Determinants of the New Zealand Yield Curve: Domestic vs. Foreign Influences

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Abstract

This paper examines the relationship between the New Zealand government yield curve and the contribution of global and domestic factors influencing it. We apply the Nelson and Siegel method, which has been widely used internationally for fitting a yield curve, to decompose it into three independent factors – level, slope and curvature. We then analyse the link between each New Zealand yield curve factor, the global factors and observable domestic and international macroeconomic variables.

We find that approximately half the movement in the level factor for New Zealand, which drives the yield curve at long maturities, is explained by the global level factor. Meanwhile, the global slope factor explains around a third of the movement in New Zealand's slope factor. Of the remaining domestically driven components, it is difficult to identify a significant role for any specific domestic macroeconomic variables. However, domestic variables have a larger impact on the slope and curvature factors as shorter maturities are more directly under the control of the monetary authority and react to macroeconomic fundamentals. The output gap in particular is highly relevant in explaining the slope of the yield curve.

JEL CLASSIFICATION G1; E4; C5

KEYWORDS Term structure; Interest rate; Global yield; Dynamic factor model

Executive Summary

As a small open economy with internationally well-integrated financial markets, New Zealand's interest rates are strongly influenced by developments in global markets. It is important to understand the different contributions made by global and domestic factors for New Zealand's yield curve as they can have significant implications for both monetary and fiscal policymakers, as well as private market participants.

This paper examines the impact of domestic and global factors in influencing the yields on New Zealand government bonds. We use the Nelson-Siegel framework, which is widely used internationally for fitting a yield curve and which estimates three latent factors that describe different characteristics of the curve – level, slope, and curvature. This methodology is applied to both the New Zealand government bond curve and to the equivalent bond curves in a set of countries with particular influence for New Zealand's interest rate markets. We then use an extension of the Nelson-Siegel model that incorporates a common global yield component and jointly model the estimated New Zealand factors with the global yield factors and a range of domestic macroeconomic variables.

The results confirm the significant influence of global developments for New Zealand's yield curve. We find that approximately half the movement in the level factor for New Zealand, which drives the yield curve at long maturities, is explained by the global level factor. Meanwhile, the global slope factor explains around a third of the movement in New Zealand's corresponding slope factor. In terms of domestic macroeconomic variables, it is difficult to identify a significant role for any specific variable, although the real exchange rate, inflation expectations, and output gap play significant roles. These variables tend to have a larger impact on the slope and curvature factors though than the longer-term level factors, likely due to the tendency for shorter maturities to be more directly under the control of the domestic monetary authority.

The results can be used to understand and predict movements in the New Zealand government bond curve, as well as providing a framework to model and simulate the response of the yield curve to various shocks. The strong influence of global factors is particularly noteworthy given ongoing uncertainty in the global economic and financial environment. For example, the results suggest that the likely upcoming rise in US long-term interest rates, due to the eventual return to conventional monetary policy in the US, will likely be mimicked by increases in long-term rates in other advanced countries such as the UK, Germany and New Zealand, regardless of their different domestic monetary conditions.

Table of Contents

List of Tables

List of Figures

Determinants of the New Zealand Yield Curve: Domestic vs. International Influences

1 Introduction

Interest rates in New Zealand are determined by a wide range of economic factors. Some reflect current and expected conditions in the domestic economy, while others reflect conditions abroad. As a small open economy with internationally well-integrated financial markets, New Zealand's interest rates are heavily influenced by global developments. Movements in New Zealand rates are often highly correlated with those in global markets, due to both the tendency for the New Zealand economy to be hit by the same shocks and the role of international investors in exploiting arbitrage opportunities across countries' rates of return.

For policymakers, it is important to understand the different contributions made by global and domestic factors to interest rate movements. For example, an increase in interest rates driven by domestic factors, such as higher inflation expectations, may need to be offset by a tighter monetary or fiscal policy stance. In contrast, an increase in interest rates driven by global factors independent of the domestic macro-economy may lead to an unwarranted tightening in financial conditions. This would require easier monetary and fiscal policy settings to offset it. In addition, understanding the drivers of interest rates is important for the Treasury's longer-term fiscal forecasting. As higher interest rates increase the costs of servicing government debt[1], the underlying drivers behind changes in these rates are an important consideration for the government's fiscal strategy.

In this paper we examine the relationship between the New Zealand government yield curve and a range of global and domestic influences. We apply the Nelson and Siegel method, which has been widely used internationally for fitting yield curves, to decompose the curve into three independent factors – level, slope and curvature. We then analyse the extent to which each of these yield-curve factors are affected by movements in global factors as well as observable domestic and international macroeconomic variables.

The results show that approximately half the movement in the level factor of New Zealand interest rates, which describes the yield curve at long maturities, is explained by the global

1 An increase in interest rates would raise the cost of newly issued debt, but would not affect the servicing cost of existing debt. The impact on the overall cost of the government's funding would depend on the maturity structure of its stock of debt and how much of its debt had to be refinanced at a higher interest rate.

level factor. Meanwhile the global slope factor, which describes shorter maturities, explains around a third of the movement in New Zealand's slope factor. Of the remaining domestically driven components, it is difficult to identify a significant role for any specific domestic macroeconomic variables. However, domestic variables tend to have a larger impact on the slope and curvature factors, with the output gap in particular having a high relevance for explaining the slope of the yield curve. This likely reflects the tighter control exerted by the monetary authority over shorter maturities and their greater sensitivity to developments in macroeconomic indicators.

The paper is organised as follows: Section 2 provides a survey of the literature on modelling the relationship between the yield curve and macroeconomic variables; Section 3 describes the data and modelling methodology used; Section 4 presents the results of the empirical analysis, decomposing the government yield curve into the three Nelson-Siegel factors and examining the empirical relationships; and Section 5 concludes.

2 Literature Survey

The literature on yield curve modelling has evolved steadily over the past few decades. While initially focused on simply describing the shape and characteristics of yield curves, it has since developed to see a greater focus on economic interpretations through linking these characteristics to specific domestic and, more recently, international macroeconomic variables.

A unifying feature of the literature on term-structure modelling has been the use of factor analysis. This analysis uses a few constructed variables, or "factors", to summarise available yield information, along with factor loadings that associate yields of different maturities to those factors. It provides a relatively simple way to analyse the large amount of bond price information at a single point in time and makes use of the fact that financial asset pricing tends to be driven by a small number of systemic risk sources (Diebold, Piazzesi and Rudebusch, 2005).

While the literature is largely uniform in its use of a factor approach, the methods used to estimate the yield factors and their factor loadings vary. Traditionally, the most common approach has focussed on estimating a handful of unobservable, or "latent", factors using flexible linear or affine forms (for overviews, see Duffie and Kan, 1996; Dai and Singleton, 2000). These models fit the yield curve at a given point in time to ensure that no arbitrage opportunities exist.

More recently, popular attention has shifted to the fitted Nelson-Siegel curve approach (see Nelson and Siegel, 1987). This method has become increasingly popular as it provides a parsimonious model with three latent factors that can be estimated simply from bond yield data using Ordinary Least Squares (OLS) regression. As described in Diebold and Li (2006), the three Nelson-Siegel factors each describe a different characteristic of the yield curve's shape – level, slope and curvature. In addition to being simple to estimate, these factors are flexible enough to represent a range of yield-curve shapes.

While these latent factor models provide useful statistical descriptions of yield curves, they traditionally provided little in the way of a macroeconomic interpretation. For example, the traditional Nelson-Siegel approach describes the shape of the curve, but gives little insight into the observable economic variables influencing this shape. Bridging this gap has been the subject of more recent research.

A range of papers have looked at how a country's domestic macroeconomic variables affect its yield curve. Two variables in particular have been used to explain the basic macro dynamics: real economic activity and the inflation rate. Estimates of how much yield movements are explained by these two variables varies. For example, Ang and Piazzesi (2003) present a vector-autoregressive (VAR) model of the yield curve that combines both traditional latent factors and constructed real activity and inflation variables[2]. They find that the two macro variables explain up to 85% of the movements in the short and medium parts of the curve, decreasing to around 40% at longer yields. These results are supported by Evans and Marshall (2007), who also find that most variability in short- and medium-term yields is driven by these two variables and finds slightly stronger long-yield results.

A commonly suggested explanation for the explanatory power of these two variables stems from the role of monetary policy as the transmission channel through which macro dynamics affect yields (see Evans and Marshall, 2007; Kozicki and Tinsley 2001). As short-term interest rates are mainly driven by near-term monetary policy rates, and long-term interest rates in turn can be thought of as expectations about future short-term rates, the key factors influencing monetary policy will influence yields across both short and long maturities. To this end, the Taylor rule implies that expectations about movements in inflation and the output gap will be the main factors influencing monetary policy rates at different points in the future and, through this, yields (Taylor, 1993).

In addition to domestic variables, a more recent extension of the literature has looked at the role that international factors play in domestic yield curve dynamics. This inclusion of global factors reflects the strengthening linkages between financial markets over the past two decades. As these links have grown, macroeconomic and financial variables across countries have increasingly co-moved in response to global shocks. While the literature is inconclusive on the nature and stability of these links, it suggests they have grown since the early 1990s, despite a small decline recently precipitated by the Global Financial Crisis (see Smith, 2002; Ciner, 2007).

The effect of global factors on domestic yield curves is an area of particular interest for small open economies, such as New Zealand. Pepper and Cassino (2011) show that the correlation of daily changes between foreign and New Zealand 10-year government bond yields has increased from an average of around 0.2 in the early 1990s to 0.5 in 2010. Schmidt-Hebbel (2006) finds a similar trend looking at short-rate correlations with the United States' Federal Funds rate.

Lewis and Rosborough (2013) use principal component analysis to examine the influence of changes in global yields on New Zealand yields. They find that the first principal component explains at least 87 percent of the variance of global interest rates. Dungey, Martin and Pagan (2000) also decompose long-term bond spreads of a number of countries into national and global factors, finding that the world factor is the dominant influence on Australian and Canadian spreads. While this study doesn't include New Zealand, the particularly strong correlation between Australian and New Zealand bond yields suggests the likelihood of a strong global influence on New Zealand yields, even if indirectly through Australia.

[2] Ang and Piazzesi (2003) construct their two variables through principal component analysis on sets of relevant macroeconomic series. The "inflation" variable is the first principal component extracted from a range of inflation measures: the Consumer Price Index (CPI), Producer Price Index (PPI), and spot market commodity prices. The "real activity" variable is the first principal component extracted from various measures of activity: unemployment, the growth rate of unemployment, the index of Help Wanted Advertising in Newspapers, and the growth rate of industrial production.

Diebold, Li and Yue (2008) examine the impact of global events on domestic yields through extending the Nelson-Siegel application to include a global yield component. They construct a model where common global level and slope factors are first extracted from government yields in the United States, Germany, Japan and the United Kingdom. Each country's Nelson-Siegel factors are then decomposed into domestic and global components. It finds strong evidence that global level and slope yield factors exist and that they explain a significant part of the variation in domestic factors. For example, 60% of the variation in the US's level factor is found to be explained by the global level factor, and up to 99% in Germany. Meanwhile, around 15% of the US and German slope factors can be explained by the global slope factor. Abbritti, Dell'Erba, Moreno and Sola (2013) find comparable, albeit smaller, results. They find global factors explain on average 54% of the forecast variation of domestic level factors in a selection of advanced economies at short horizons, rising to over 95% at a 10-year horizon. However, in that study, global factors explain only 3% of domestic slope factors at short horizons, rising to around 50% at a 10-year horizon.

In both studies, the smaller influence of the global factor on variation in the domestic slope factor likely reflects the different maturity characteristics of the factors and the more dominant role of monetary policy at short maturities. The slope factor typically reflects the short end of the yield curve, the curvature factor the medium term, and the level factor the longer term maturities. Accordingly, as the yields on shorter maturities are more directly controlled by the domestic monetary authority, the slope factor typically reacts more strongly to domestic macroeconomic fundamentals than the level factor, and thus is less influenced by global developments. Indeed, studies such as Dell'Erba and Sola (2011) have shown that the increasing integration of financial markets is leading to a progressive loss of effectiveness of central banks' abilities to influence long-term rates.

3 Methodology

This paper applies a similar methodology to Diebold et al. (2008) to decompose the factors affecting New Zealand's government bond yield curve. We estimate a macro-finance model for New Zealand using the dynamic interpretation of the Nelson-Siegel framework proposed in that paper.

In the first step, we estimate the three Nelson-Siegel factors for New Zealand and each of a selection of countries using monthly yield data. We then estimate the common global factors using principal components analysis of the estimated level, slope and curvature factors for all countries excluding New Zealand. Since the principal components derived from these factors represent the common factors driving the individual components, we interpret them as the "global" yield curve factors. In the final step, we develop the macro-finance model by jointly modelling the estimated New Zealand factors with global yield factors and domestic macroeconomic variables.

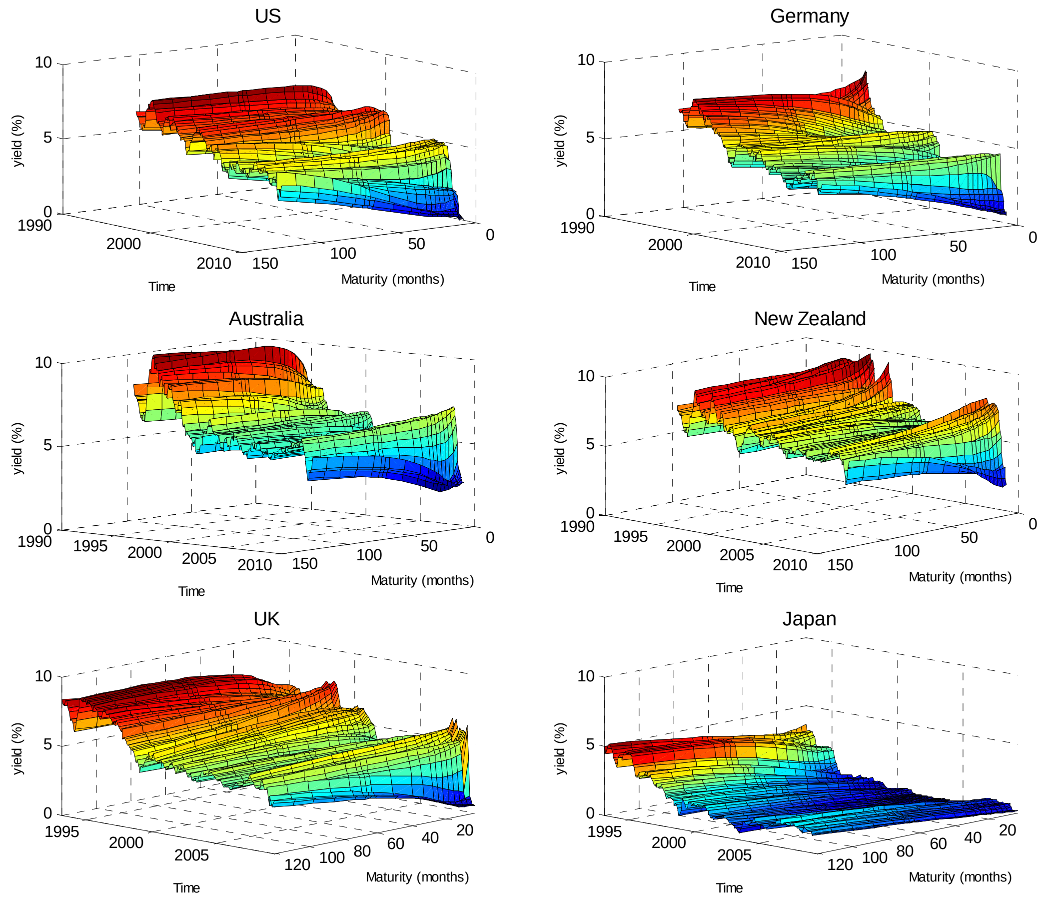
3.1 Data description

The yield data we use consists of monthly government zero-coupon yield curves for New Zealand, Australia, Canada, Switzerland, Germany, Japan, Sweden, the UK and the US, as constructed in Wright (2011). Our sample covers the period from January 1993 to

May 2009[3], for maturities of 3, 6, 9, 12, 15, 18, 21, 24, 30, 36, 48, 60, 63, 66, 72, 84, 96, 108 and 120 months.

Figure 1 plots the dynamic yield curves from countries with a particular influence on New Zealand's interest rate market. A strong correlation can be seen across these curves, illustrating the importance of common factors in driving yield curve movements. A clear downward trend can be seen in the level of the curves across the time horizon, while the slopes have been consistently positive since the onset of the Global Financial Crisis as central banks made significant reductions in policy rates at the short end of the curve.

Figure 1: Yield curves across selected countries and time (Jan 1993 through May 2009)



The accompanying New Zealand macroeconomic data used in our baseline model comprises the quarterly inflation rate (CPI), two-year inflation expectations, output gap, debt-to-GDP ratio and real exchange rate. The majority of the macroeconomic data are downloaded using Haver, which sources the data from Statistics New Zealand, the Reserve Bank of New Zealand and the New Zealand Treasury. The output gap variable is estimated using the New Zealand Treasury's small macro model (see Szeto, 2013). Since the macroeconomic variables are only available at quarterly frequency, the estimated monthly factors are converted into quarterly frequencies during estimation.

3 The analysis excludes the post-Global Financial Crisis episode as the standard Nelson-Siegel framework is not easily applicable when the interest rates are near their zero lower bound.

Figure A1 in the Appendix shows the evolution of all the variables used in our study on a quarterly basis for the period from January 1993 to May 2009.

3.2 Factor model representation

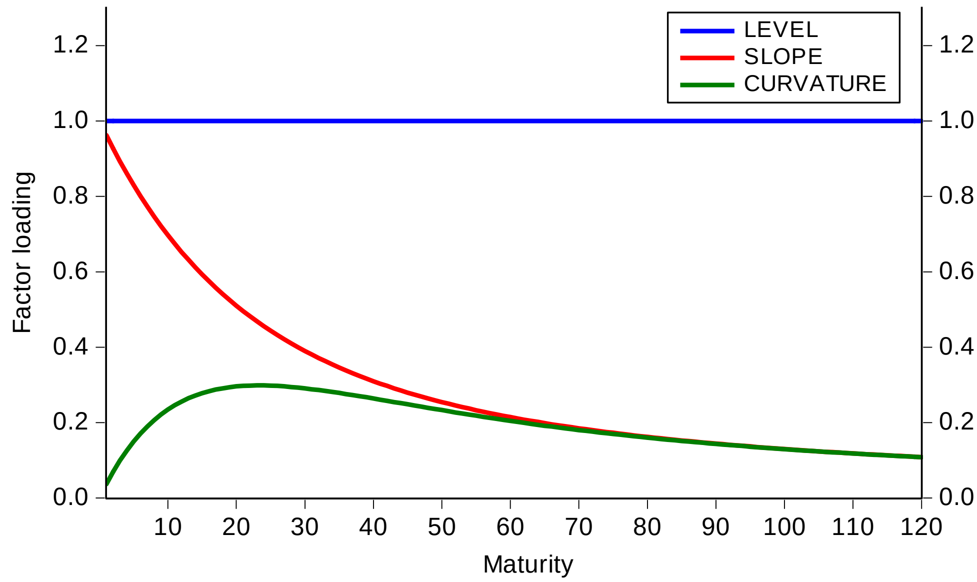
We fit the yield curve for each country using the following specification of the Nelson-Siegel yield curve, at time *t* for yields of maturity *n*:

$$y_{t,n} = L_t + S_t\left(\frac{1-e^{-\lambda n}}{\lambda n}\right) + C_t\left(\frac{1-e^{-\lambda n}}{\lambda n} - e^{-\lambda n}\right) + \varepsilon_{t,n} \qquad (1)$$

where L_t, S_t and C_t are time-varying latent factors, and λ is a constant that determines the exponential rate of decay of the second and third regressors. Following Diebold, Rudebusch and Aruoba (2006), we treat λ as constant rather than as a parameter to estimate ($\lambda = 0.077$).

Using this approach, the latent factors L_t, S_t and C_t can be interpreted as level, slope and curvature factors respectively based on their rates of decay and associated shapes of their factor loadings. The loading on the slope factor $\left(\frac{1-e^{-\lambda n}}{\lambda n}\right)$ is a monotonic increasing function that starts at 1 and decays to zero as *n* increases. It therefore affects the short end of the yield curve more than it does the long end, thus determining the slope of the yield curve. The loading on the curvature factor $\left(\frac{1-e^{-\lambda n}}{\lambda n} - e^{-\lambda n}\right)$ is also a monotonic increasing function that starts at 0, increases at medium term maturities, and then decays to zero in the long term. It therefore results in a hump-shaped increase along the yield curve and determines how much the curve bends at medium term maturities. Finally, the factor loading on L_t is 1 and constant throughout, therefore affecting the level of all maturities equally along the yield curve. To illustrate, the factor loadings for New Zealand maturities are plotted in Figure 2.

Figure 2: Nelson Siegel factor loadings for New Zealand



Given the treatment of λ as constant, the factor loadings can be calculated *a priori* for each maturity and Equation (1) can be estimated for each cross-sectional yield using OLS. The relationship between the set of country yields and the factor loadings is represented as:

$$Y_t = X\beta_t + u_t \qquad (2)$$

where Y_t is the time varying yield data, X represents the constant Nelson-Siegel factor loadings, $\beta_t = [L_t, S_t, C_t]$ is the time-varying Nelson-Siegel factors and u_t is the residuals. The Nelson-Siegel factors (β_t) for each time period can be estimated using the OLS formula:

$$\widehat{\beta_t} = (X'X)^{-1}X'Y_t. \qquad (3)$$

Once the Nelson-Siegel factors are estimated for each country, the common "global" factors behind the co-movement of yields can then be derived. The global factors are unobserved and must be inferred from the data using statistical techniques. For example, Diebold et al. (2008) uses a statistical filtering method (a Kalman Filter) to estimate the unobserved global factors from a set of cross-country yields. However, the results from this approach are subject to significant uncertainty due to the need to estimate a large set of parameters. A more tractable approach to estimate the global factors is to use principal components analysis to extract the common element behind cross-country movements. Estimated this way, the first principal component refers to the weighted average of the time series of the yield curve factors that minimises the sample variation explained by idiosyncratic factors. To this end, we estimate the global yield curve factors as the first principal components obtained from the foreign country factors[4].

Finally, the macro-finance model can be specified and estimated using a VAR model. This model, with p lags, is of the form:

$$y_t = c + A_1 y_{t-1} + \cdots. + A_p y_{t-p} + u_t$$

where $y_t = (Global\ factors, Domestic\ factors, Macro\ variables)$ is a set of K time-series variables, A_i is a $(K \times K)$ coefficient matrix and u_t is an unobservable error term. We impose additional restrictions on the model to prevent any feedback from the New Zealand factors to the global factor, consistent with the construction of the global factors excluding New Zealand. The dynamics of the model can then be analysed using the domestic factors' forecast-error variance decompositions, as well as the impulse responses of the domestic factors to shocks in the global factors.

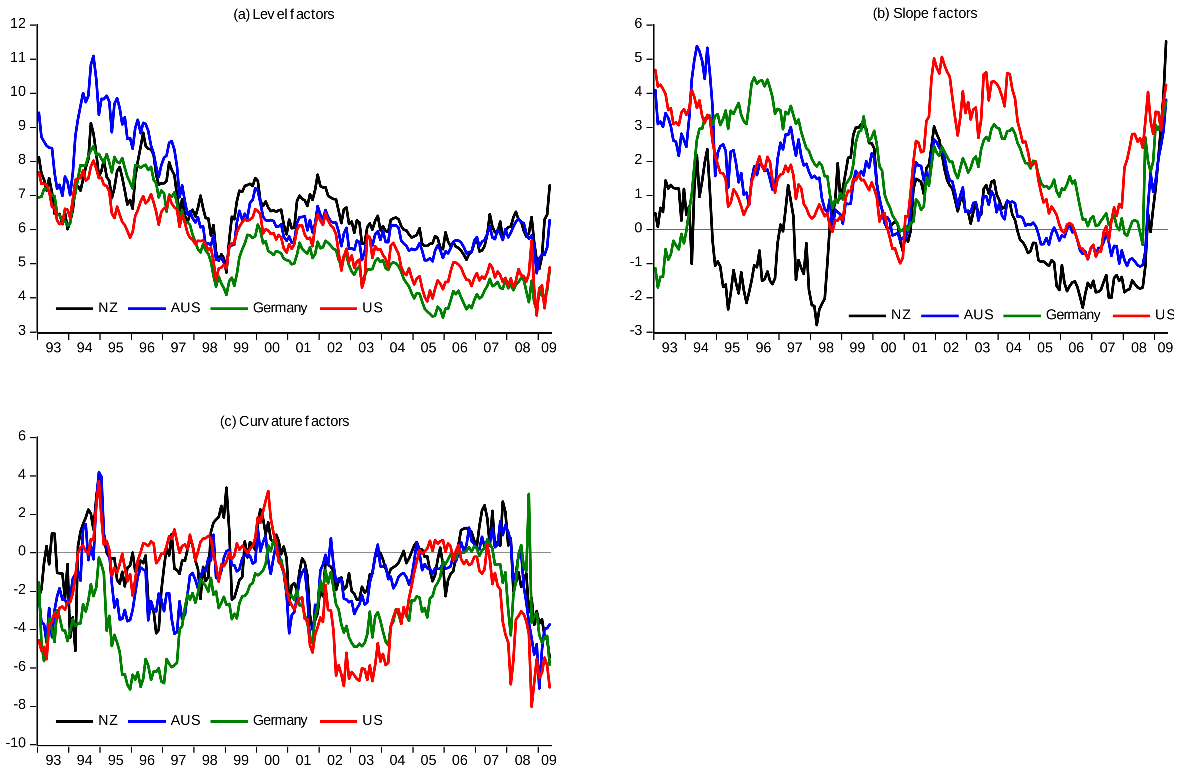
4 New Zealand is excluded from the principal components estimation as the global factors represent factors external to New Zealand.

4 Empirical Analysis

4.1 Estimation of the country factors

Applying this methodology, Figure 3 shows the estimated Nelson-Siegel country factors for a selection of countries over the sample period. Figure A2 in the Appendix shows the distributional characteristics of the yield curve factors for all countries considered.

Figure 3: Key countries' level, slope and curvature factors



Looking firstly at the country level factors (Figure 3a), one observation is that their evolution can be broadly characterised by two distinct periods: a period of steep decline from 1994 to 1998, and a decade of relative stability from 1998 to 2008. This characterisation likely reflects the adoption of stronger inflation-targeting in advanced economies over the mid-1990s.

As described previously, movements in the level factor reflect movements in the long end of the yield curve. These, in turn, are typically associated with expectations of future inflation (see Diebold et al., 2006; Ang and Piazzesi, 2003). As Krippner (2010) explains, the real purchasing power of a nominal payment in the future falls as inflation increases. This means that if inflation is expected to be high, nominal yields will need to be higher to maintain a stable real return. As returns over longer periods are more sensitive to the compounding impact of inflation as well as having a greater exposure to inflation risks, inflation expectations strongly affect longer yields, and with them, the level factor. The downward trend seen in New Zealand's level factor over the mid-1990s therefore likely reflects growing market confidence in the Reserve Bank's ability to maintain low and stable inflation following the formal adoption of inflation targeting at the beginning of the decade (Krippner, 2010).

The second observation about the countries' level factors is that the very ability to jointly characterise their movements into these periods reflects a strong tendency for them to move together. The factors are highly correlated, with correlation coefficients ranging from between 0.64 for New Zealand and Japan to 0.97 for Germany and Sweden. All the level factors also exhibit strong persistence over time. Looking at New Zealand, the level factor fluctuates around a median value of 6.4 percent and is less volatile than those of the other countries.

Looking next at the country slope factors (Figure 3b), we can see that slopes have been positive on average across the sample period, with New Zealand having the lowest average slope estimate over the sample[5]. This can mainly be attributed to two distinctly negative periods in New Zealand's slope factor, from 1994Q4 to 1998Q4 and 2004Q3 to 2008Q3. During these periods particularly tight monetary policy was used to control strong inflationary pressures and house price growth respectively, leading to expectations of downward interest rate movements and downward sloping yield curves. In all the countries, the slope of the curve increased sharply at the end of the sample, as central banks reacted to the impact of the Global Financial Crisis and lowered short-term interest rates relative to longer-term rates.

The slope factors also show a similar, albeit weaker, tendency for co-movement across countries as that seen in the level factors. The cross-country correlation coefficients for the slope factors range from 0.14 for New Zealand and Switzerland to 0.67 for Switzerland and Germany. These slightly lower correlations indicate that, as mentioned earlier, country-specific factors tend to play a greater explanatory role for the dynamics of shorter maturities than the longer-term level factors. Just as inflation expectations are commonly associated with movements in the level factor, real business activity is typically associated with the slope factor as the current state of economic activity strongly affects the near-term monetary policy stance (see Diebold et al., 2008). As Rudebusch and Wu (2003) interpret it, the level factor reflects the market's view of the central bank's underlying inflation target, while the slope factor reflects the central bank's response to the cyclical position of the real economy to achieve this medium-term target. As might be expected given the relative similarity in business cycles, New Zealand's slope factor has strongest correlation with the slope factors of Australia and the US.

The estimated curvature factors (Figure 3c) also exhibit some commonality. This is stronger than the slope factors but weaker than for the levels, with cross-country correlation coefficients ranging between 0.26 for the US and Japan to 0.77 for Sweden and Germany. It is difficult to meaningfully interpret the curvature factor as the literature is largely inconclusive on its economic interpretation. Diebold et al. (2006) finds that it shows little relation to any of the main macroeconomic variables.

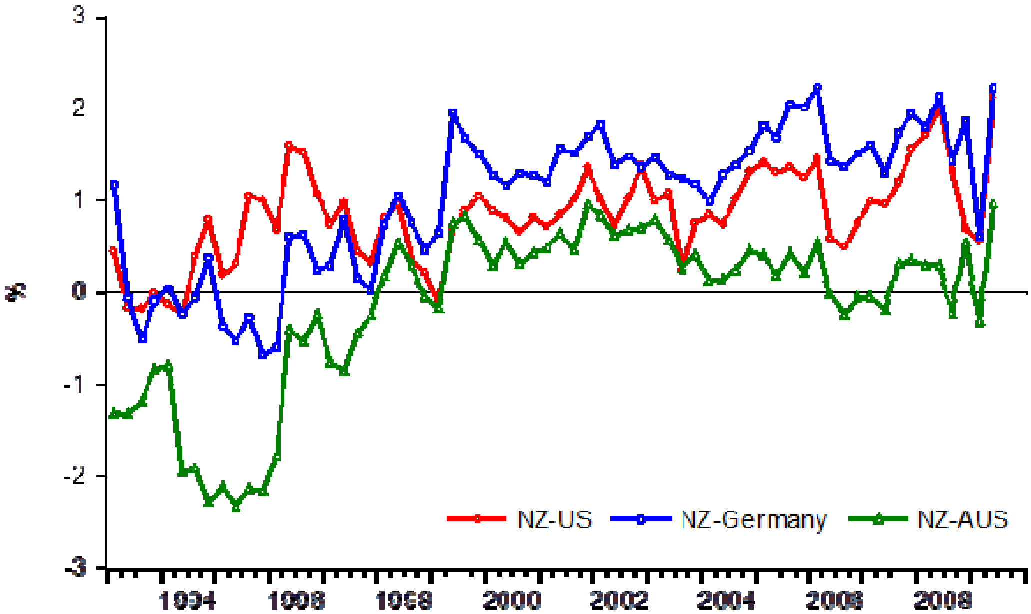
Finally, to test the fit of the estimated Nelson-Siegel factors, Figure A4 in the Appendix shows the fitted values from the Nelson-Siegel model applied to the New Zealand yield curves at a set of randomly selected dates. The fitted values closely follow the actual values, indicating that the model provides a good explanation of the sample variation in bond yields irrespective of the shape of the yield curve.

One additional feature of the estimated Nelson-Siegel factors that's worth mentioning is their illustration of a well-documented feature of New Zealand's interest rates since the late 1990s: the persistent positive differential of New Zealand yields relative to the US, Germany and Australia. Figure 4 shows New Zealand's level factor relative to the level

5 We have plotted the negative of the slope factor for easier interpretation. Therefore, negative (positive) slope coefficients indicate a downward (upward) sloping yield curve at each point in time.

factors of these countries. It can be seen that prior to the late 1990s, spreads were relatively volatile and negative compared with Germany and Australia. However, since 1997, spreads have been mainly positive, with median spreads relative to the US, Germany and Australia of approximately 120, 130 and 40 basis points respectively.

Figure 4: New Zealand's relative level-factor spreads



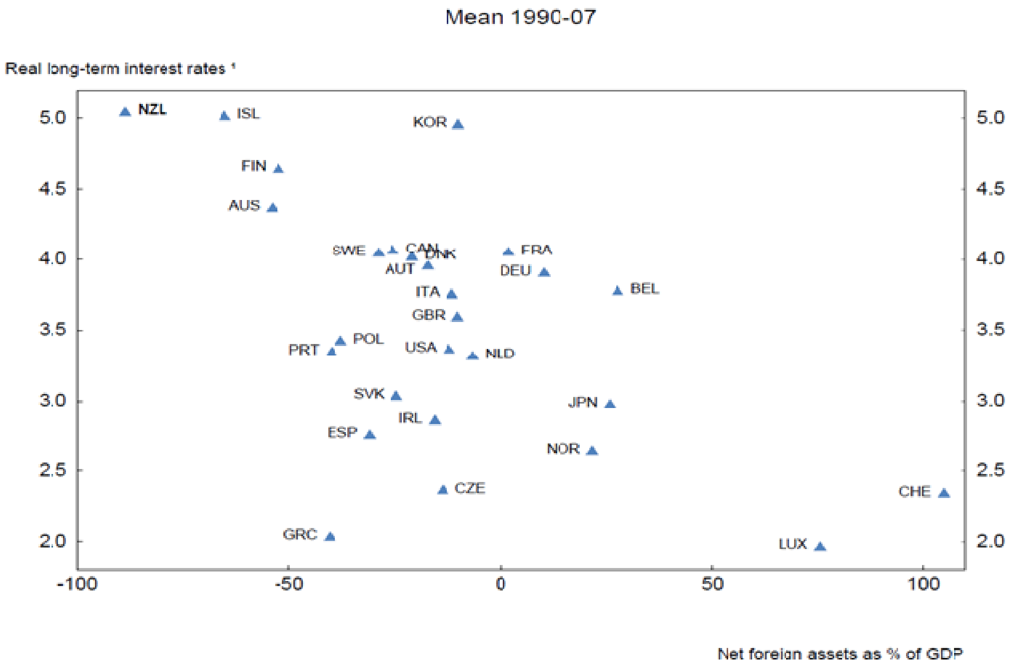
Several empirical studies have attempted to shed light on the likely determinants of these persistent interest rate differentials. Using a twenty-country data set spanning the period 1980-2004, Rose (2010) finds that interest rates are sensitive to net international investment positions (NIIP). He shows that countries with high net international liabilities such as New Zealand pay a premium to access international capital. His study also highlights the importance of country size for explaining national differences in interest rates, as fewer risk-spreading opportunities present in smaller economies leads investors to require higher rates of return to compensate for greater uncertainty about future returns.

The negative relationship between the NIIP and real interest rates has also been highlighted in both Cheung (2013) and Plantier (2003), both of which use a panel of OECD countries. Plantier (2003) finds that New Zealand's large negative net foreign asset position is responsible for the persistent gap in real interest rates, while also finding that government debt plays an important role in driving New Zealand's interest rate premiums.

However, it is important to note that despite the statistical significance reported in these studies, the estimated economic significance of the impact of changes in NIIP on interest rate differentials is generally fairly small. For example, the estimation results from Cheung (2013) indicate that a 10 percentage point increase in net foreign debt as a share of GDP is only associated with a 13 basis point increase in long-term real interest rates. Similar estimates are reported in the other studies mentioned.

In addition, the robustness of the findings that use cross-country panel data is likely to be influenced by several outlying observations. For example, the negative correlation between real interest rates and net foreign assets is strongly influenced by a small number of outlier countries (Figure 5). If Switzerland and Luxembourg are omitted from the sample due to their financial safe-haven status, the negative relationship would be much weaker[5].

Figure 5: Real interest rates and net foreign assets across countries (mean 1990-07)



Source: OECD (2013)

4.2 Estimating the global factors

Using the individual countries' Nelson-Siegel factors, we estimate common "global" factors — slope, curvature and level — by deriving the first principal components of the respective country factors. These global factors, which represent the underlying cross-country co-movements seen in Figure 3, are shown in Figure 6.

It can be seen that the global level factor exhibits a positive relationship with global inflation, particularly in the pre-crisis period. The steep decline following the Global Financial Crisis, on the other hand, is likely to be associated with the large increase in the US monetary base. The movements in the global slope and curvature factor are typically associated with the global business cycle, as proxied by the growth rate of G7 countries.

For illustrative purposes, Figure 7 shows the global level factor shown in Figure 6 but rescaled by the individual country factor loadings. This provides a proxy for the long-term world interest rate. It can be seen that the global rate closely tracks the rates of US and Germany, with sustained differences between the global rate and New Zealand and Australian rates.

5 We have reproduced this chart using an extended data covering 1990-2011. The results are very similar.

Figure 6: Global level, slope, and curvature factors

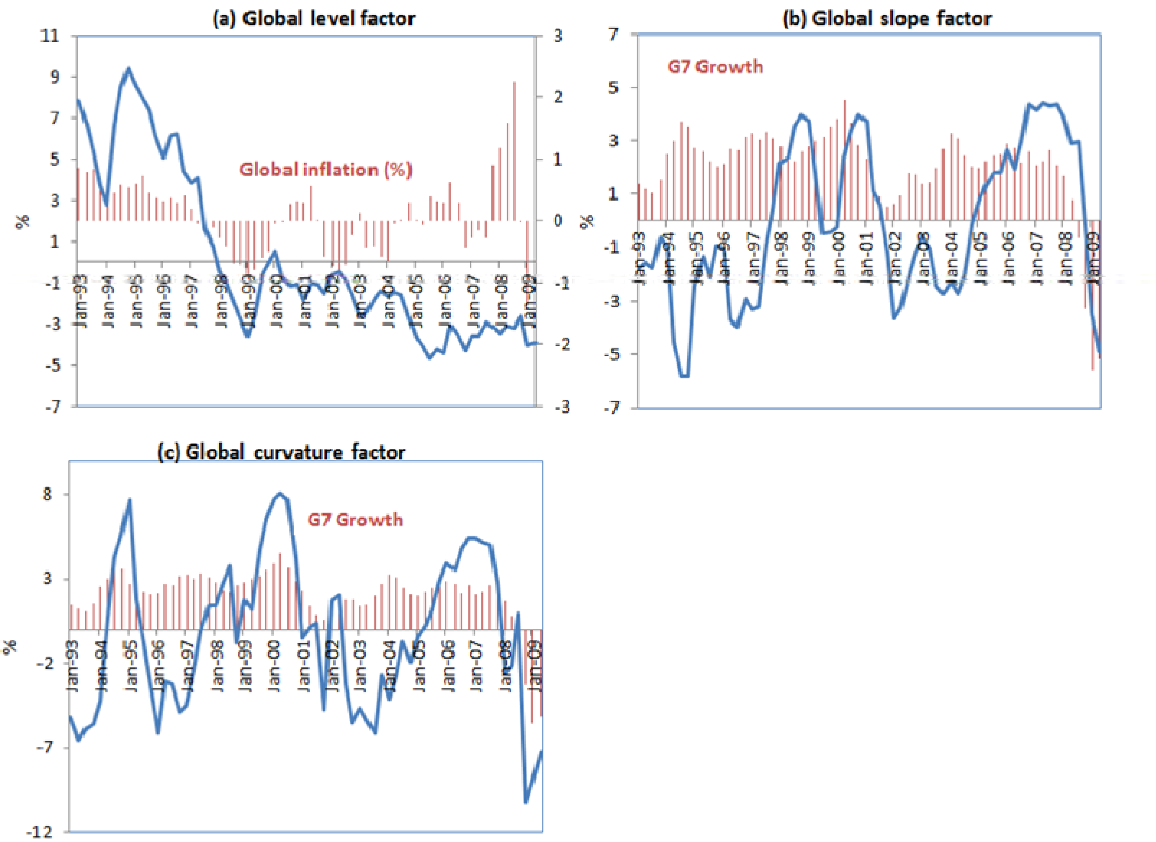
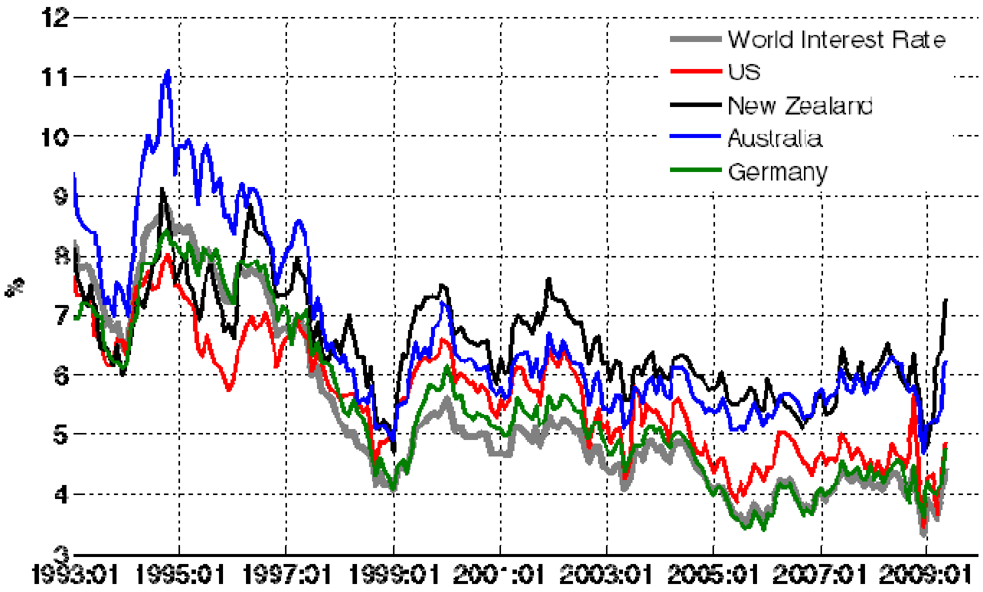


Figure 7: World interest rate vs. individual level factors



4.3 Estimating the yield-macro model

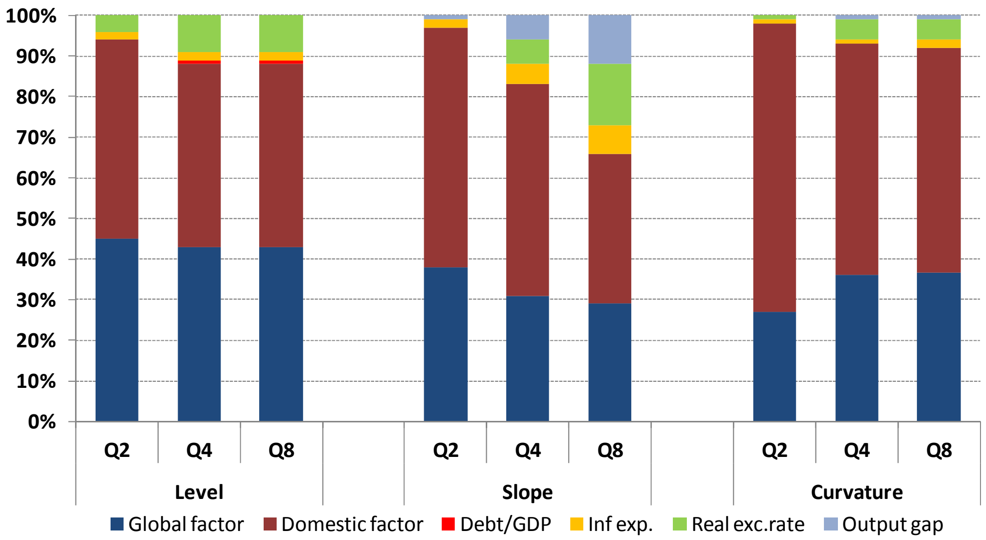
To analyse the dynamic effects of global and domestic influences on New Zealand's yield curve, we use a structural VAR model that includes the New Zealand factors jointly with their corresponding global factors and a range of domestic macroeconomic variables. Consistent with the literature, we include inflation expectations and the output gap as the conventional macroeconomic variables to capture inflation and real business activity. Also, given New Zealand's relatively high debt level and small open economy characteristics, we include the debt-to-GDP ratio and the real exchange rate. We then decompose the forecast-error variation of New Zealand's Nelson-Siegel factors into the parts driven by the global factors, undetermined domestic factors and, where possible, specifiable domestic macroeconomic variables.

For our baseline specification, we follow a recursive ordering and place the corresponding global factor as the first variable, followed by the corresponding New Zealand Nelson-Siegel factor and then domestic macroeconomic variables. This allows the New Zealand factors and macroeconomic variables to react to changes in the global factor, both contemporaneously and with lags. We order the Nelson-Siegel factors before the macroeconomic variables as they are dated as the first observation of the first month of each quarter. Furthermore, we restrict the model to prevent any feedback from the New Zealand factors to the global factor, consistent with the construction of the global factors as exogenous to New Zealand.

The formal statistical tests for stationarity reported in Appendix A3 suggest that the global and domestic level factors, debt-to-GDP ratio and real exchange rate variables are non-stationary in levels and stationary in first-differences. We therefore transform these variables into stationary series by taking their first differences.[6] We estimate the VAR using two lags based on the Akaike Information Criterion, which leaves no residual autocorrelation in the residuals.

The results of the forecast-error variance decomposition are presented in Figure 8.

Figure 8: Forecast error variance decomposition of New Zealand's yield curve factors



[6] As a robustness check, we also estimate the model in levels. This produced similar results.

While varying slightly across the three Nelson-Siegel factors, the global factors explain a significant proportion of the variation in New Zealand's domestic factors over both short and long horizons. This ranges from 30% of the variation of the slope and curvature factors to over 45% of variation in the level factor. The stronger influence of the global factor on the movement of New Zealand's level factor is consistent with the literature and the earlier examination of the country factors' co-movements. As described, this likely reflects the long-maturity nature of the level factor and the stronger control of New Zealand's monetary authority over shorter-term yields.

While the relative importance of these global components between factors is broadly consistent with other studies, the absolute size of the components is generally smaller. For example, as mentioned, Diebold et al. (2008) found that the global factor explained between 60% to 99% of the variation of the level factors for the countries considered in their study, and 15% to 95% of the slope factor movements. Given New Zealand's typically strong price-taker role in international markets, the smaller global influence for New Zealand's interest rates is slightly surprising. However, this could reflect factors such as the lower level of liquidity in the New Zealand government bond market relative to larger markets.

In terms of the drivers of the remaining domestic component, the majority is unable to be explained by any identifiable macroeconomic variable. Less than 10% of the variation in the level and curvature factors can be attributed to specific variables, increasing slightly for the slope factor at long horizons. Of these, inflation expectations explain consistently around 3% across each of the factors and forecast horizons. As expected, the output gap explains the largest proportion of variation in the slope factor, and the contribution of the debt-to-GDP ratio is negligible for each factor.

Unlike other studies, the real exchange rate is the macroeconomic variable found to play the single greatest role, explaining on average 6% of the variation across all three factors and across different forecast horizons. The impact of the exchange rate in influencing inflationary pressures may be greater for a small open economy such as New Zealand than for larger economies. In addition, the high proportion of non-resident investors in the New Zealand government bond market, who may be concerned about exposure to exchange rate risk, may also contribute to the role of the exchange rate in affecting the shape of the yield curve.

The remaining "domestic factor" consistently represents the largest component. However, it is important to note that this component represents the residual that can't be allocated to either global factors or any specific domestic variable.

For robustness, we have experimented with a range of other macroeconomic variables that may affect the dynamics of the New Zealand yield curve.[7] For the case of the VAR including the debt-to-GDP ratio, we find similarly small contributions when including the gross domestic saving rate, current account balance and net international investment position as percentages of GDP. However, it's worth noting that variables such as the debt-to-GDP ratio are likely to have a non-linear relationship with the level of interest rates that will not be captured by our model.

We conduct a further robustness check by changing the ordering of the variables in the VAR model, placing the domestic yield curve factors after the global factors and

7 Given our relatively short sample size, we have implemented this by swapping different variables one at a time while keeping the total number of variables in the VAR identical (i.e. five).

macroeconomic variables. Since this specification assumes that yield curve factors are affected by changes in the macroeconomic variables contemporaneously, we use average yields when deriving New Zealand's yield curve factors. While the results turn out to be qualitatively similar, the relative importance of the global factors in this specification is found to be more pronounced.[8]

Overall, these results are broadly in line with previous studies and highlight the importance of global factors on domestic yields. While domestic developments explain the greatest proportion of movements in New Zealand's yield curve, exogenous global developments contribute significantly.

4.4 Impulse response analysis

To further assess the influences upon the New Zealand yield curve, we analyse the dynamic responses of the yield curve factors to unexpected shocks in the global factors. To this end, we use an extended version of our baseline model that includes the three domestic yield curve factors together with the global factor and macroeconomic variables.

The three columns in Figure 9 show the responses of each variable in the model to a one standard deviation shock to the corresponding global factor, listed as the first chart in each column. The dotted lines represent the 90% confidence bands obtained using 1000 Monte Carlo simulations.

Looking first at a shock to the global level factor, these results show that a positive one standard deviation innovation, corresponding to an increase in the level of global interest rates by 0.86 percentage points, leads to a statistically significant increase in New Zealand's level factor by approximately 0.4 percentage points. The upward shift of the yield curve leads to smaller increases in both the slope and curvature factors, with responses that are relatively short-lived as they are modelled in first differences.

The rise in global and domestic level factors also flows through to the macroeconomic variables. The output gap increases, possibly due to the exchange rate decline , although the change is largely insignificant. Meanwhile, the response of inflation is positive and significant for approximately five quarters. This effect is highly persistent and consistent with the close relationship between inflation and the level of the yield curve, as well as the demand pressures arising from the positive output gap. The real exchange rate falls in response to the global level shock but the effect is not significant.

Looking next at a shock to the global slope factor, this has a broadly similar impact on the domestic Nelson-Siegel factors as a shock to the level factor, but with a more limited impact on the macroeconomic variables. A positive innovation to the global slope factor (i.e. a steeper yield curve) leads to statistically significant changes in all the domestic factors, with the positive impact on the domestic slope and level factors likely reflecting a flow through of global developments to expectations for New Zealand. The effects on the macroeconomic variables on the other hand are largely insignificant, with the exception of a slight decline in the exchange rate in the short run.

Finally, a positive innovation in the global curvature factor affects both the slope and curvature components of the New Zealand yield curve and leads to higher inflation, a larger output gap and a lower exchange rate.

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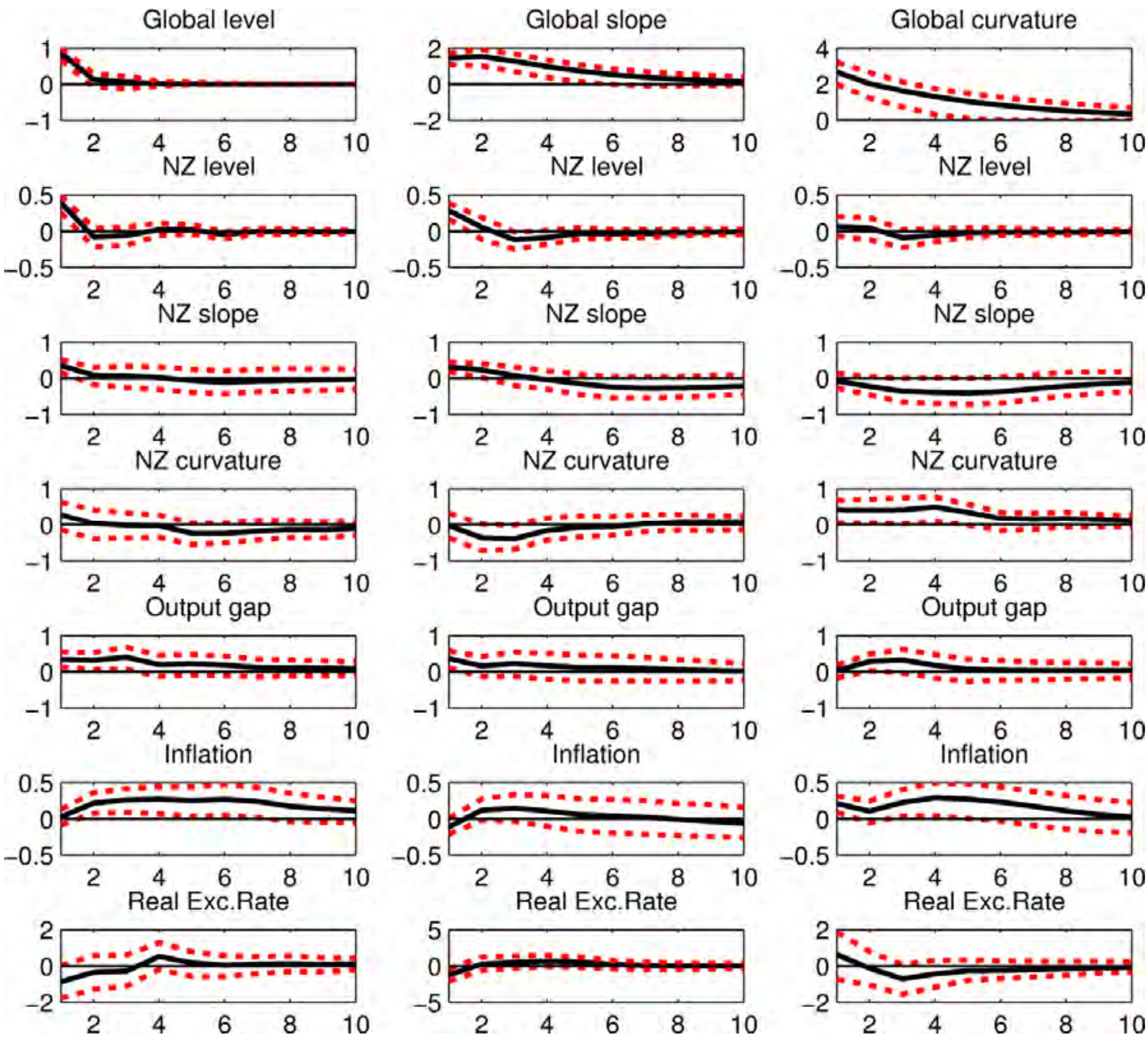
[8] Results are available upon request.

Overall, these statistically significant responses of New Zealand's yield curve factors to changes in the global factors reinforce the previous findings and confirms the importance of global developments for New Zealand's yield curve characteristics.

Figure 9: Impulse response functions for shocks to global factors



5 Conclusion

New Zealand's interest rates are strongly influenced by developments in global markets. This influence is likely to have strengthened over the past two decades as global financial linkages have continued to grow, a feature highlighted by previous studies.

In this paper, we have examined the factors influencing the yields on New Zealand government bonds using the Nelson-Siegel framework. This method has been applied to both the New Zealand government bond curve and to the equivalent bond curves in a set of countries with particular influence for New Zealand's interest rate markets.

We find that movements in the yield curve are generally highly correlated across countries, with developments in global markets having a significant influence on New Zealand's yield curve characteristics. Approximately half the movement in the level factor for New Zealand, which drives the yield curve at long maturities, is explained by the global level factor. Meanwhile, the global slope factor explains around a third of the movement in New Zealand's slope factor.

Of the remaining domestically driven components, it is difficult to identify a significant role for any specific domestic macroeconomic variable. Domestic variables tend to have a larger impact on the slope and curvature factors than the longer-term level factors, likely due to the tendency for shorter maturities to be more directly under the control of the domestic monetary authority. The output gap in particular is highly relevant in explaining the slope of the yield curve. Overall, these findings are broadly consistent with those of other studies.

The results can be used as a framework to model the response of the New Zealand government bond curve to various shocks. They could be used to forecast future movements in the curve, to simulate the impact of international and domestic shocks on New Zealand interest rates, and as an input for analysing the impact of macroeconomic shocks on investment portfolios. The results also provide a useful guide for monetary policy formulation by providing a clearer picture of the sources of the yield curve's movements and therefore appropriate policy responses. For example, for increases in interest rates driven by domestic factors a tightening of monetary policy settings may be required, whereas an increase in interest rates driven by global factors may lead to an unwarranted tightening in financial conditions and require looser monetary policy settings.

One possible implication of the results is that the rise in US long-term interest rates resulting from the eventual return to conventional monetary policy settings in the US is likely to be mimicked with increases in long-term interest rates in other advanced countries such as UK, Germany, Australia and New Zealand, regardless of the differences in the domestic monetary conditions in these countries.

There is considerable scope for further research. Firstly, a comparison could be done of whether the factors driving yields on government bonds are the same as those driving other domestic interest rates, such as swaps or mortgage rates. The swaps market is more liquid than the government bond market, so a comparison of the results between the two markets may provide insights into the extent to which the bond market results reported in this paper are explained by liquidity factors. Secondly, the link between the global yield curve factors and international macroeconomic variables could be modelled. This work could expand the structure of the model to allow for the impact of global macroeconomic variables on domestic macroeconomic conditions. In principle, this could then be used to forecast the global interest rate factors and provide an input into forecasts of New Zealand interest rates. Finally, further work could be carried out to try to explain the large unattributed component of the domestic factors.

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Appendix

Figure 10: Appendix A.1: Variable plots

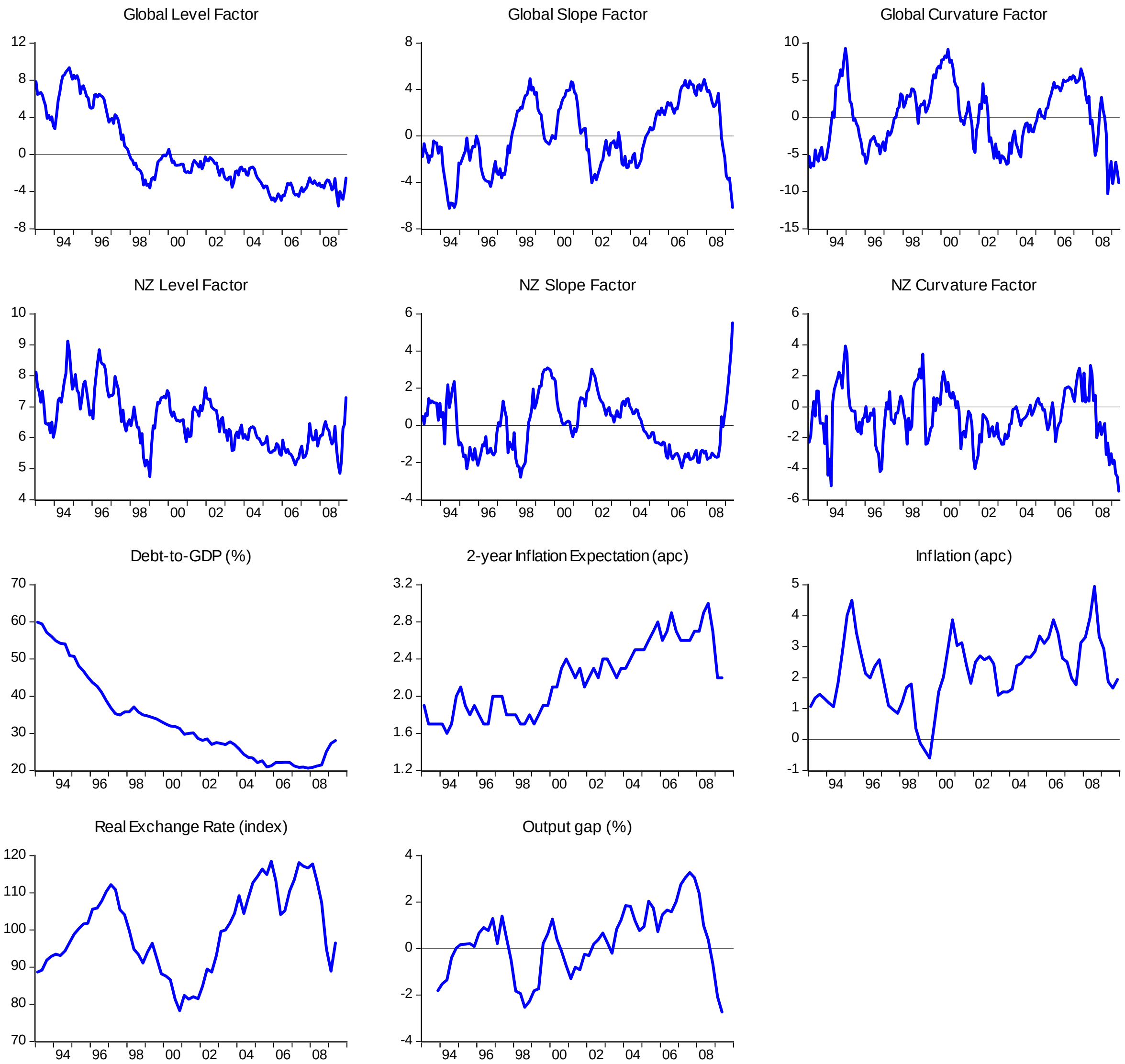

Figure 11: Appendix A.2: Descriptive statistics of the estimated NS factors

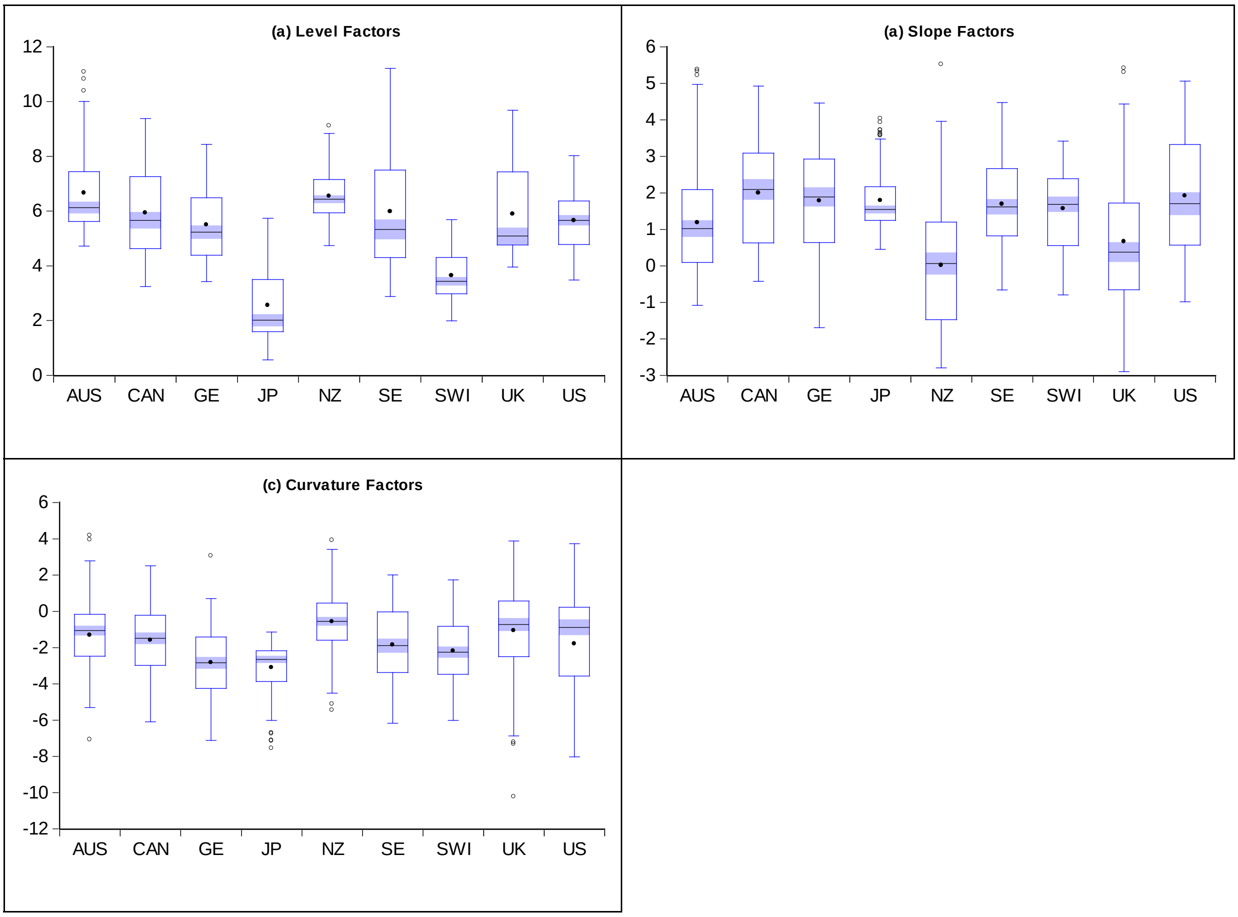

Table 1: Appendix A.3: Correlation coefficients among the yield curve factors

Level Factors

	AUS	CAN	GE	JP	NZ	SE	SWI	UK	US
AUS	1								
CAN	0.92	1							
GE	0.95	0.96	1						
JP	0.89	0.83	0.84	1					
NZ	**0.84**	**0.82**	**0.86**	**0.64**	1				
SE	0.96	0.96	0.97	0.89	**0.81**	1			
SWI	0.93	0.92	0.96	0.85	**0.82**	0.95	1		
UK	0.95	0.91	0.94	0.93	**0.76**	0.96	0.9	1	
US	0.87	0.93	0.91	0.79	**0.86**	0.89	0.88	0.84	1

Slope Factors

	AUS	CAN	GE	JP	NZ	SE	SWI	UK	US
AUS	1								
CAN	0.65	1							
GE	0.35	0.50	1						
JP	0.49	0.30	0.57	1					
NZ	**0.49**	**0.43**	**0.12**	**-0.14**	1				
SE	0.31	0.42	0.74	0.36	**0.28**	1			
SWI	0.17	0.45	0.84	0.28	**0.14**	0.60	1		
UK	0.76	0.68	0.42	0.51	**0.36**	0.35	0.27	1	
US	0.50	0.75	0.17	-0.13	**0.56**	0.12	0.25	0.61	1

Curvature Factors

	AUS	CAN	GE	JP	NZ	SE	SWI	UK	US
AUS	1								
CAN	0.54	1							
GE	0.60	0.58	1						
JP	0.28	0.11	0.57	1					
NZ	**0.68**	**0.56**	**0.42**	**0.13**	1				
SE	0.63	0.62	0.78	0.38	**0.48**	1			
SWI	0.49	0.57	0.68	0.24	**0.44**	0.66	1		
UK	0.59	0.54	0.48	0.24	**0.45**	0.63	0.58	1	
US	0.46	0.71	0.28	-0.26	**0.49**	0.42	0.43	0.59	1

Table 2: Appendix A.3: ADF unit root test results (Null: variable has a unit root)

	t-Stat	P-Val
Global level	-1.3796	0.5867
Global slope	-2.6255	**0.0094***
Global curvature	-2.6619	**0.0085***
NZ level	-2.6616	**0.0865****
NZ slope	-2.7258	**0.0071***
NZ curvature	-2.5716	**0.0109***
Debt to GDP ratio	-0.1483	0.9929
2-year inflation exp.	-1.4611	0.5467
Inflation	-1.2364	0.1966
Output gap	-2.8871	**0.0046***
Real exchange rate	-1.8473	0.3548

(and ** denote the rejection of the null at 5% and 10% levels respectively)*

Figure 12: Appendix A.4: Actual and fitted yield curves for New Zealand