**(0.07124)**	**(0.00624)**
	[0.64555]	[0.63565]	**[15.5842]**	[-1.27892]	[-1.33154]	**[2.42120]**	**[-3.21878]**
BB4(-1)	**0.075769**	**-0.074988**	**0.113636**	**0.671522**	0.014351	-0.08499	-0.003965
	(0.02450)	**(0.03203)**	**(0.05649)**	**(0.07505)**	(0.01783)	(0.06907)	(0.00605)
	[3.09298]	**[-2.34102]**	**[2.01166]**	**[8.94803]**	[0.80486]	[-1.23045]	[-0.65574]
M1(-1)	-0.018526	0.103376	0.133077	-0.03412	**0.80491**	0.145639	0.025707
	(0.06827)	(0.08927)	(0.15743)	(0.20914)	**(0.04969)**	(0.19250)	(0.01685)
	[-0.27137]	[1.15803]	[0.84533]	[-0.16314]	**[16.1983]**	[0.75659]	[1.52564]
M2(-1)	0.033113	-0.011846	0.080896	-0.068661	**0.045707**	**0.559005**	-0.006374
	(0.02731)	(0.03571)	(0.06298)	(0.08367)	**(0.01988)**	**(0.07701)**	(0.00674)
	[1.21238]	[-0.33168]	[1.28444]	[-0.82059]	**[2.29918]**	**[7.25874]**	[-0.94559]
M3(-1)	-0.093569	0.018902	-1.213124	-0.002183	0.254734	1.286991	0.054052
	(0.36638)	(0.47907)	(0.84484)	(1.12239)	(0.26667)	(1.03304)	(0.09043)
	[-0.25539]	[0.03946]	[-1.43592]	[-0.00195]	[0.95523]	[1.24582]	[0.59775]
C	-2.499072	0.711653	-7.057352	3.403569	**-4.963627**	**45.19468**	0.445975
	(2.75417)	(3.60134)	(6.35096)	(8.43743)	**(2.00467)**	**(7.76575)**	(0.67976)
	[-0.90738]	[0.19761]	[-1.11123]	[0.40339]	**[-2.47603]**	**[5.81974]**	[0.65607]

Figure 20 Svensson yield macro model parameter estimated:

Traditional approach

Standard errors in ( ) & t-statistics in [ ]

	B1	B2	B3	M1	M2	M3
B1(-1)	**0.869933** **(0.04568)** **[19.0426]**	0.043958 (0.07113) [0.61803]	-0.007338 (0.14608) [-0.05023]	0.005257 (1.84878) [0.00284]	0.396932 (0.23211) [1.71007]	-0.571492 (0.49322) [-1.15869]
B2(-1)	-0.045897 (0.02460) [-1.86548]	**0.981727** **(0.03831)** **[25.6288]**	-0.10819 (0.07867) [-1.37520]	0.534177 (0.99567) [0.53650]	**0.553861** **(0.12501)** **[4.43063]**	-0.41804 (0.26563) [-1.57377]
B3(-1)	0.003763 (0.01394) [0.27003]	0.029146 (0.02170) [1.34324]	**0.875876** **(0.04456)** **[19.6542]**	-0.354321 (0.56400) [-0.62822]	0.094284 (0.07081) [1.33149]	0.146941 (0.15047) [0.97656]
M1(-1)	**0.000697** **(0.00025)** **[2.80076]**	-0.000442 (0.00039) [-1.14036]	0.000107 (0.00080) [0.13438]	**1.015871** **(0.01007)** **[100.894]**	-0.002309 (0.00126) [-1.82681]	0.002506 (0.00269) [0.93293]
M2(-1)	**0.033077** **(0.01627)** **[2.03287]**	-0.006757 (0.02533) [-0.26673]	0.083759 (0.05203) [1.60987]	0.834999 (0.65847) [1.26809]	**0.471585** **(0.08267)** **[5.70433]**	0.080363 (0.17567) [0.45747]
M3(-1)	-0.007799 (0.00448) [-1.74232]	0.012804 (0.00697) [1.83716]	0.005511 (0.01431) [0.38501]	-0.052504 (0.18116) [-0.28983]	0.043459 (0.02274) [1.91076]	**0.85427** **(0.04833)** **[17.6760]**
C	**-3.288077** **(1.63466)** **[-2.01147]**	0.841308 (2.54507) [0.33056]	-8.798451 (5.22706) [-1.68325]	-103.4122 (66.15350) [-1.56322]	**53.16921** **(8.30560)** **[6.40161]**	-7.537836 (17.64870) [-0.42710]

Figure 21 Nelson-Siegel yield macro model parameter estimated: Correlation based approach

Standard errors in ( ) & t-statistics in [ ]

	BB1	BB2	BB3	BB4	M1	M2	M3
BB1(-1)	**0.626123**	0.006601	0.407463	**12.61043**	-1.329993	0.30218	-0.873395
	(0.07716)	(0.17503)	(0.53369)	**(5.75776)**	(1.70039)	(0.23369)	(0.48560)
	[8.11493]	[0.03771]	[0.76348]	**[2.19016]**	[-0.78217]	[1.29309]	[-1.79860]
BB2(-1)	0.005649	**0.900798**	-0.34662	-0.853543	-0.506546	**0.489025**	-0.293747
	(0.03735)	**(0.08472)**	(0.25832)	(2.78693)	(0.82304)	**(0.11311)**	(0.23504)
	[0.15127]	**[10.6324]**	[-1.34182]	[-0.30627]	[-0.61546]	**[4.32335]**	[-1.24976]
BB3(-1)	0.007406	**0.083384**	**0.393842**	**-2.432116**	**-1.264549**	0.090067	0.050053
	(0.01533)	**(0.03477)**	**(0.10603)**	**(1.14390)**	**(0.33782)**	(0.04643)	(0.09647)
	[0.48317]	**[2.39787]**	**[3.71448]**	**[-2.12615]**	**[-3.74327]**	[1.93996]	[0.51882]
BB4(-1)	**0.003737**	**0.007273**	**-0.032343**	**0.302787**	-0.011719	0.007404	-0.009014
	(0.00155)	**(0.00352)**	**(0.01074)**	**(0.11588)**	(0.03422)	(0.00470)	(0.00977)
	[2.40667]	**[2.06469]**	**[-3.01135]**	**[2.61305]**	[-0.34246]	[1.57423]	[-0.92240]
M1(-1)	**0.001643**	3.83E-05	-0.001713	**-0.058848**	**1.020167**	-0.002148	0.003813
	(0.00038)	(0.00087)	(0.00264)	**(0.02846)**	**(0.00840)**	(0.00116)	(0.00240)
	[4.30796]	[0.04425]	[-0.64924]	**[-2.06789]**	**[121.388]**	[-1.86001]	[1.58881]
M2(-1)	0.005443	0.072474	0.154263	-0.181359	**1.373872**	**0.534099**	0.030656
	(0.02564)	(0.05816)	(0.17733)	(1.91316)	**(0.56500)**	**(0.07765)**	(0.16135)
	[0.21230]	[1.24612]	[0.86991]	[-0.09480]	**[2.43164]**	**[6.87837]**	[0.18999]
M3(-1)	0.00594	0.003014	-0.007025	-0.508169	-0.08072	**0.045736**	**0.865291**
	(0.00731)	(0.01659)	(0.05058)	(0.54571)	(0.16116)	**(0.02215)**	**(0.04602)**
	[0.81231]	[0.18171]	[-0.13888]	[-0.93122]	[-0.50087]	**[2.06496]**	**[18.8011]**
C	0.073016	-7.398045	-17.37459	-0.45689	**-155.5543**	**47.25887**	-2.007904
	(2.59587)	(5.88884)	(17.95540)	(193.71400)	**(57.20780)**	**(7.86221)**	(16.33740)
	[0.02813]	[-1.25628]	[-0.96765]	[-0.00236]	**[-2.71911]**	**[6.01088]**	[-0.12290]

Figure 22 Svensson yield macro model parameter estimate:

Correlation based approach

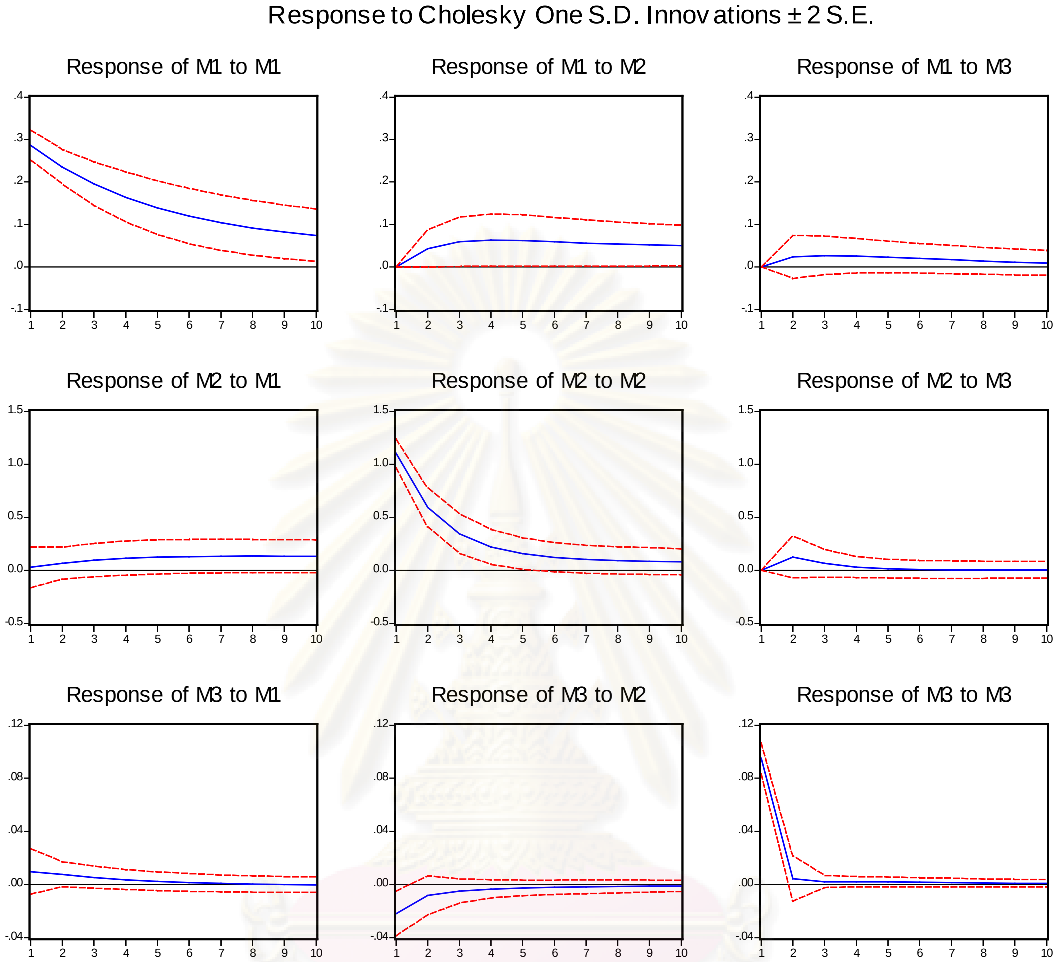

Figure 23 The impulse response of Nelson-Siegel model:

Macro responses to macro shocks (Traditional approach)

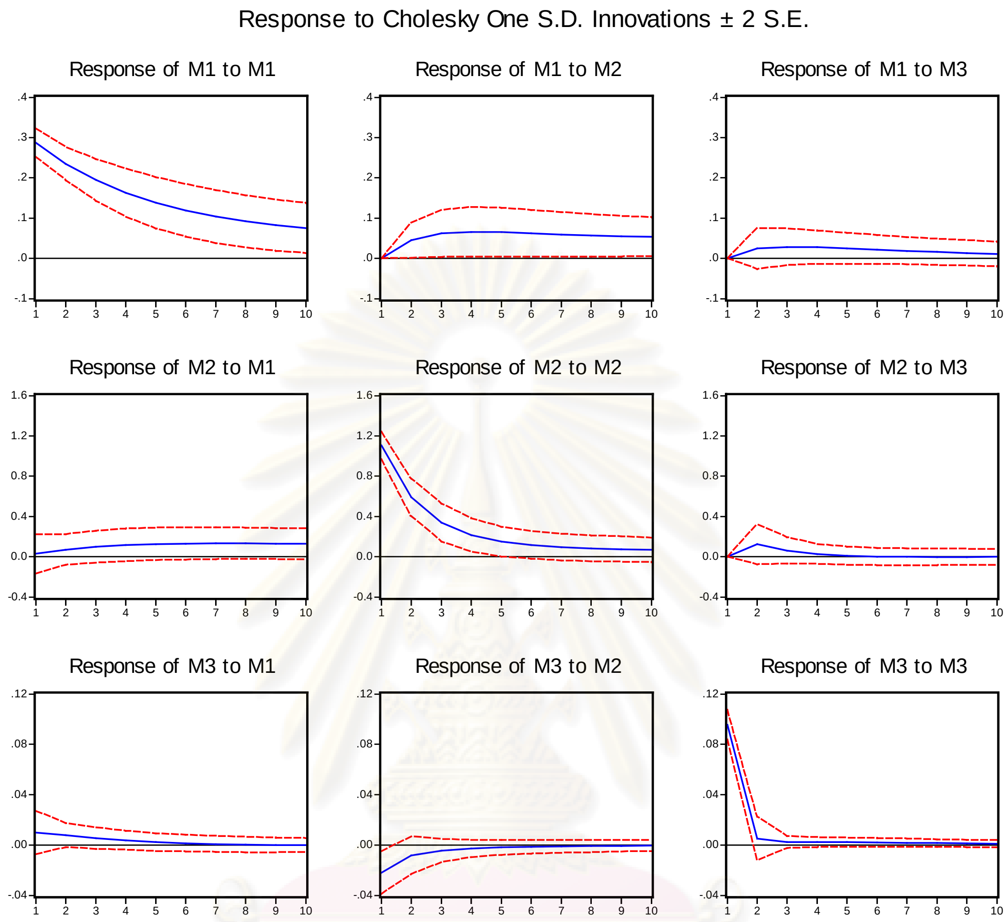

Figure 24 The impulse response of Svensson model:

Macro responses to macro shocks (Traditional approach)

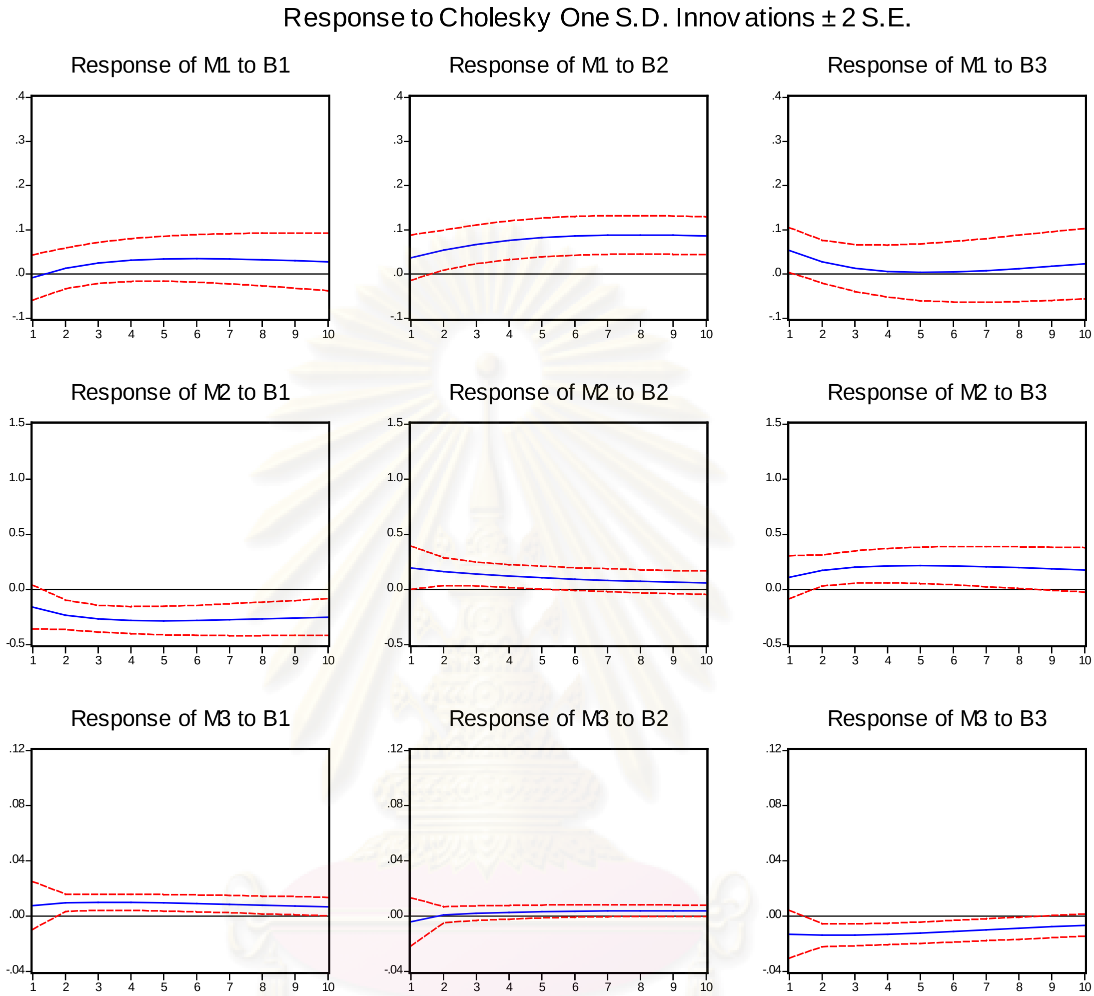

Figure 25 The impulse response of Nelson-Siegel model:
Macro responses to yield curve shocks (Traditional approach)

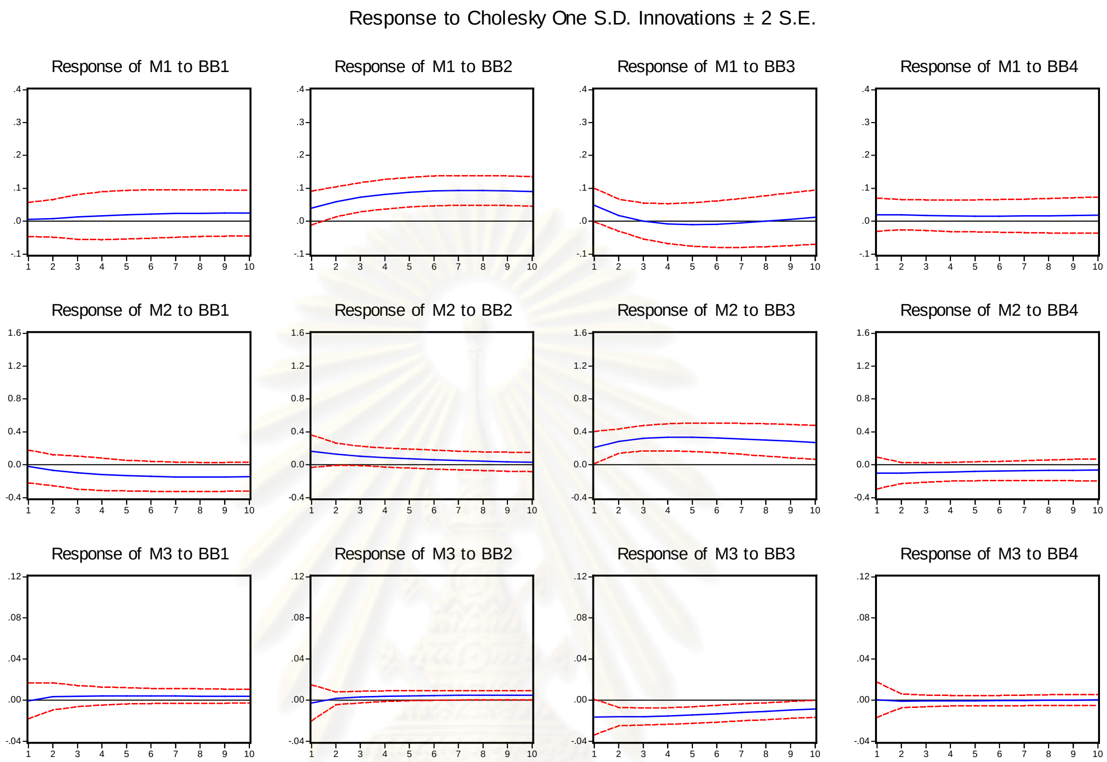

Figure 26 The impulse response of Svensson model:

Macro responses to yield curve shocks (Traditional approach)

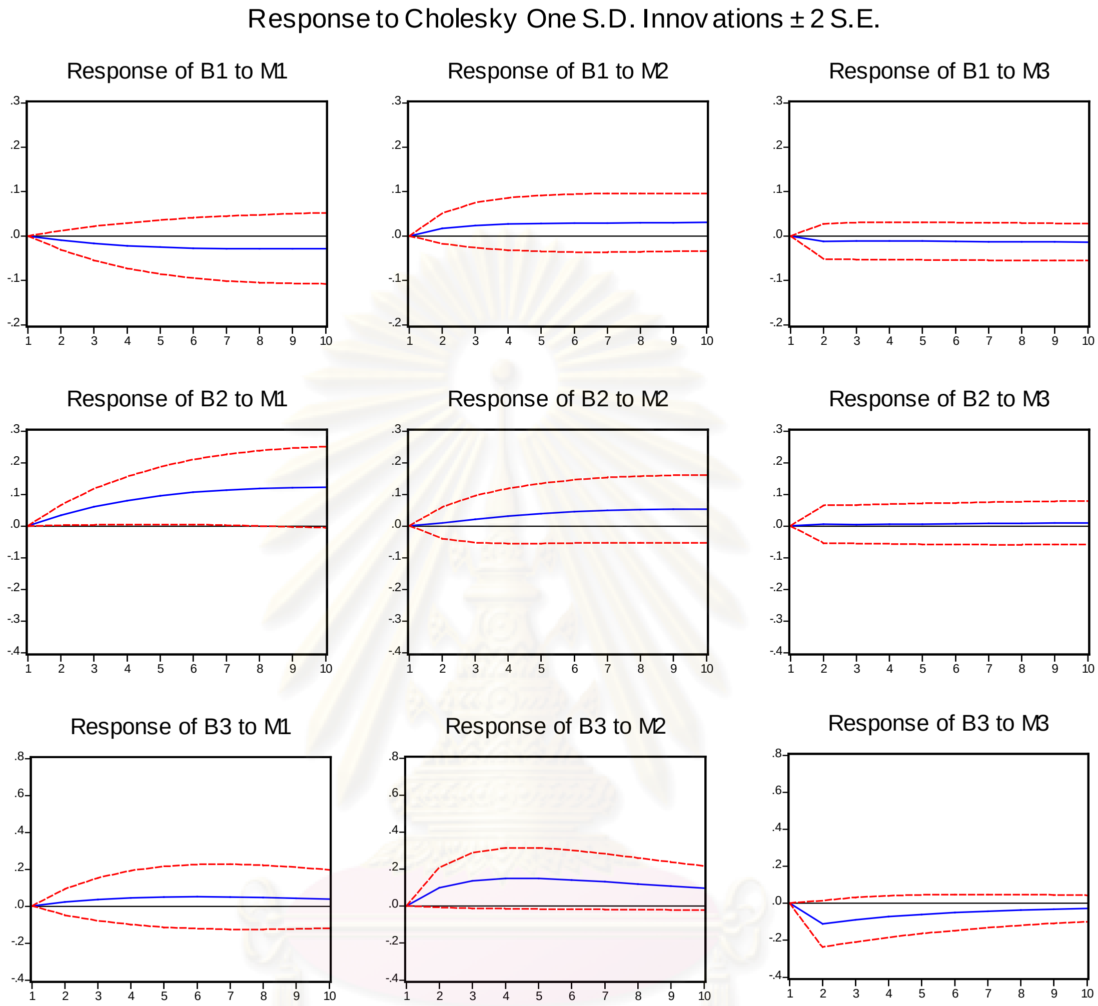

Figure 27 The impulse response of Nelson-Siegel model:
Yield curve responses to macro shocks (Traditional approach)

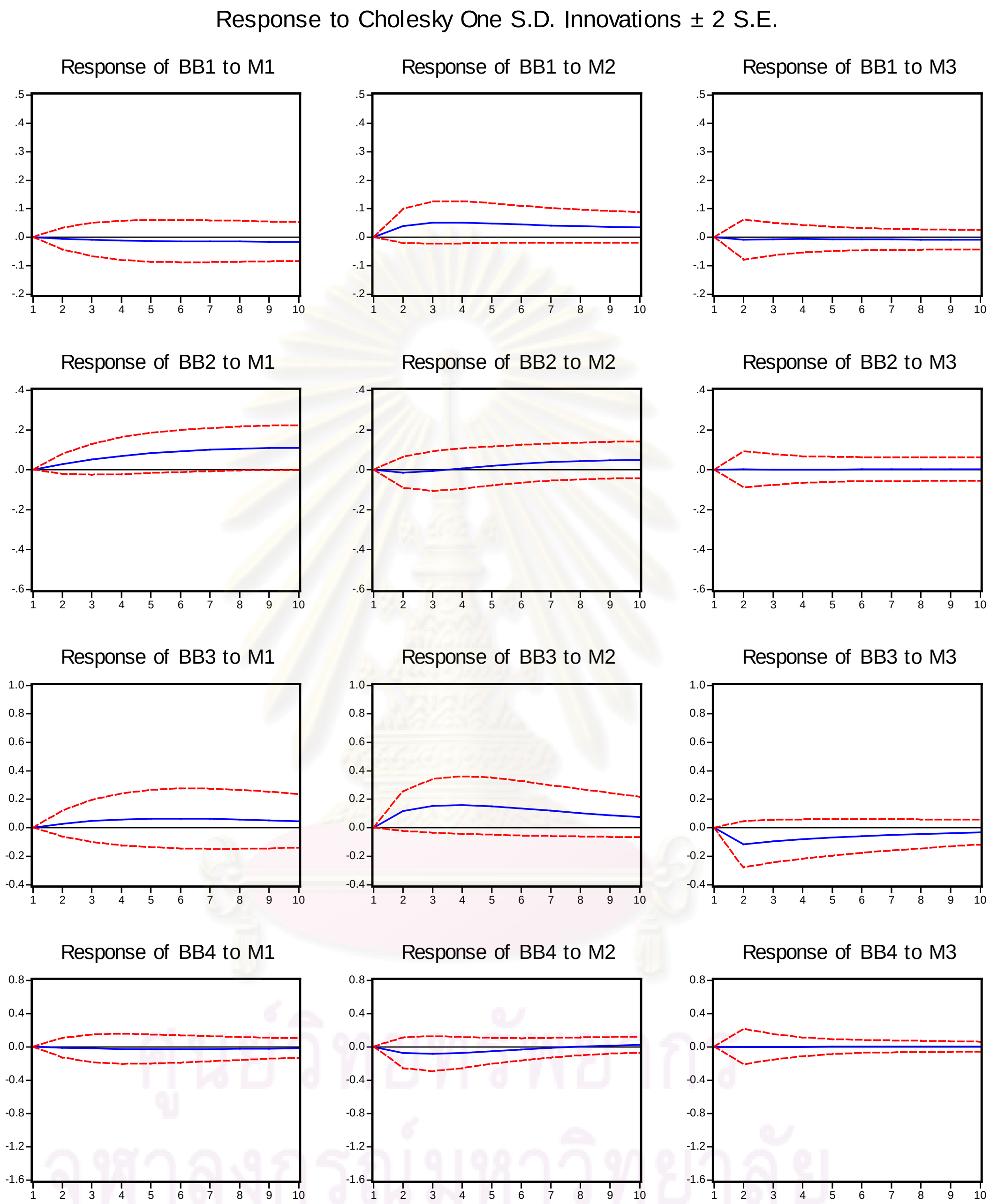

Figure 28 The impulse response of Svensson model:

Yield curve responses to macro shocks (Traditional approach)

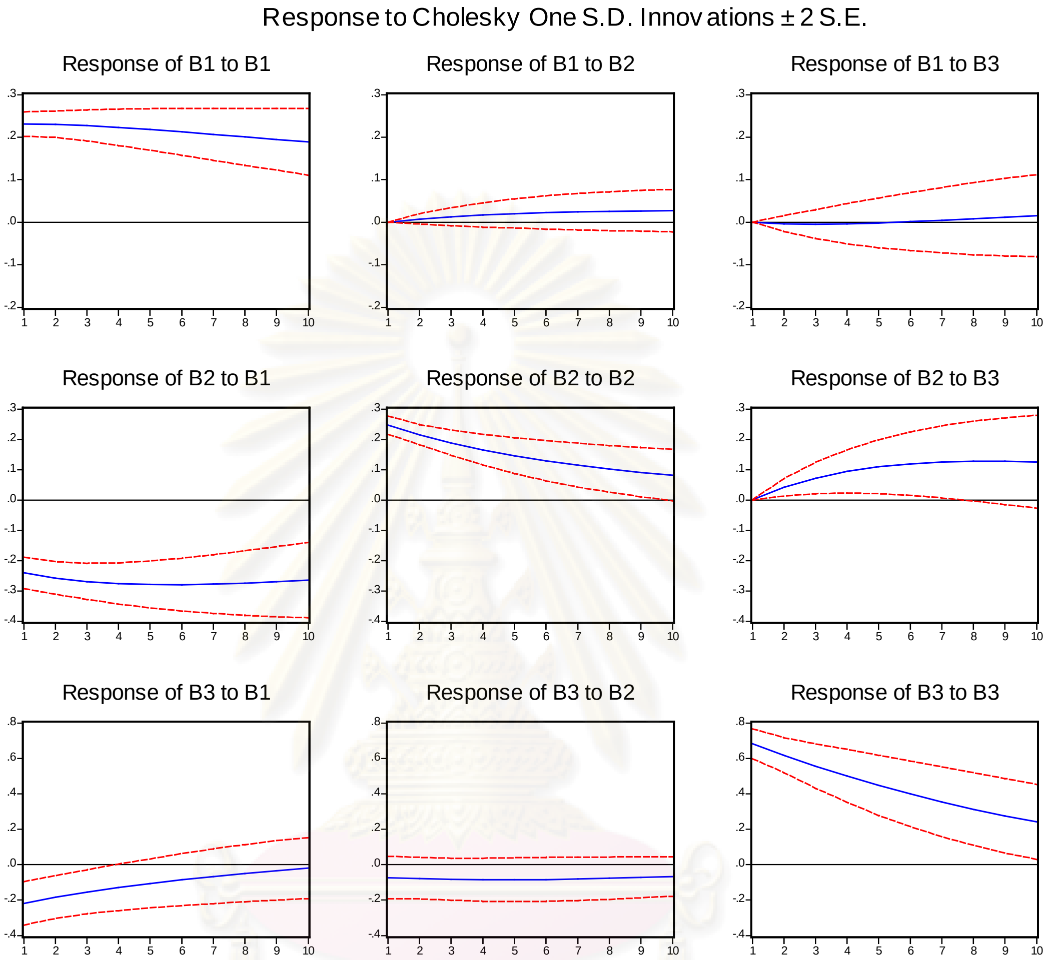

Figure 29 The impulse response of Nelson-Siegel model:

Yield curve responses to yield curve shocks (Traditional approach)

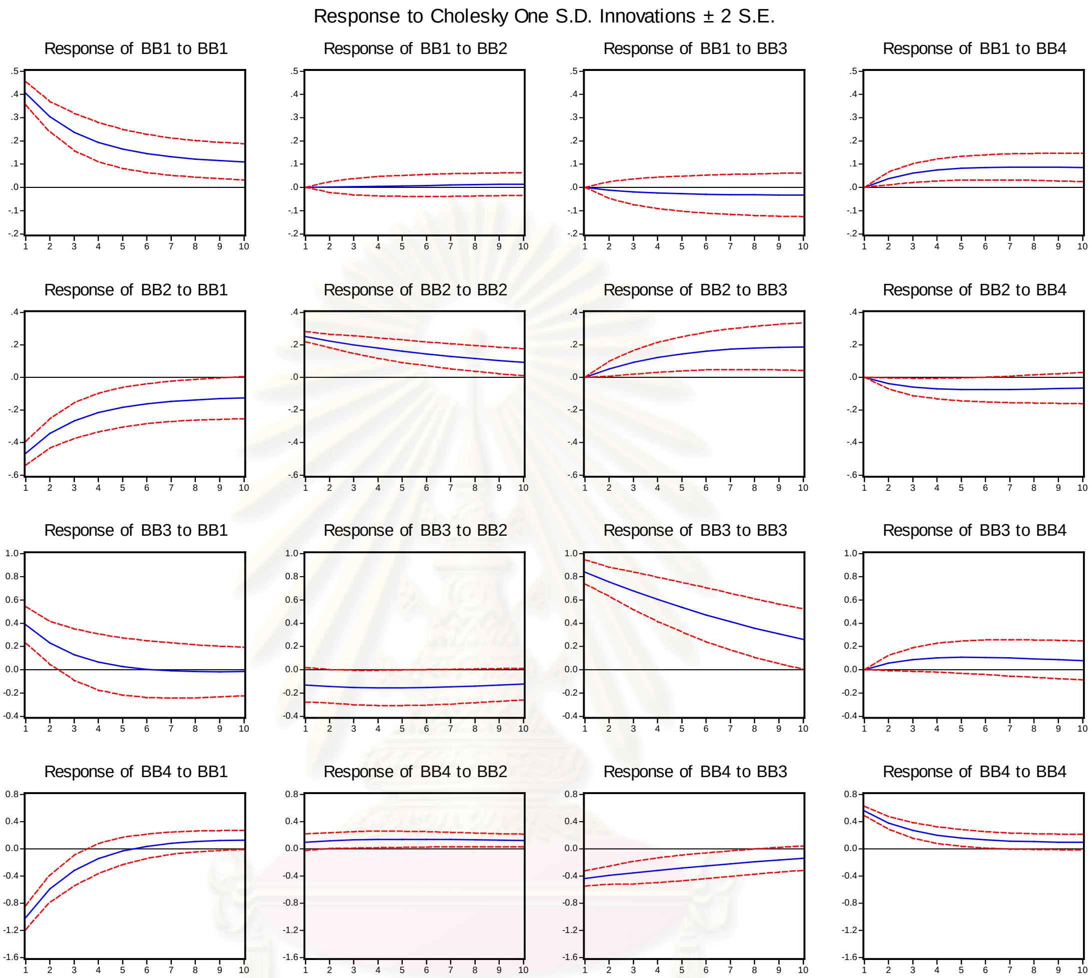

Figure 30 The impulse response of Svensson model:

Yield curve responses to yield curve shocks (Traditional approach)

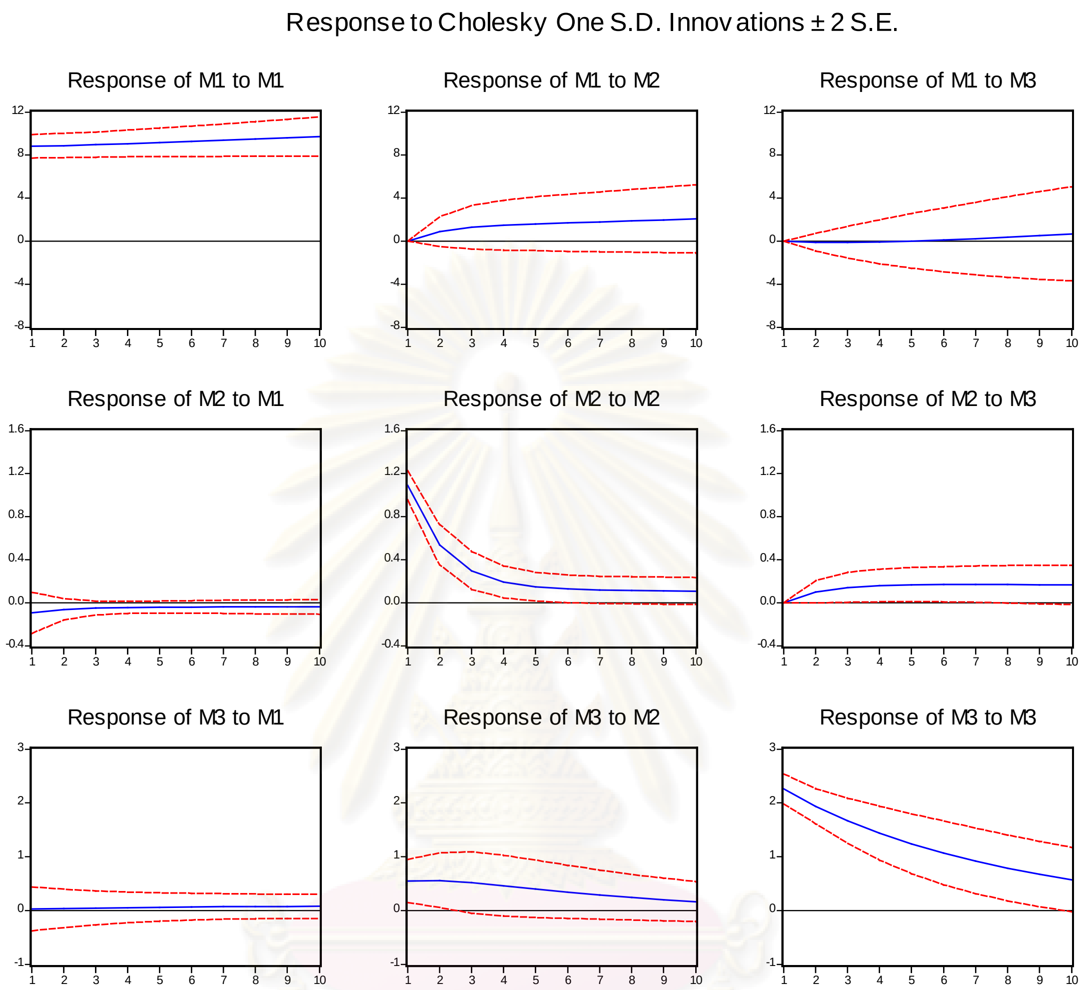

Figure 31 The impulse response of Nelson-Siegel model:

Macro responses to macro shocks (Correlation-based approach)

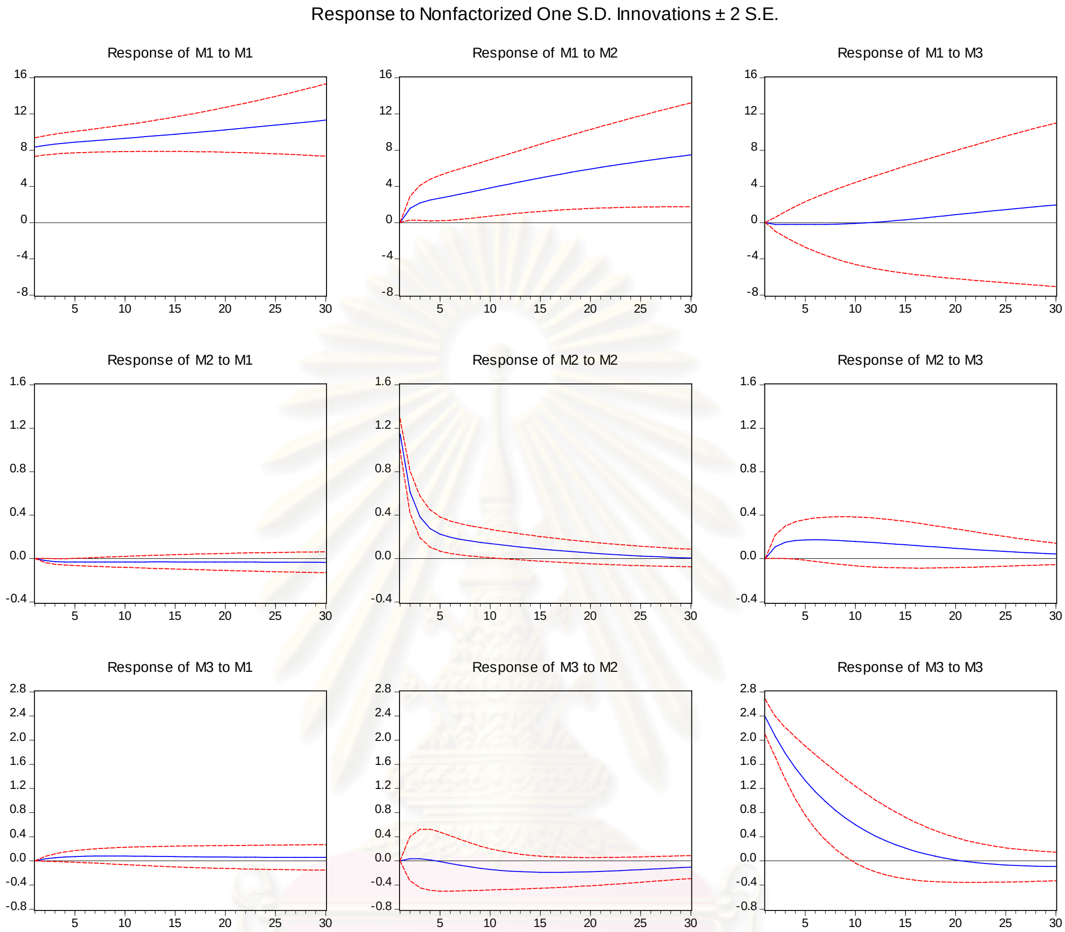

Figure 32 The impulse response of Svensson model:

Macro responses to macro shocks (Correlation-based approach)

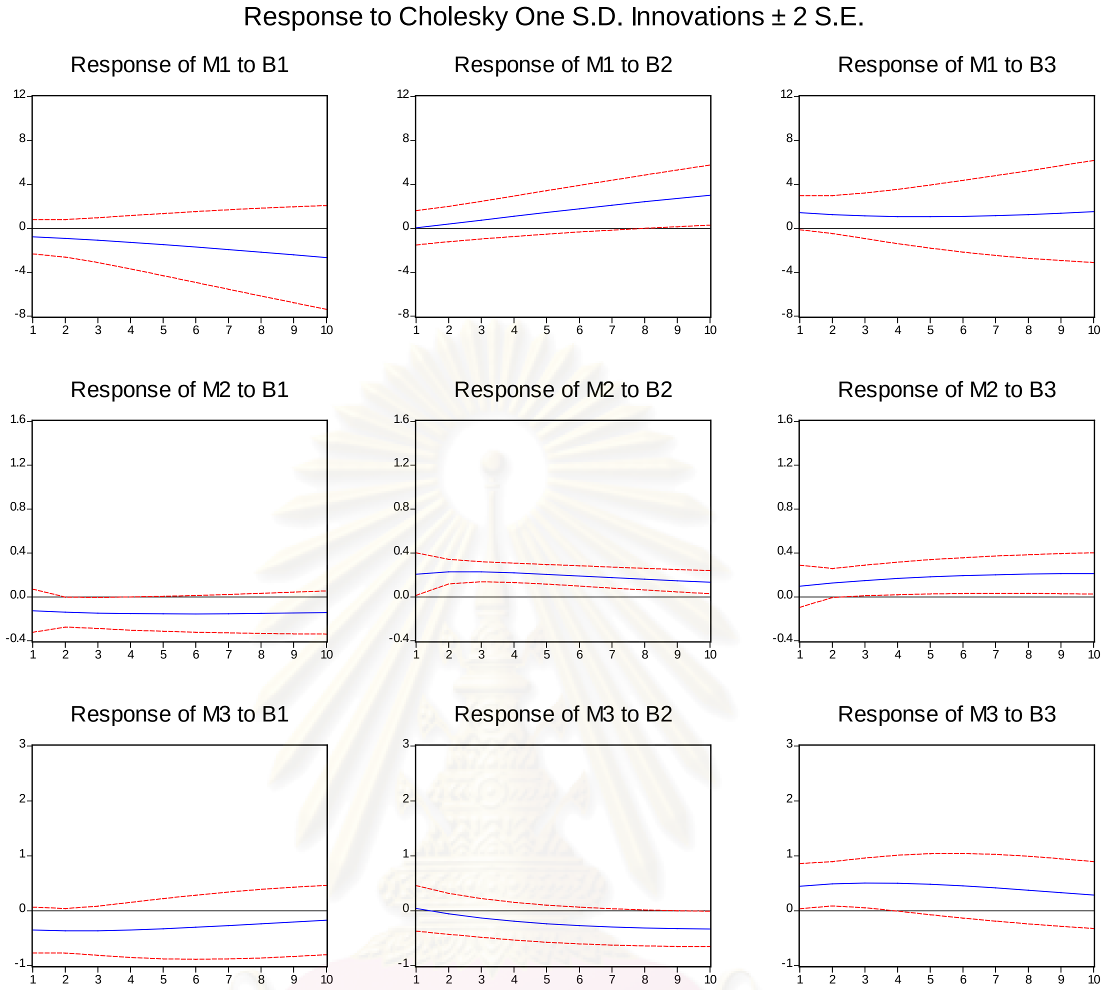

Figure 33 The impulse response of Nelson-Siegel model:

Macro responses to yield curve shocks (Correlation-based approach)

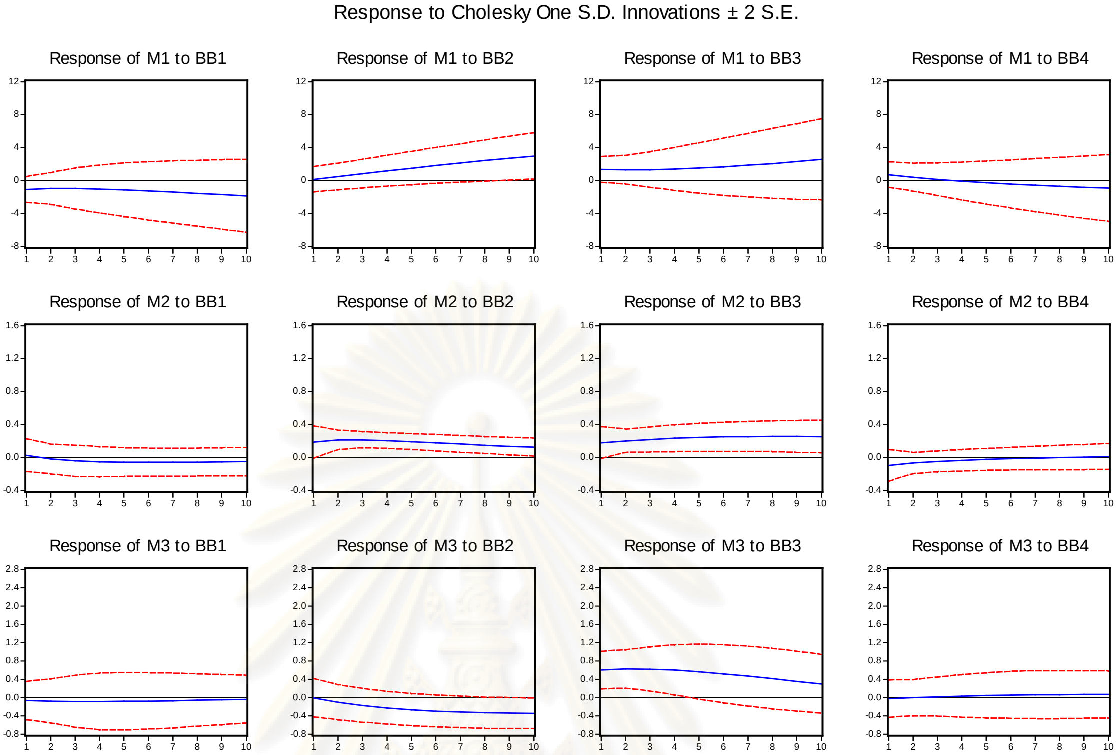

Figure 34 The impulse response of Svensson model:

Macro responses to yield curve shocks (Correlation-based approach)

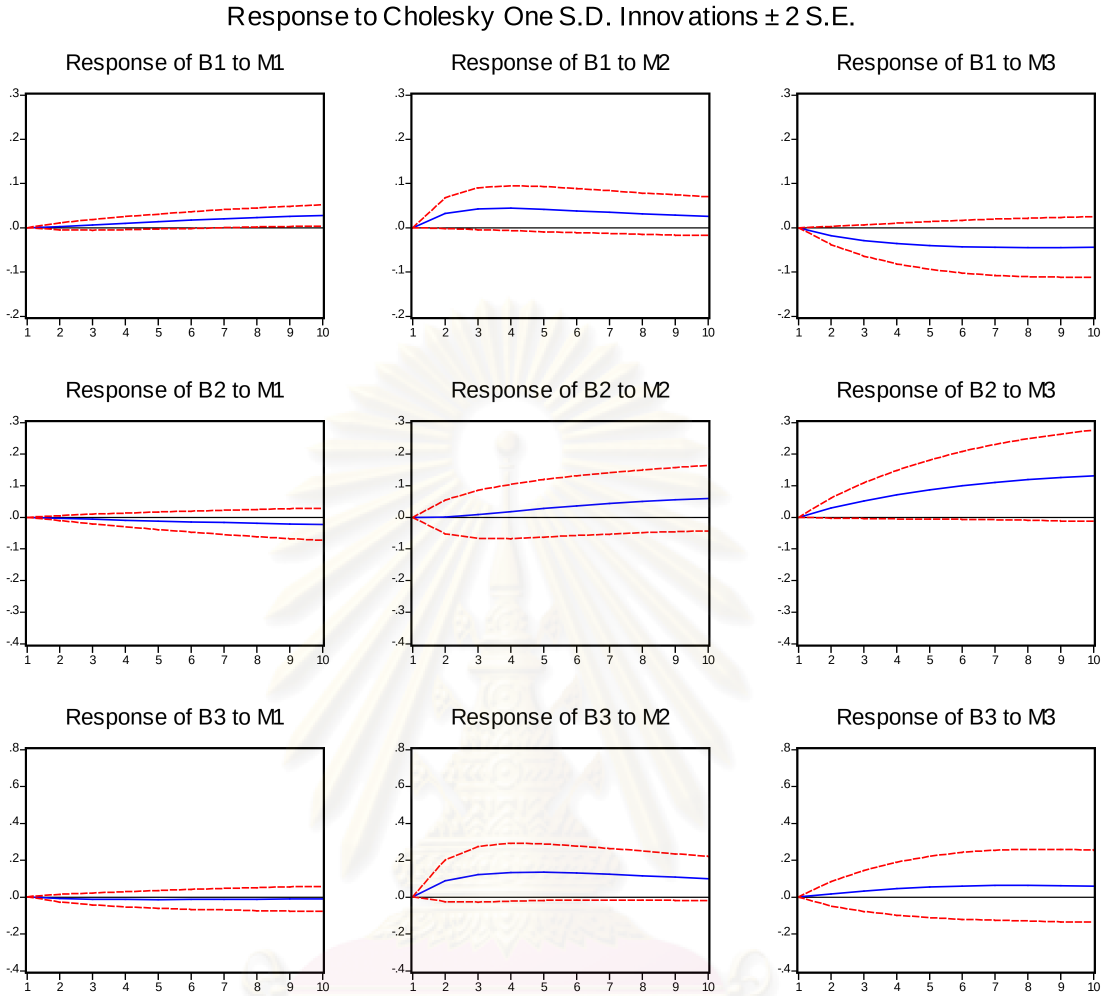

Figure 35 The impulse response of Nelson-Siegel model:

Yield curve responses to macro shocks (Correlation-based approach)

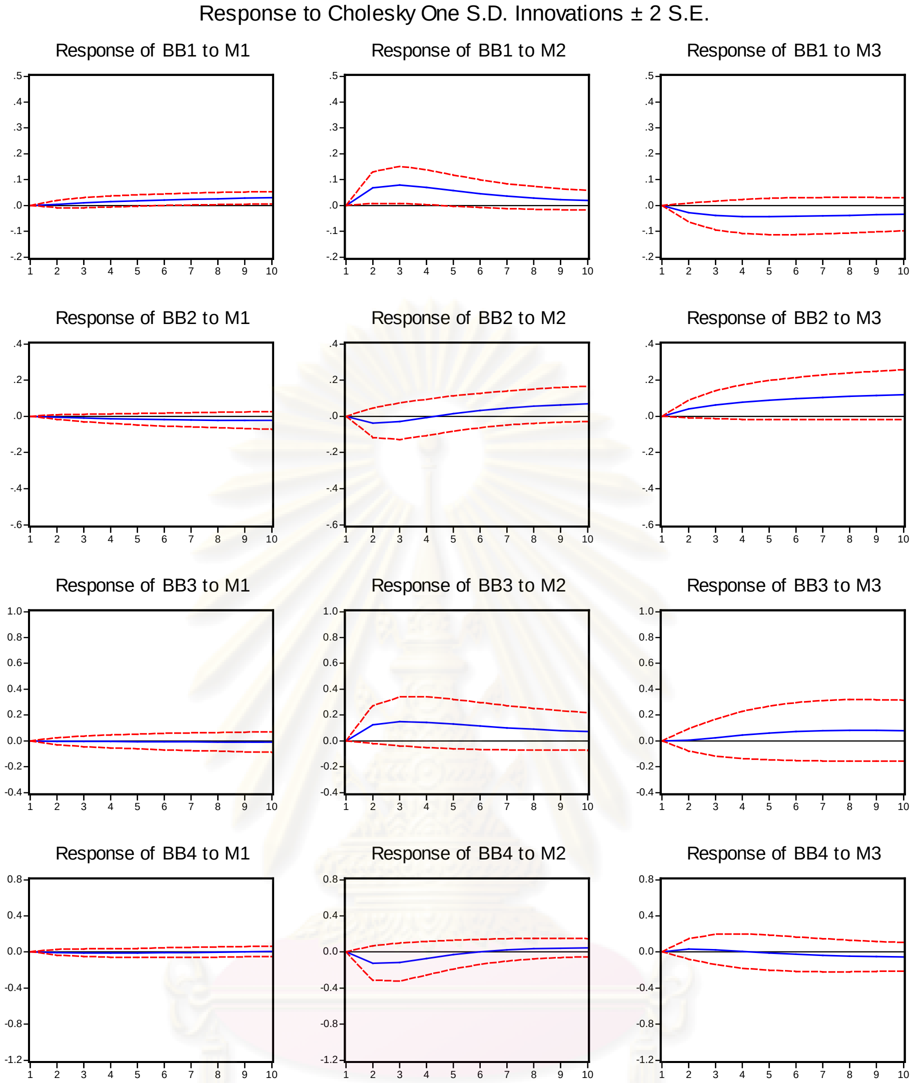

Figure 36 The impulse response of Svensson model:
Yield curve responses to macro shocks (Correlation-based approach)

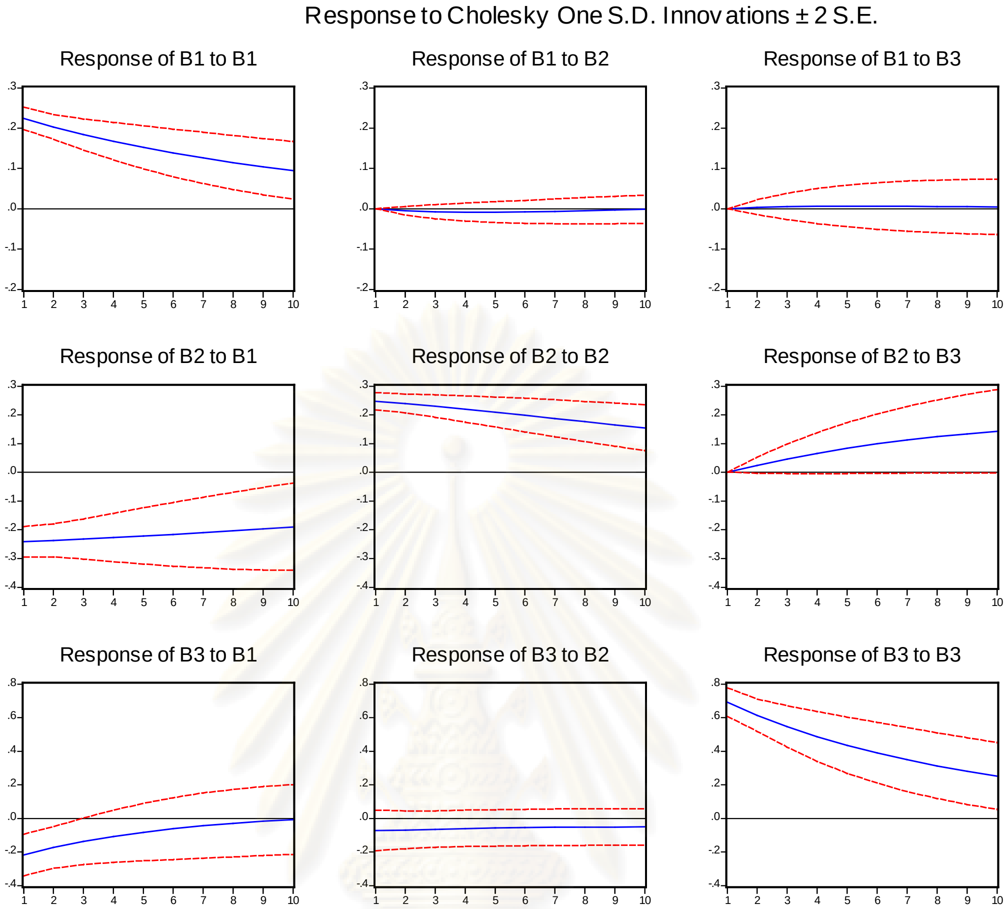

Figure 37 The impulse response of Nelson-Siegel model:

Yield curve responses to yield curve shocks (Correlation-based approach)

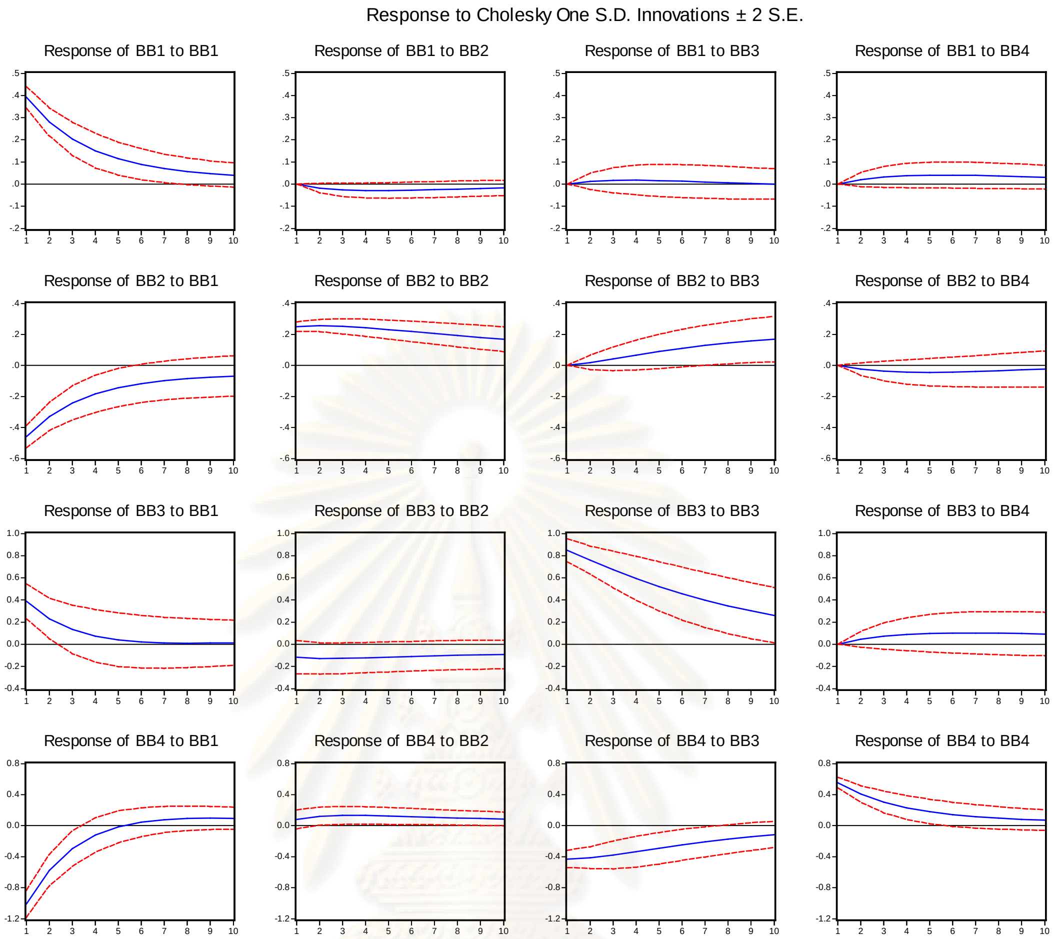

Figure 38 The impulse response of Svensson model:

Yield curve responses to yield curve shocks (Correlation-based approach)

BIOGRAPHY

Miss Supaluck Meephokee was born on March 21, 1985, in Bangkok. At the secondary school, she graduated from Samsenwittayalai School. At the undergraduate level, she graduated from the Faculty of Engineering, Chulalongkorn University in May 2006 with a Bachelor of Civil Engineering degree. After that, she worked at Meinhardt Thailand, the consulting company as structural engineer. She joined the Master of Science in Finance program, Chulalongkorn University in June 2008.