

The Effect of Monetary Policy on the New Zealand Dollar: a Bayesian SVAR Approach

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1. Introduction

As a small open economy, New Zealand is susceptible to fluctuations in the exchange rate in both domestic prices and economic activities. Understanding the responses of exchange rate to monetary policy shocks is important to the monetary policymakers. Along with pursuing price stability as a key objective, the Policy Targets Agreement introduced in December 1999 thus requested the Reserve Bank of New Zealand to “...seek to avoid unnecessary instability in output, interest rates and the exchange rate”. Motivated by its importance, this chapter greatly contributes to the literature of monetary policy – exchange rate analyses for New Zealand, which has been rather scant, by using the Bayesian structural vector autoregression (SVAR) approach to re-examine the impact of monetary policy shocks on exchange rate of New Zealand dollar (NZD) against US dollar (USD).

The theory of uncovered interest parity (UIP) is the central block in macroeconomic models connecting the expected changes of exchange rate to the interest rate differentials. As the domestic central bank tightens monetary supply, the UIP theory implies a greater appreciation of domestic currency in the short-run than its long-run level, the so-called overshooting phenomenon. Despite its popularity, the UIP validity has been strongly challenged by empirical evidence, including mine. I estimate an SVAR for five variables of the US and New Zealand money market rates, stock prices, and the bilateral nominal exchange rate, using the Bayesian approach introduced by Baumeister and Hamilton (2015) by explicitly imposing prior information on the structural parameters. By doing so, I am transparent about the influence of prior information on posterior results. The findings show that an unexpected increase in New Zealand’s short-run interest rate causes a contemporaneous appreciation of NZD against the US dollar (USD) and even stronger NZD in the long-run than prior to the shock.

The central problem in investigating the interest rate – exchange rate relationship is the endogeneity of the variables. The biggest contribution of this chapter is to employ stock prices and the co-movements between interest rates and stock prices to untangle the unexpected

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monetary policy shocks from other shocks that simultaneously affect interest rates and exchange rate, including economic news shocks and currency premium shocks. A surprised monetary policy tightening is associated with higher short-term interest rates and lower stock prices whereas a positive economic news shock likely results in increases in both stock prices and interest rates to stabilize economic growth and inflation. A positive currency risk premium shock, for example, capital flow episodes into New Zealand which lead to NZD appreciation as defined in this chapter, may damage exports and domestic stock prices and encourage the central bank to lower interest rate.

Existing studies have employed various identification approaches to analyse the impacts of monetary policy shocks, largely focusing on unexpected interest rate changes, on exchange rate movements. The first is event-study approach. To isolate the surprise from anticipated monetary policy shocks, a number of papers look at very short windows, for example, in minute, day, or intra-day windows around the central banks' announcement or communication events for the variations of exchange rates. This approach of using high-frequency data is popular in examining the responses of asset prices to monetary policy shocks. For instance, Zettelmeyer (2004) focuses on (immediate but dynamic) responses of exchange rates to the shocks associated with specific policy actions, such as changes in official interest rates or the overnight rate targets, and uses the reactions of market rates as measures of the unanticipated component of the actions. From both OLS and instrumental variable (IV) regressions across the sample of Australia, Canada, and New Zealand during the 1990s, he finds that a 1% increase in the 3-month interest rate appreciates the exchange rate by 2–3%. Later, Kearns and Manners (2006) additionally add the United Kingdom into their 4-country sample and also use the changes of market rates to measure the surprise component of monetary policy reactions. They use instead intraday data – a 70-minute event window – to eliminate the events jointly affecting both interest rate and exchange rate. The studied periods vary across the four countries; the included events for New Zealand occurred during the 17/3/1999 – 10/6/2004 period. The average results for the four countries show that the exchange rate appreciates by around 0.35% to a surprising 25-basis-point increase in the policy interest rates. More recently, Rosa (2011) also uses intraday data with 30- and 60-minute windows for five currencies (the exchange rate of USD against the euro, the Canadian dollar, the British pound, the Swiss franc, and the Japanese yen) and finds a greater impact of the Federal Open Market Committee's monetary policy surprises on exchange rates. On average, the USD exchange value depreciates by 0.5% in response to an unanticipated 25-basis-point cut in the Federal Funds target rate.

Another approach is the identification through heteroscedasticity (ITH), which was first introduced by Rigobon (2003). The idea of this approach is that, to solve the identification problem in simultaneous-equation models, i.e., when the structural estimators must be recovered from the reduced parameters and there are fewer equations than the number of unknown parameters, I need to impose additional information or restrictions. Instead of the exclusion, sign, short-run, and long-run restrictions, which are traditional in the literature, Rigobon (2003) proposed to use the heteroscedasticity of the structural shocks across regimes (or subsamples) contained in the data to add more equations into the system, while keeping other aspects of the structure identical including the assumption of uncorrelated structural shocks. By using the difference in the variance of residuals of the structural equations across regimes, the system is exact-identified. Ehrmann, Fratzscher, and Rigobon (2011), for example, employ the ITH approach to examine the financial linkages between the US and the euro area money markets, bond markets, equity markets, and foreign exchange markets. They estimate a structural system using 2-daily windowed data over 1989-2008 of the US 3-month Treasury bill rate, the US 10-year Treasury bond rate, the S&P 500 index, the 3-month interbank rate (the FIBOR rate before 1999 and the EURIBOR after 1999), the German 10-year government bond, and the S&P Euro index. Other variables are included to control for economic news in the US and the euro area, and oil price changes. This chapter is more related to Ehrmann, Fratzscher, and Rigobon (2005)'s working paper version, estimating the changes instead of levels of the variables. In any case, they compute the rolling windows variances of 20 two-day observations for each variable, i.e., each asset variable is multifactor modeled and a heteroscedasticity regime is identified if at least 16 observations for which the relative variances of at least one asset returns are larger than their average value plus one standard deviation. Then they use the estimated covariance matrices of 7 out of 28 identified heteroscedasticity regimes to generate new data in each bootstrap replication, and choose the estimators to minimize $g'g$ with $g = A' \sum_i A - \Omega_i$, where A is the structural matrix capturing the contemporaneous interactions of the variables, \sum is the variance of the structural shocks, and Ω is the variance-covariance matrix estimated in each regime i . As leaving the impact of interest rate on exchange rate unrestricted, they find in the Ehrmann et al. (2005) version that, on average, a 1% increase in the short-term interest rate lead the USD to appreciate by 3.698% against the euro. Their results also stress the existence of international spillover effects within as well as across asset classes and asset prices are more responsive to domestic asset price shocks rather than to international shocks.

Other studies such as Sims (1992), Eichenbaum and Evans (1995), and Karim, Lee, and Gan (2007) rely on the SVAR recursive Cholesky approach to identify monetary shocks and the responses of exchange rates. The exchange rate effects of monetary shocks are ambiguous, however. Sims (1992), for example, finds evidence of exchange rate puzzle with large and persistent domestic currency depreciation for France and Germany following interest rate increases. By contrast, a responding pattern consistent with the theory, i.e., monetary policy contraction raises the value of domestic currency, is found for Japan, the UK, and the US. Similarly, Eichenbaum and Evans (1995) show that a US monetary policy contraction, identified as the shocks to either the Federal Funds rate, the ratio of non-borrowed to total reserves, or the Romer and Romer index of monetary policy, leads to persistent and significant appreciation of the USD. In a study for New Zealand, Karim et al. (2007) also apply the SVAR with Cholesky decomposition method, which imposes a recursive ordering on the structural model, for an 8-variable system including foreign output, non-oil commodity price index, consumer price index, and bank rate which are placed before New Zealand block of output, consumer price index, effective exchange rate, and official cash rate. Using a quarterly data sample covering the 1985Q1-2003Q4 period across four major partners of New Zealand including Australia, Japan, the US, and the UK, they find no evidence of exchange rate puzzles. Both nominal and real effective exchange rates of NZD are found to appreciate immediately and depreciate subsequently to an unexpected monetary policy contraction. The responses in all cases are insignificant, however. Besides, they find a modest role of the monetary policy shocks (from 0.2 to 3%) to explain the variations of exchange rates of NZD.

Cushman and Zha (1997) argue that the recursive approach to monetary policy identification while being plausible for the US studies because the movements in the US interest rates are less likely affected by foreign shocks are less valid for smaller and open economies. The central banks in such economies more likely to adjust interest rates to respond to foreign markets, thus invalidating the assumption of independent interest rates and generating puzzling exchange rate responses to interest rate changes. Cushman and Zha (1997) emphasize the need of using appropriate procedures to identify monetary policy shocks in smaller and open economies than the US. They propose a structural non-recursive approach with zero restrictions for Canada, i.e., a structural VAR model with block exogeneity, allowing monetary policy to react contemporaneously to a range of foreign and domestic variables whose data is available immediately to the policymakers and vice versa. The structural parameters in their system reflecting simultaneous relations will become zero in the recursive Cholesky approach. They

identify monetary policy shocks as the changes in the money stock and find evidence consistent with the standard theory: a decline in monetary stock is followed by an immediate and significant Canadian dollar appreciation. Kim and Roubini (2000) also use the non-recursive SVAR approach for monthly data from 7/1974 to 12/1992 for non-US G7 countries whose exchange rates (against the USD) are found to appreciate initially and gradually depreciate after a few months following a monetary contraction. In their study, monetary policy shocks are identified by modeling money supply as a response function of monetary authorities, exchange rate, world oil price, price level, and the US Federal Funds rate.

Another SVAR approach is proposed to impose sign restrictions on structural coefficients (for example, see Kim and Lim (2018)) and/or lagged coefficients such that the signs of impulse responses reflect strong expectations established in the literature. This traditional approach was criticized by Baumeister and Hamilton (2015) for not being agnostic as described, only delivering an identification set that satisfies the imposed sign restrictions, thus limiting the possible distributions. Baumeister and Hamilton (2015) emphasize the need to explicitly acknowledge how the informative priors affect the structural estimation, which makes the Bayesian approach an unambiguous improvement in comparison to the traditional frequentist approach. The Bayesian approach yields a posterior distribution for the structural parameters and other objects of interest such as impulse response functions, which are consistent with the traditional sign-restricted SVAR and handy to check their sensitivity to the imposed priors. In this sense, this chapter serves as a contributor to the scant literature of examining the effect of monetary policy on exchange rate of NZD against USD by using the Bayesian SVAR approach, transparently combining sign restrictions where intuitive and prior modes from existing studies. This study is most close to Grisse (2020), which is the very first paper applying the Bayesian method for the Switzerland case. They find strong evidence to support the UIP theory that the exchange rates of Swiss franc (against euro and USD) overshoot on impact and depreciate in the following weeks after the increases in Swiss short-term interest rates.

The remainder of this chapter proceeds as follows. Section 2 introduces the theoretical motivation. Section 3 presents the empirical framework and data used to examine the effects of New Zealand monetary policy shocks on exchange rate of NZD against the USD. Section 4 reports the results. Section 5 extends the study by relaxing several restrictions in the baseline model. Section 6 concludes.

2. Theoretical motivation

One of the contributions of this chapter is to employ stock prices to disentangle monetary policy shocks from other shocks that jointly drive interest rates, stock prices, and exchange rate including economic news shocks and currency premium shocks. First, I present below the traditional equations linking interest rates, stock prices, and exchange rate as the motivation for my empirical framework. Then I will discuss the related empirical findings, providing useful information for the chosen priors.

Impact of interest rate on exchange rate

Uncovered interest parity is the cornerstone condition for macroeconomic analysis of small open economies. According to the UIP, the basic equilibrium condition of the foreign exchange market is:

$$i_t - i_t^* = E_t(\Delta e_{t+1}) + \rho_t \quad (1)$$

, where i_t and i_t^* are the short-term domestic and foreign interest rates, respectively, $E_t(\Delta e_{t+1})$ is the expectation of percentage change in nominal exchange rate of domestic currency against foreign currency ($E_t(\Delta e_{t+1}) = e_{t+1} - e_t$; e_t, e_{t+1} in natural logarithm form; higher e refers to domestic currency appreciation in this chapter), and ρ_t is a risk premium. Equation (1) predicts that, when risk premium is very small, a rise in domestic short-term interest rate relative to foreign interest rate should be associated with domestic currency appreciation.

Equation (1) can be rewritten as:

$$e_t = e_{t+1} - (i_t - i_t^*) + \rho_t \quad (2)$$

Solving equation (2) using forward-looking rational expectations (i.e. the law of iterated expectation) after n repeated substitutions to get:

$$e_t = E_t(e_{t+n+1}) - \sum_{j=0}^n E_t(i_{t+j} - i_{t+j}^*) + \sum_{j=0}^n E_t(\rho_{t+j}) \quad (3)$$

Equation (3) tells us three possible transmission channels through which monetary policy can influence today's exchange rate: market expectations of future exchange rate (the first term), market expectations of interest rate differentials (the second term), and market expectations of future risk premia (the last term). The first-difference of equation (3) says that a tighter domestic monetary policy should be associated with exchange rate appreciation. The predictions from equations (1) and (3) tell us about the overshooting phenomenon, i.e., the

short-run response of exchange rate appreciation is greater than its long-run response when the domestic central bank tightens monetary supply.

Impact of interest rate on stock price

Understanding the effects of monetary policy changes on asset prices is crucially important to monetary policymakers. The most direct and indirect impacts of monetary policy innovations are on financial markets, which in turn affect the macroeconomic volatility, thus understanding these transmission mechanisms will help monetary policymakers react appropriately to achieve the ultimate objectives. In this subsection, I begin with equation (4) below to show the theoretical mechanism of interest rate's influence on stock price, and will discuss the related empirical findings on the interactions of monetary policy and asset prices shortly:

$$R_{t+1} \equiv \frac{P_{t+1} + D_{t+1}}{P_t} \quad (4)$$

, where R_{t+1} is ex-post stock market return, P_t and P_{t+1} are stock prices at time t and $t+1$ respectively, and D_{t+1} is the dividend from time t to time $t+1$. Taking the logarithm of both sides of equation (4), deriving a log-linearization approximation to the logarithm, then solving forward for n repeated substitutions, and decomposing ex-post return into excess return and short-term interest rate ($er_t \equiv r_t - i_t$), I get:

$$p_t \approx \sum_{j=0}^n \rho^j \kappa + \rho^{n+1} (E_t p_{t+n+1} - E_t d_{t+n+1}) - \sum_{j=0}^n \rho^j E_t (er_{t+j+1} + i_{t+j+1}) + \left[\sum_{j=0}^n (1 - \rho) \rho^j E_t d_{t+j+1} + \rho^{n+1} E_t d_{t+n+1} \right] \quad (5)$$

, where p_t , r_t , d_t are logarithms of the stock price, return, and dividend respectively; κ and ρ are parameters with $\kappa > 0$ and $0 < \rho < 1$. In the right-hand side of equation (5), the first term is a constant, and the second term, i.e., expected price-dividend ratio, will approach some equilibrium value when n is sufficiently large. The last two terms suggest two channels through which conventional monetary policy shocks can affect stock prices. First, a higher interest rate depresses stock prices by increasing the risk-free components of discount rate and hence a lower present discounted value of dividends (the third term). Second, an increasing interest rate should be associated with a deteriorating growth outlook and thus lower expected dividends (the last term).

Examining the interactions between asset prices and monetary policy has been standing as an attractive topic in the empirical literature. Rigobon & Sack (2003, 2004) examine both sides of

the interactions using the heteroscedasticity identification approach. Rigobon and Sack (2003) point out two channels including wealth and the financing cost to businesses through which stock price movements impact the US macroeconomy and thus determine monetary policy decisions (as equity accounts for a large proportion of the US households' total financial wealth and non-financial corporations' assets). Using the daily US data for the 3-month Treasury bill rate and the return on the S&P 500 index from 3/1985 to 12/1999, they find that a 5% unexpected increase in the S&P 500 index increases the Federal Funds rate by about 14 basis points, i.e., 1% increase in the S&P 500 index increases the Federal Funds rate by 0.021%. Rigobon and Sack (2004) study the other side of the relationship, i.e., the impact of monetary policy on asset prices, by implementing the heteroskedasticity identification as IV and generalized-method-of-moments (GMM) regressions using a variety of stock market indices and longer-term interest rates from 03/01/1994 to 26/11/2001. The IV and GMM estimators are very close in magnitude, in particular, a 1% increase in the short-term interest rate causes the S&P 500 index to decline by 6.81% (for the IV estimator) and 7.19% (for the GMM estimator). Motivated by the same question of stock market' responses to monetary policy, Bernanke and Kuttner (2005) use the event-study approach to show that, for the period from 06/1989 to 12/2002, an unexpected 1% easing in the Federal Funds target rate is associated with an approximate 4.68% increase in broad stock indices. They also find that the predominant effects of monetary policy on the stock market come through expected future excess equity returns. The negative impact of monetary tightening on equity prices are in line with Claus, Claus, and Krippner (2018), quantifying the responses of a variety of the US asset price indices to conventional and unconventional monetary policy shocks separately by using a latent factor model with heteroscedasticity identification for monetary and non-monetary policy event days.

3. Empirical framework and data

3.1. Empirical framework

Based on equations (3) and (5), I construct the following equations in the linear empirical model, temporarily excluding lagged terms and constant:

$$i_t^* = \alpha_s^* s_t^* + u_t^{i^*} \quad (6)$$

$$s_t^* = \beta_i^* i_t^* + u_t^{s^*} \quad (7)$$

$$i_t = \alpha_{i^*} i_t^* + \alpha_{s^*} s_t^* + \alpha_s s_t + \alpha_e e_t + u_t^i \quad (8)$$

$$s_t = \beta_{i^*} i_t^* + \beta_{s^*} s_t^* + \beta_i i_t + \beta_e e_t + u_t^s \quad (9)$$

$$e_t = \gamma_{i^*} i_t^* + \gamma_{s^*} s_t^* + \gamma_i i_t + \gamma_s s_t + u_t^e \quad (10)$$

, where i_t^* and i_t are the US and New Zealand short-term interest rates, respectively; s_t^* and s_t are the US and New Zealand stock price indices; and e_t is nominal exchange rate of NZD against USD, i.e. an increase in exchange rate implies NZD appreciation. As a conventional monetary policy operates by changing short-term interest rate, the structural residuals $u_t^{i^*}$ and u_t^i in equations (6) and (8) are interpreted as the US and New Zealand monetary policy shocks. A positive monetary policy shock, i.e., monetary tightening, is expected to move interest rates up and stock prices down. The last terms in equations (7) and (9), $u_t^{s^*}$ and u_t^s , can be interpreted as the US and New Zealand economic news shocks which are expected to cause interest rates and stock prices to move in the same direction. In equation (10), u_t^e is interpreted as currency premium shock, reflecting the shocks to financial risk premia unrelated to monetary policy and economic news shocks. As government bonds provide a hedge against the shocks which make stock investment risky, a positive currency premium shock, which leads to NZD appreciation as defined in this chapter, lowers both stock and bond prices. To cover up, interest rates and stock prices co-vary in the same direction to positive economic news shocks and currency premium shocks but negatively to positive monetary policy shocks. The way I identify the monetary policy shocks by employing the co-movements of interest rates and stock prices in response to monetary policy shocks, economic news shocks, and currency premium shocks are in line with the literature, for example, see Matheson and Stavrev (2014), Cieslak and Schrimpf (2019), and Jarociński and Karadi (2020). These papers, however, use high-frequency co-movements of interest rates and stock prices around the communication events by central banks to isolate the unexpected policy shocks from other shocks contained in the central banks' announcements or communication. The non-monetary policy shocks are defined as economic news shocks by Matheson and Stavrev (2014), as news about economic growth and news affecting financial risk premia by Cieslak and Schrimpf (2019), and as "central bank information shocks", i.e., the way the central banks assess economic outlook, by Jarociński and Karadi (2020).

In equations (6) and (7), I also assume that the US economic conditions do not immediately respond to those in New Zealand. In equation (8), the response of New Zealand interest rate, apart from taking into account the US interest rate, follows the Taylor rule, subject to the growth condition, inflation, and exchange rate. I also describe the initial expectations on the contemporaneous impacts; some of the sign expectations will be relaxed in the baseline model and robustness checks. An increasing domestic stock price may reflect an expected favorable

economic growth, which is usually associated with a higher inflation rate and thus a higher interest rate ($\alpha_s, \alpha_s^* > 0$). If the net effect from exchange rate appreciation on exports and imports is negative, I also expect a lower economic growth rate and inflation, and thus a loosening monetary policy ($\alpha_e < 0$). In equations (7) and (9), higher interest rates should be associated with lower stock prices ($\beta_i, \beta_i^* < 0$). Similarly, for equation (9), I expect a negative impact of exchange rate appreciation on exports and domestic stock price ($\beta_e < 0$). Equation (10) is motivated by equation (3), implicitly assuming that today's interest rate is a linear function of expected interest rates. Equation (3) implies that a higher domestic (foreign) interest rate should be associated with domestic currency appreciation (depreciation), i.e. $\gamma_i > 0$ and $\gamma_{i^*} < 0$. Similarly, a higher domestic (foreign) stock price indicates an improved economic growth in the domestic (foreign) country and thus domestic currency appreciates or $\gamma_s > 0$ (depreciates or $\gamma_{s^*} < 0$). I also assume a co-movement of domestic and foreign interest rates ($\alpha_{i^*} > 0$) based on historical data plotted in Figure 1 (left panel) and stock prices ($\beta_{s^*} > 0$) based on Figure 2 (left panel).

I proceed with the SVAR specification as follows

$$Ay_t = b_0 + \sum_{l=1}^m B_l y_{t-l} + u_t \quad (11)$$

, where y_t is the $(n \times 1)$ vector of endogenous variables, the objects A and B_l are $(n \times n)$ matrices of structural and lagged coefficients, b_0 is the $(n \times 1)$ vector of constants, u_t is the $(n \times 1)$ vector of structural shocks with u_t assumed to be normally distributed $u_t \sim N(0, D)$ and the covariance matrix D being diagonal, and m is the number of lags. Specifically, $y_t = (i_t^*, s_t^*, i_t, s_t, e_t)'$, $u_t = (u_t^{i^*}, u_t^{s^*}, u_t^i, u_t^s, u_t^e)'$, and

$$A = \begin{bmatrix} 1 & -\alpha_s^* & 0 & 0 & 0 \\ -\beta_i^* & 1 & 0 & 0 & 0 \\ -\alpha_{i^*} & -\alpha_{s^*} & 1 & -\alpha_s & -\alpha_e \\ -\beta_{i^*} & -\beta_{s^*} & -\beta_i & 1 & -\beta_e \\ -\gamma_{i^*} & -\gamma_{s^*} & -\gamma_i & -\gamma_s & 1 \end{bmatrix}$$

In the estimation, i_t^* and i_t are the first-differences of the US and New Zealand short-term interest rates; s_t^* and s_t are the log-differences of the US and New Zealand stock price indices; and e_t is the log-difference of NZD nominal exchange rate against the USD. The very first prior information imposed in the structural matrix A is that New Zealand economic conditions do not affect those in the US in the same week and this is reflected in the upper right block of zero in the matrix A . In the baseline model, I also follow the literature by assuming no international cross-market spillover effects, i.e., the US stock market (interest rate) has no

impact on the New Zealand interest rate (stock market), or $\alpha_{s*} = \beta_{i*} = 0$.² This assumption will be relaxed later. Without further assumptions, the structural model in equation (11) is unidentified. There are 17 parameters to be estimated, including 12 unknown parameters in the matrix A and 5 diagonal elements in the covariance matrix D of the structural shocks while I have only 15 known unique elements in the (5×5) variance-covariance matrix of the reduced-form residuals. To exactly identify the model, one needs at least two more equality restrictions. In this study, I proceed with the Bayesian approach by following Baumeister and Hamilton (2015), specifying a full prior distribution rather than just sign and zero restrictions for the unknown structural parameters to get a set identification. In particular, the prior information is imposed on the elements in the matrix A , not the inverse matrix (A^{-1}) . I will discuss the chosen priors in more detail in the next section.

3.2. Data description

The “raw” data includes the US 3-month Treasury bill rate, the S&P 500 index, the New Zealand 3-month Bank bill rate, the NZSE index, and the nominal bilateral exchange rate of NZD against the USD; all in daily frequency. The sample covers the period from 03/01/1999, when data on the NZSE series started being available, to 18/09/2020. I use weekly data based on the final trading day of the week to avoid the different daily timestamps across the markets. I believe that data of higher frequency (such as daily) contain too much noise whereas data of lower frequency (such as monthly or quarterly) may mute too many variations in stock prices and exchange rates. Appendix Table A.1 describes data sources in more detail.

For monetary policy reference rates, as the market rates are longer and are more subject to change than the target rates, I choose the US 3-month Treasury bill rate and New Zealand 3-month Bank bill rate instead of the Federal Funds rate and New Zealand Official Cash rate. The left panel in Figure 1 shows that the target rates are relatively stable, especially the New Zealand Official Cash rate, compared to the market rates. For example, the Official Cash rate was fixed at 2.5% for almost three years from the week ended on 18/03/2011 to 07/03/2014. As the market rates appear to co-move strongly with the target rates (the Fed Funds rate and the US 3-month Treasury bill rate since 2000 as well as the Official Cash rate and New Zealand 3-month Bank bill rate since 1999), I prefer to estimate the market rates with more variations contained. The left panel in Figure 1 also shows the positive correlation between the US and

² For example, Ehrmann et al. (2011) impose a similar assumption of no international spillover effects across the US and European stock markets and interest rates.

New Zealand market rates, especially clearly from 2004 to 2014. The correlation is not discernible before 2004 or after 2014.

The exchange rate is quoted per NZD, indicating that a higher value of exchange rate reflects NZD appreciation. The right panel in Figure 1 implies the positive correlation of New Zealand 3-month Bank bill rate and the nominal exchange rate (in natural logarithm), i.e., higher interest rate is associated with higher NZD value. This positive correlation does not imply a causal relationship between New Zealand monetary policy and exchange rate because the interest rate may be driven by other factors such as foreign interest rates and economic news that may also cause the exchange rate to change. Therefore, the crucial task is to ensure the unexpected interest rate changes to be disentangled from other shocks that jointly drive the movements of both interest rates and exchange rate.

There are various measures of the share market performance in New Zealand. The most popular measurements are the S&P/NZX family of indices. Among the available proxies, I collect data on the following: S&P50NZ, NZSE10, NZSEMC, NZSESC, and NZSE; all in nominal NZD. The S&P50NZ index measures the performance of the 50 largest index-eligible stocks listed on the NZX Main Board by float-adjusted market capitalization. The S&P50NZ data started from 29/12/2000 and is widely considered as New Zealand's pre-eminent benchmark stock price index. The NZSE10 measures the performance of the 10 largest New Zealand listed companies within the S&P50NZ index. The NZSEMC measures the performance of New Zealand's core mid-cap equity market, covering the constituents of the S&P50NZ index but excluding those that are also constituents of the NZSE10 index. The NZSESC index is designed to measure the performance of New Zealand's smaller listed companies that are not covered in the S&P50NZ index. The NZSE index is considered as the total market indicator for the New Zealand equity market, comprising all eligible securities quoted on the NZX Main Board. Apart from those S&P/NZX indices, there is also the MSCI New Zealand index (MSCINZ), which is designed to measure the performance of the large and mid-cap segments of the New Zealand market. The MSCINZ index covers 7 constituents, approximately accounting for 85% of the free float-adjusted market capitalization in New Zealand. The left panel in Figure 2 plots the natural logarithms of New Zealand stock prices, implying several common trends in their variations: all indices increase until the global financial crisis and recover afterward before entering another declining phase in early 2020 due to the Covid-19 pandemic. Among those indices, the NZSE series is a composite index based on the prices of stocks excluding dividends, not a total return stock index. Other S&P/NZX series such as S&P50NZ, NZSE10,

NZSEMC, and NZSESC as well as the MSCINZ index are size-and-style stock indices by including the stock prices of specific groups of constituents. Despite so-called the benchmark index, the S&P50NZ series is the shortest among the S&P/NZX family indices with available since 2000. While these S&P/NZX indices are strongly correlated, I use the NZSE index for estimation for a longer sample (from 1990 after merging with other variables), which is also in line with the S&P 500 series used to proxy the US stock market performance. In the right panel in Figure 2, I plot the S&P 500 and the NZSE indices, all in natural logarithm. I find that the two stock price indices increase over the 1990-2020 period though their growth rates do not resemble all the time.

3.3. Unit root tests and optimal lag length

I conduct multiple unit root tests including Augmented Dickey–Fuller (ADF) test, Phillips–Perron (PP) test, Kwiatkowski–Phillips–Schmidt–Shin (KPSS) test, and Zivot & Andrews (ZA) test for stationary testing of the variables. The null hypotheses are different across those tests. In the ADF and PP tests, the null hypothesis of non-stationarity, i.e. series has a unit root, is tested against the alternative hypothesis of stationarity. By contrast, in the KPSS test, the null hypothesis of stationarity is tested against the alternative hypothesis of non-stationarity. Rejection of the null hypotheses in the ADF and the PP tests, and rejection of the alternative hypothesis in the KPSS test indicate the series is stationary. In the ZA test, the null hypothesis is that series has a unit root with a structural break(s) and the alternative hypothesis is that series is stationary with a break(s). Rejection of the null hypothesis in the ZA test indicates the series is stationary with a break(s). However, the ZA test can suggest only one break in one test. I consider all possible cases by including either constant or time trend or both in each test. Table 1 briefly reports the unit root test results at 5% significance level for five series (interest rates in percent, stock prices, and exchange rate in natural logarithm), showing whether the tested series is stationary (I(0)) or non-stationary (I(1)). Detailed results are provided in Appendix Table A.2.

Table 1 conclusively suggests at 5% level of significance that, the four series including New Zealand 3-month Bank bill rate, and logs of the S&P 500 index, the NZSE index, and NZD exchange rate are non-stationary in levels and stationary in first-differences. The only inconclusive case is the US 3-month Treasury bill rate, which is suggested to be stationary in the ADF and the PP tests with a time trend included but non-stationary in other tests. Because all four unit root tests suggest that the US 3-month Treasury bill rate is stationary in first-

difference, I include the first-differences of the US and New Zealand market rates as well as the log-differences of the US and New Zealand stock price indices and NZD exchange rate in the estimation.

Next, I check the optimal lag lengths based on the Akaike Information criterion (AIC), the Hannan Quinn criterion (HQ), the Schwarz criterion (SC), and the Final Prediction Error criterion (FPE). The AIC and the FPE suggest a similar lag length of 19 while the HQ suggests 4 and the SC suggests 1 as the optimal. Because of the inconsistency of the optimal lags suggested across those criteria, I proceed with 8 lags for the weekly data.

3.4. Priors for the structural parameters

I follow Baumeister and Hamilton (2015, 2018) by assigning t-distributions with 3 degrees of freedom as priors for 12 unknown parameters in the structural matrix A . I will specify the prior modes, scales, and sign restrictions where possible and intuitive to the literature. All of the chosen prior modes, except for the effect of exchange rate on New Zealand stock price (β_e), are from Ehrmann et al. (2005). As mentioned in Section 1, their paper studies the financial transmission between short-term interest rates, bond yields, and equity returns, and exchange rate within and across the US and the euro area. The reasons I chose that paper as an index of the prior modes are: they use the ITH approach to report the contemporaneous coefficients in the structural matrix A , not the inverse matrix A^{-1} ; and they estimate the changes instead of the levels of variables as reported in the Ehrmann et al. (2011) version. The prior modes are the average of their estimated coefficients for the US and the euro markets. For example, the prior mode 0.006 for the effect of stock prices on interest rates (α_s, α_s^*) are average of their reported estimators 0.0113 and 0.001. Column 3 in Table 2 provides the prior modes for 12 contemporaneous parameters.

Ehrmann et al. (2005) also report a positive impact of exchange rate on stock price, i.e., a 1% euro appreciation against USD is associated with a 0.5766% increase in the S&P Euro index. The S&P 500 index is irresponsive to exchange rate movements, however. For a small open export-driven economy such as New Zealand, I initially expect instead a negative correlation as exchange rate appreciation more likely damages export and possibly the stock prices. It is, however, inconclusive because the impact also depends on the share of export-oriented constituents in the stock market. Figure 3 plots the NZSE index and NZD exchange rate, revealing their positive correlation from 1990 to 2015 though their correlation appears to be reversed since then. To approximately quantify the contemporaneous impact of NZD exchange

rate on the NZSE index (β_e), I simply conduct simple OLS estimations which also control for the dynamic effects of both exchange rate and stock price as follows³

$$\Delta LNZSE_t = c_0 + c_1 t + c_2 D + \sum_{i=1}^p \beta_i \Delta LNZSE_{t-i} + \sum_{j=0}^q \gamma_j \Delta LNZDUSD_{t-j} + u_t \quad (12)$$

, where $\Delta LNZSE$ and $\Delta LNZDUSD$ are the log-differences of the NZSE and NZD exchange rate against the USD. The unit root tests (including the ADF, the PP, the KPSS, and the ZA tests) suggest that the two series $LNZSE$ and $LNZDUSD$ are non-stationary in levels but stationary in first-differences. I also include t for the time trend and D as a dummy variable to represent the break dates of $LNZSE$ suggested by the ZA test (either $D1$ which gets 1 since 19/10/2007 and 0 otherwise, $D2$ which gets 1 since 28/12/2007 and 0 otherwise, or $D3$ which gets 1 since 23/12/2011 and 0 otherwise). Also, c_0 is a constant and u_t is the error term. As I will assign the estimated coefficient as the prior mode of β_e 's t-distribution, at this stage, I ignore other determinants and control variables that could affect the NZD exchange rate and the NZSE index. In the summation terms, p and q are the optimal lag structure, chosen by the AIC. While the Bayesian Information criterion (BIC) suggests the same lag structure of (2,1) for p and q for all cases, the AIC suggests the lag structure of (6,2) if including time trend and a dummy either $D1$ or $D2$, and (6,1) if including time trend and $D3$. Although I prefer the BIC as a consistent-model selector, I also do not want to under-fit my model, and thus I proceed with the lag structures chosen by the AIC. The coefficient of interest is γ_0 . Apart from the three OLS estimations controlling for different suggested structural breaks, I also conduct an OLS estimation excluding both time trend and dummy variable. The full results are presented in detail in Appendix Table A.3. In any case, the contemporaneous coefficients are very close, ranging from 0.21 to 0.218 and all significant at 1% level. As leaving other determinants aside, the estimators implies a positive association between the NZSE index and the exchange rate, i.e. 1% appreciation of NZD is associated with approximately 0.2% increase of the stock price,

³ See Bahmani-Oskooee and Saha (2015) for an extensive review of the studies on the relations between stock prices and exchange rate. Existing studies either use univariate models or control for other determinants of stock prices and exchange rate. In any case of using either linear or non-linear models, most of the studies find no or weak evidence on the long-run equilibrium of the stock prices – exchange rate nexus. Specifically for New Zealand, Obben, Pech, and Shakur (2006) use the weekly data (average of daily data) of the NZSE index and disaggregated New Zealand exchange rates (against the USD, the Australian dollar, the British pound, and the euro) with a cointegrating VAR approach and find ambiguous evidence of the long-run relationship between stock price and exchange rates. In their equation of the USD/NZD exchange rate, the error correction terms, despite being negative, are not significant at 5% significance level, indicating no long-run equilibrium exists between these variables. The short-term coefficients of USD/NZD exchange rate, despite being positive, which implies that the NZD appreciation is associated with New Zealand stock price increases, are not significant either. No contemporaneous coefficients are reported in Obben et al. (2006)'s study. Therefore, we estimate equation (12) using OLS, including both contemporaneous for prior mode and the lagged variables to control for the dynamic effects.

rather than a causal relationship. I will assign 0.2 as the prior mode of β_e and discuss more this “positive” impact in Section 4 after achieving posterior distributions and impulse responses.

Next, I impose sign restrictions on the structural parameters, reflecting the interactions between stock markets, monetary policies, and exchange rate. First, higher stock prices are often associated with economic booms and inflation, and interest rate is expected to increase to stabilize inflation, I assume a positive impact of stock prices on interest rates. This assumption is consistent with the central banks’ mandate. Vice versa, I follow the literature to assume a negative effect of unexpected interest rate changes on stock prices. For example, Matheson and Stavrev (2014) impose similar sign restrictions in their bivariate SVAR to examine the US financial market responses following the Federal Reserve’s taper talk on 22/05/2013 by disentangling the unexpected monetary shocks from economic news shocks. The intuition is that a positive economic news shock leads to higher stock prices and a higher interest rate to stabilize inflation whereas an unexpected tighter monetary policy leads to a higher interest rate and lower stock prices. Using daily data of 01/2003-06/2014, they find that the immediate rise in the 10-year Treasury bond yields following the May 22 taper talk is mainly driven by monetary policy shocks while the effects of positive news shocks become more prominent during the subsequent months. I also assume a negative effect of exchange rate on monetary policy, i.e., exchange rate appreciation likely lowers interest rate. Although the positive correlation between exchange rate and stock price in New Zealand from the OLS estimations is in line with Ehrmann et al. (2005)’ results, the findings on the impact are not conclusive in the literature. On the one hand, exchange rate appreciation can curtail exports, profits, and stock prices of export-oriented companies. On the other hand, appreciation decreases costs of imported inputs, lowers the production costs of non-exporting firms, hence increases their profits and stock prices. For this reason, the effect of NZD exchange rate on New Zealand stock price is left unrestricted. Additionally, despite the positive (negative) prior modes imposed on the effects of New Zealand (the US) interest rate and stock price on NZD exchange rate, I also leave their signs unrestricted for more possible posteriors to be achieved. Although the sign restrictions imposed in traditional SVAR, i.e., sign and exclusion restrictions, are based on the reasonable belief of the researchers on certain impacts, they restrict the set of identification. In addition, I agree with Baumeister and Hamilton (2015, 2018)’ criticism on the sign restriction approach which implicitly assumes that the influence of the priors on posterior will vanish asymptotically. Those impacts of key interest are left unrestricted in this chapter to allow more effect scenarios to be obtained. By disclosing the prior information, I am transparent about the

effect of the imposed priors on the posterior distributions and impulse responses. Lastly, I impose positive sign restrictions on the effects of the US interest rate (stock market) on New Zealand interest rate (stock market) as those indicators in a small open economy such as New Zealand will tend to follow the US markets.

Once prior modes and degrees of freedom are chosen, the prior scales determine the prior width. I choose the scales reasonably so that they meet the sign restrictions accordingly and more importantly, they are consistent with the previous studies. For instance, the prior for α_s and α_s^* – the effects of stock prices on interest rates – allows a large probability of 70.46% for them to be positive, also covering the estimator of 0.021 found by Rigobon and Sack (2004). For the effect of interest rates on stock prices, I allow a probability of 78.03% for the estimated parameters β_i and β_i^* to be negative, covering other existing estimators of -7.19 and -6.81 found by Rigobon and Sack (2003), and of -4.68 by Bernanke and Kuttner (2005). Wang and Mayes (2012)'s estimators for the effects of New Zealand and Australia monetary policy shocks on stock prices (-3.694 for New Zealand and -1.127 for Australia) using event-study approach are also included in the prior distributions of β_i and β_i^* . For other parameters with unrestricted signs such as β_e , the prior implies a possibility of 32.57% for a negative impact, i.e., NZD exchange rate appreciation drives New Zealand stock price to decrease, and 67.43% for a positive impact. This chosen prior of β_e includes the Ehrmann et al. (2005)' estimator of 0.5766. For γ_i and γ_{i^*} , the chosen priors assign a very large probability of 97.3% for γ_i (γ_{i^*}) to be positive (negative). The prior distribution of γ_i is in line with existing estimators in the literature, including the coefficients of from 2 to 3 found by Zettelmeyer (2004), of approximately 1.4 by Kearns and Manners (2006), and of 2 by Rosa (2011). By contrast, the priors imposed on γ_s (γ_{s^*}) imply an equal probability of about 53.58% for them to be positive (negative).

4. Results

Figure 4 plots prior distributions (solid red curves) and posterior distributions (blue histograms) for the short-run effects (structural parameters). The key interest is γ_i , i.e., the contemporaneous effect of New Zealand interest rate on NZD exchange rate against the USD, about which the historical data slightly revises my beliefs as the prior and posterior distributions are very similar. Despite being sign-unrestricted, the prior and posterior distributions strongly imply that, following an increase in New Zealand short-term interest rate, the NZD exchange rate appreciates immediately on impact. I also find it less likely to revise

my belief about the effect of the domestic stock price on short-term interest rate in the US (α_s^*) but more likely to revise for the New Zealand market (α_s) as the posterior distribution for New Zealand is narrower than the prior distribution. The prior and posterior distributions of γ_s – the contemporaneous effect of New Zealand stock price on NZD exchange rate – also resemble. However, my beliefs about other short-run effects are revised far more strongly when the posterior distributions are typically narrower than the prior distributions. The historical data favors a lower (larger) range for the effect of New Zealand (US) interest rate on stock price. The data also supports a smaller impact of NZD exchange rate on New Zealand short-term interest rate (α_e) compared to the chosen prior. The posterior distribution of foreign interest rate's impact on exchange rate (γ_{i^*}), while being unrestricted, is far narrower than the prior, favoring a much smaller effect which is quite close to zero. The data also revises my beliefs about the effect of NZD exchange rate on New Zealand stock price (β_e), with posterior distribution favouring the negative impact, and the effect of the US stock price on NZD exchange rate (γ_{s^*}), with posterior distribution favouring the positive impact. For the international spillover effects within the same asset class, the data supports a stronger co-movement of stock prices (β_{s^*}) but a smaller for short-term interest rates (α_{i^*}).

The median posterior values for the impulse response functions are shown as the solid lines in Figure 5, along with the 68% and 95% credibility sets. To a 1% unexpected increase in New Zealand short-term interest rate, I find that the NZD appreciates immediately by 1.51% on impact. The shaded 68% credibility regions exclude zero, strengthening my belief about the contemporaneous effect of monetary policy tightening on exchange rate appreciation. The 95% credibility regions include zero, however. As soon as the interest rate falls back to the initial level, exchange rate gradually depreciates to its original level. The posterior median of the direct impact (1.51) is close to other existing findings for New Zealand, such as 1.8–2 found by Kearns and Manners (2006) but much far from the prior mode (3.698) taken from Ehrmann et al. (2005).

Most of the other contemporaneous effects are as expected including increasing interest rates dampen stock prices, New Zealand short-term interest rate (stock price) co-moves positively with the US interest rate (stock price), a positive US monetary policy shock leads to NZD depreciation, the US short-term interest rate responds positively to the US economic news shock (the evidence for New Zealand is weak as the 68% credibility set includes zero), and the New Zealand interest rate increases in response to a positive currency premium shock. Despite the zero restrictions on the international spillover effects across asset markets, a higher US

interest rate does cause New Zealand stock price to decrease for two weeks following the shock. The US stock price has no impact on New Zealand interest rate, however. Interestingly, I find that a positive economic news shock either in Zealand or in the US leads NZD value to increase immediately. Last but not least, the results show a negative response of New Zealand stock price to a positive currency premium shock despite the chosen prior of a positive impact. However, the impact is overall uncertain because the 68% credibility set of the direct response of New Zealand stock price to a currency premium shock also contains zero.

Figure 6 plots the median posterior values of cumulative impulse responses. The results show that the NZD exchange rate keeps appreciating persistently in response to a positive monetary policy shock: the 6-month accumulated response to a 1% increase in short-term interest rate is approximately 3.5% and there is no signal of “delay overshooting” over 6 months after the shock. I also expand the horizon up to one year (52 weeks) following the shock and find very similar responses of NZD exchange rate: the one-year accumulated appreciation of NZD exchange rate remains at 3.5%. The results are partly consistent with many existing studies that find contradict evidence to the UIP theory, which predicts subsequent exchange rate depreciations following an initial appreciation after a monetary policy contraction. Again, the findings on the effect of interest rate shocks on exchange rate are largely controversial in the empirical literature. Some studies, such as Sims (1992) show that the exchange rate depreciates after monetary tightening, which is the so-called exchange rate puzzle. Most of the other studies, for example, Cushman and Zha (1997), Kim and Roubini (2000), Kim (2005), as well as Kim and Lim (2018) report the evidence supporting the “delay overshooting” phenomenon with the delay lasting shortly, for example at best 6 months found by Kim and Lim (2018). Scholl and Uhlig (2008), however, document the more prolonged delay from one to three years before exchange rate starts to depreciate. Various explanations for the failure of the UIP theory have been discussed. One of them focuses on the invalidity of the two fundamental behavioral assumptions of the UIP theory in the data: market participants are risk-neutral and they have rational expectations about future exchange rate movements. If market participants are not risk-neutral, they will require a risk premium to hold foreign assets over domestic assets. In a recent paper, Granziera and Sihvonen (2020) relax the second assumption by allowing agents to have sticky expectations about short-term rates and illustrate that the increase in short-term rate forecast with sticky expectation occurs with a lag. Because of sticky expectations, agents have gradually updated their expectations about the short-term rates, the home currency keeps appreciating. This explains the failure of the UIP theory.

In addition, the results of cumulative impulse responses using the 68% credibility regions suggest the persistent impacts of short-term interest rates on stock prices and vice versa, of the US interest rate (stock price) on New Zealand interest rate (stock price), of the US interest rate on NZD exchange rate, of New Zealand stock price on NZD exchange rate, and of NZD exchange rate on New Zealand short-term rate. The persistent appreciation of NZD to a positive economic news shock in the US and the decrease of US stock price to a positive economic news shock in New Zealand, however, are unexplainable.

Table 3 reports the US and New Zealand variables' median variance shares, accumulated over 6 months, explained by the monetary policy shocks, economic news shocks, and currency premium shocks. The results show that New Zealand monetary policy shock plays a very modest role in explaining the variance of NZD exchange rate (2.62%), which is very close to Karim et al. (2007)' estimate of 2.92% (for 4-quarter forecast errors). The largest variance share of NZD exchange rate is explained by currency premium shocks (75.84%), followed by New Zealand economics news shocks (11.89%), and the US economic news shocks (9.45%). For other variables for New Zealand, I find that currency premium shocks can explain 7.32% of the variance of the short-term interest rate while the contributions of the US monetary policy and economic news shocks are very small (about 1%). However, the US economic news shocks can explain up to 17.3% of the variations of the New Zealand stock price, followed by New Zealand monetary policy shocks (7.97%) and currency premium shocks (6.75%). As expected, the shocks to New Zealand monetary policy, economic news, and NZD exchange rate attribute very little to the variances of the US variables.

5. Robustness check

In this section, I cross-check the baseline results by relaxing several restrictions. One of the assumptions in the benchmark model restricts the international cross-market spillover effects. This restriction, despite being intuitive and similar to Ehrmann et al. (2011) that assume no spillover effects across the US and European stock markets and interest rates, could be relaxed to allow the possible cross-market effects of the US stock price (interest rate) on New Zealand interest rate (stock price). In a sequent check, I also relax the sign restriction on the effect of exchange rate on interest rate (α_e). While the baseline model supports a negative relationship between exchange rate and interest rate - domestic currency appreciation is associated with lower interest rate - this additional check instead allows an opposite scenario to happen when the currency appreciation caused by a positive risk premium may be associated with a higher

interest rate, i.e. investors switch to riskier assets rather than government bonds. As stock prices could also increase in that scenario, currency appreciation still leads to a comovement of stock price and interest rate. In any case, the main findings remain – a higher interest rate leads NZD to appreciate immediately and even stay stronger in the long-run. The sub-sections below describe the results in more detail.

5.1. International cross-market effects

First, to allow the New Zealand interest rate (stock price) to respond to the US stock price (interest rate), I impose a tight t-distribution with 3 degrees of freedom, prior mode of zero, prior scale of 0.1, and non-restricted sign on α_{s^*} - direct effect of the US stock price on the New Zealand interest rate and β_{i^*} - direct effect of the US interest rate on the New Zealand stock price. The results are provided in Appendix Figures A.1 - A.3 for prior and posterior distributions, impulse responses, and cumulative impulse responses. Figure A.1 includes the prior and posterior distributions of 14 contemporaneous parameters: the posterior distributions of 12 existing parameters are very similar to the baseline results and those of the two newly added parameters (α_{s^*} and β_{i^*}) appear very sharply peaked, even more around zero for β_{i^*} . In Figure A.2 for the impulse responses, New Zealand stock price decreases as a response to a higher US interest rate (significantly at 68% credibility set but insignificantly at 95% credibility set). New Zealand interest rate, however, shows insignificant responses to the US stock price changes. This result makes sense as New Zealand monetary policy tends to stabilize the domestic inflation rather than reflects the stock price changes in the US market. The negative responses of the New Zealand stock prices to the US monetary policy, however, are intuitive as reflecting the comovement of stock prices across the two markets. Relaxing the cross-market spillover effects also leaves the responses of other variables unchanged, except a larger appreciation of NZD (3% in the short-run and 5.4% in the long-run approximately) due to a 1% increase in New Zealand interest rate, which is statistically significant at 68% credibility set (Figures A.2 – A.3).

5.2. Effect of exchange rate on interest rate

This second check relaxes both international cross-market spillover effects and the sign restriction on the impact of exchange rate on interest rate. Specifically, apart from imposing the tight t-distribution for α_{s^*} and β_{i^*} as in Section 5.1, the parameter α_e now has an unrestricted sign. The results are included in Appendix Figures A.4 - A.6. Although the posterior distribution of α_e now includes positive values due to the sign relaxation, a large

proportion of its posterior distribution falls in negative territory (Figure A.4), which indicates a tiny impact of the prior distribution on the true effect of exchange rate on interest rate. The posterior distributions of other contemporaneous parameters are unchanged. Consistently, the impulse responses in the short-term and the long-term of all variables are very similar to the benchmark and the above robustness check (Figures A.5 - A.6). New Zealand interest rate significantly decreases as a response to exchange rate appreciation, implying the sign restriction imposed in the baseline model is strongly supported by the data. The responding magnitude of exchange rate remains the same as in the above cross-check with a 3% appreciation of NZD in the short-run and 5.4% in the long-run following a tighter monetary policy.

6. Conclusion

This chapter revisits an old question in the literature in examining the effects of New Zealand monetary policy shock on NZD exchange rate. By applying the Bayesian SVAR approach, I am transparent about the influence of the chosen priors on posterior distributions and impulse response functions, avoiding being too dogmatic as the traditional SVARs. I estimate a system of five variables including the US and New Zealand short-term interest rates and stock prices, and NZD exchange rate against the USD using the weekly data from 03/01/1999 to 18/09/2020. The contribution of this chapter also belongs to the specification, employing stock prices to disentangle the monetary policy shocks from other shocks that jointly drive interest rates and exchange rate. The monetary policy shocks are identified as unexpected changes in short-term interest rates. The results show that, to an unexpected increase in New Zealand short-term interest rate, the NZD appreciates immediately and keeps appreciating without a sign of “delay overshooting” at least for one year in the estimation. The findings are in line with other empirical studies with significant evidence that contradict the UIP theory prediction. The New Zealand monetary policy shocks, however, contribute very modestly to the variances of NZD exchange rate.

Table 1 Summary of the unit root test results

		US 3-month Treasury bill rate		Log(S&P 500)		NZ 3-month Bank bill rate		Log(NZSE)		Log(NZDUSD)	
Test type		Level	1 st -difference	Level	1 st -difference	Level	1 st -difference	Level	1 st -difference	Level	1 st -difference
	None		I(0)		I(0)		I(0)		I(0)		I(0)
ADF	Constant	I(1)		I(1)		I(1)		I(1)		I(1)	
	Trend	I(0)		I(1)		I(1)		I(1)		I(1)	
PP	Constant	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)
	Trend	I(0)		I(1)		I(1)		I(1)		I(1)	
KPSS	Constant	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)	I(1)	I(0)
	Constant & trend	I(1)		I(1)		I(1)		I(1)		I(1)	
ZA	Constant	I(1) [15/12/2000]	I(0)	I(1) [12/10/2007]	I(0)	I(1) [03/10/2008]	I(0)	I(1) [19/10/2007]	I(0)	I(1) [27/09/2002]	I(0)
	Trend	I(1) [16/05/2014]		I(1) [02/02/1996]		I(1) [21/12/1990]		I(1) [23/12/2011]		I(1) [13/09/2013]	
	Constant & trend	I(1) [02/11/2007]		I(1) [01/09/2000]		I(1) [03/10/2008]		I(1) [28/12/2007]		I(1) [09/08/2002]	

Note: The variables include the US 3-month Treasury bill rate; log of the S&P 500 index; New Zealand 3-month Bank bill rate; log of New Zealand NZSE index; log of NZD nominal exchange rate against USD. Results are at 5% significance level. Suggested break dates are in square brackets. Detailed test-statistics and critical values are provided in Appendix Table A.2.

Table 2 Priors for the structural coefficients

Parameter	Meaning	Prior mode	Prior scale	Sign restriction
α_s, α_s^*	Effect of stock price on interest rate	0.006	0.01	+
α_e	Effect of exchange rate on interest rate	- 0.048	0.04	-
β_i, β_i^*	Effect of interest rate on stock price	- 1.423	1.6	-
β_e	Effect of exchange rate on stock price	0.2	0.4	none
$\gamma_i, -\gamma_{i^*}$	Effect of interest rate on exchange rate	3.698	1.2	none
$\gamma_s, -\gamma_{s^*}$	Effect of stock price on exchange rate	0.039	0.4	none
α_{i^*}	Effect of foreign interest rate on domestic interest rate	0.256	0.4	+
β_{s^*}	Effect of foreign stock price on domestic stock price	0.308	0.4	+

Table 3 Decomposition of variance of 6-month-ahead forecast errors

	US monetary policy shock	US economic news shock	NZ monetary policy shock	NZ economic news shock	Currency premium shock
US 3-month Treasury bill rate	0.18 [98.45%] (0.16, 0.19)	0 [0.73%] (0, 0.01)	0 [0.24%] (0, 0)	0 [0.31%] (0, 0)	0 [0.27%] (0, 0)
US stock price	0.03 [0.79%] (0.01, 0.21)	3.39 [97.76%] (3.11, 3.66)	0.02 [0.45%] (0, 0.04)	0.02 [0.48%] (0, 0.05)	0.02 [0.51%] (0, 0.05)
NZ 3-month Bank bill rate	0 [0.6%] (0, 0)	0 [1.06%] (0, 0)	0.02 [89.24%] (0.01, 0.02)	0 [1.78%] (0, 0)	0 [7.32%] (0, 0)
NZ stock price	0.02 [0.1%] (0.01, 0.06)	0.5 [17.3%] (0.39, 0.63)	0.2 [7.97%] (0.08, 0.43)	1.54 [67.88%] (0.69, 1.87)	0.17 [6.75%] (0.01, 1.13)
NZD exchange rate	0.01 [0.2%] (0, 0.04)	0.18 [9.45%] (0.13, 0.25)	0.07 [2.62%] (0.01, 0.26)	0.22 [11.89%] (0.01, 1.03)	1.26 [75.84%] (0.53, 1.58)

Note: Estimated contribution of each structural shock to the 6-month-ahead median squared forecast error of each variance in bold, and expressed as a percent of total MSE in brackets. Parentheses indicate 95% credibility intervals.

Figure 1 The US and New Zealand interest rates and exchange rate

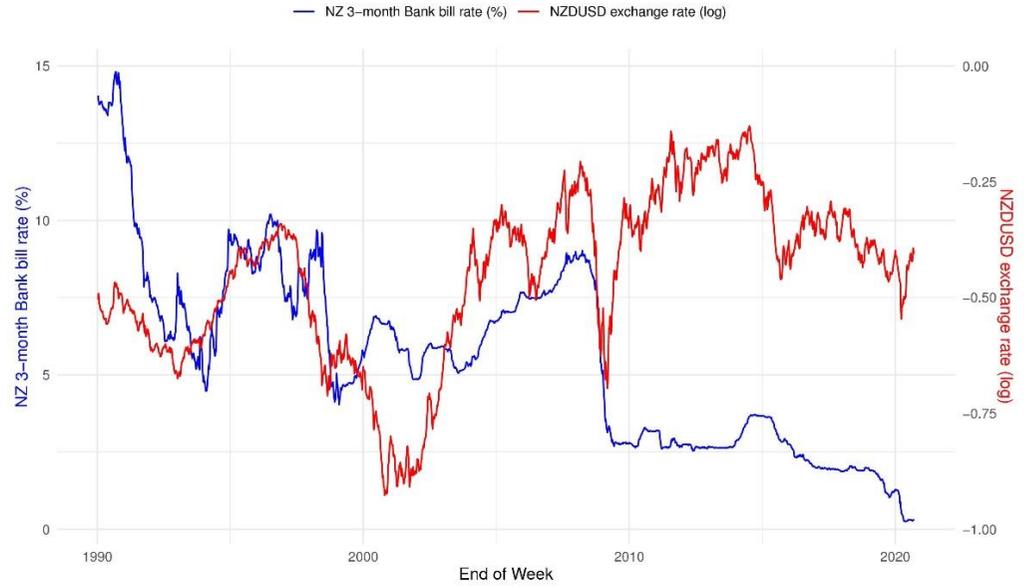
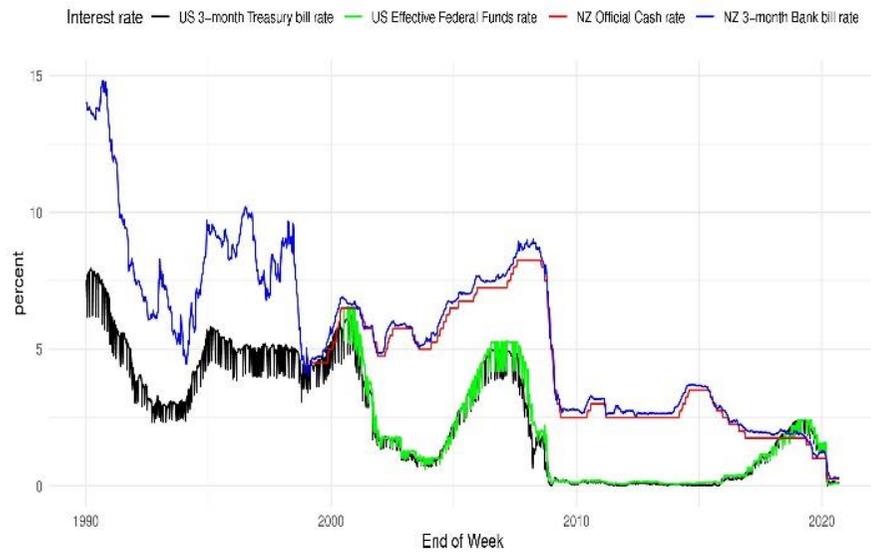


Figure 2 The US and New Zealand stock price indices

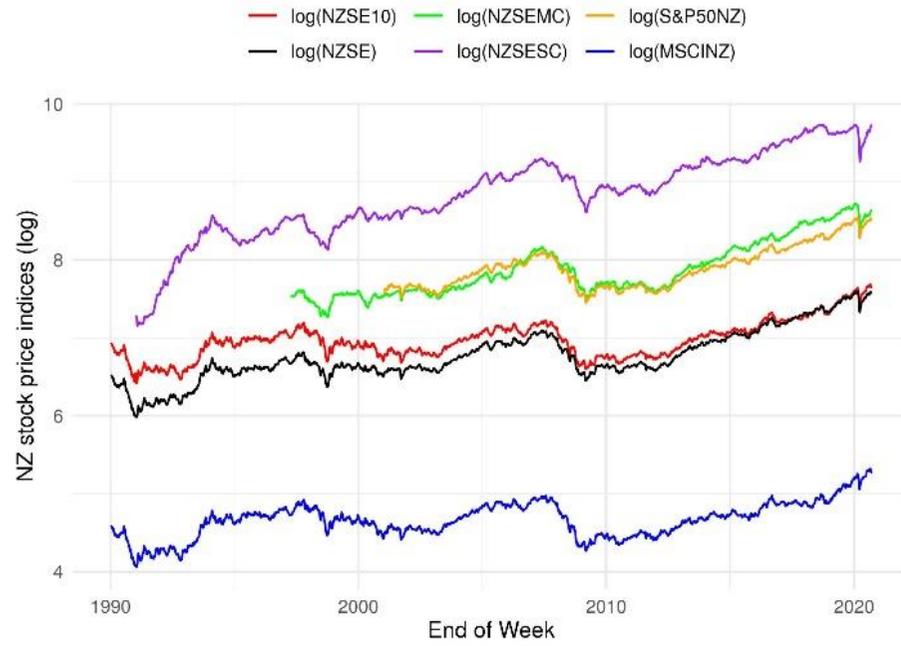


Figure 3 NZSE index and New Zealand exchange rate

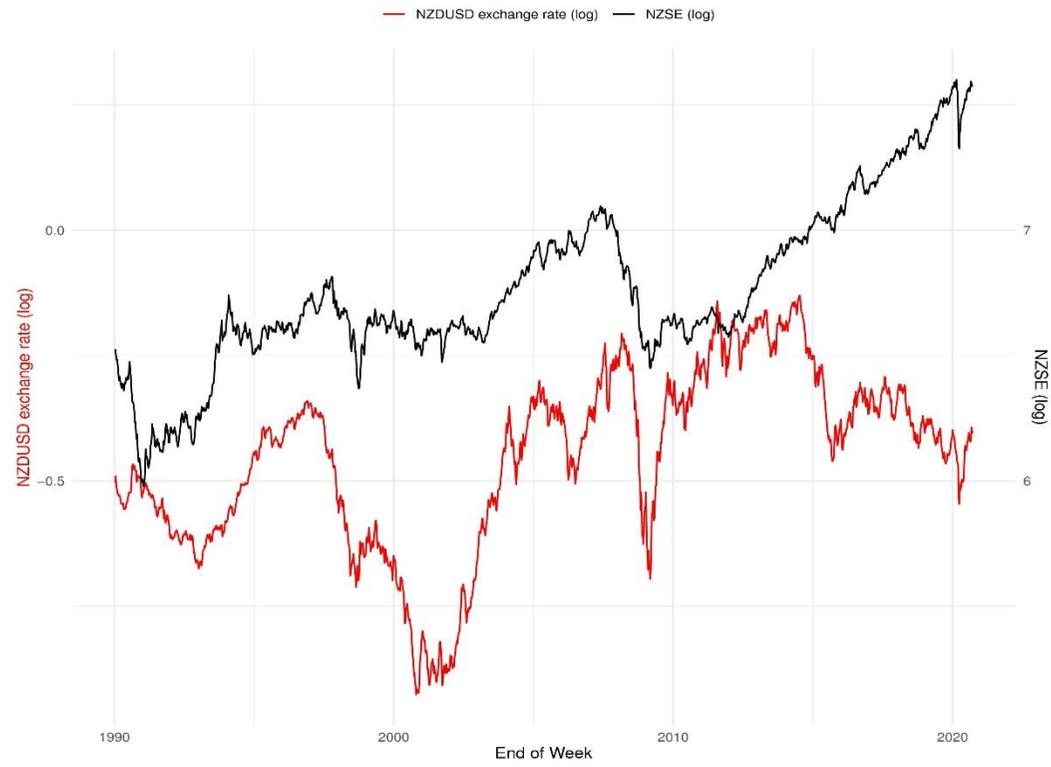
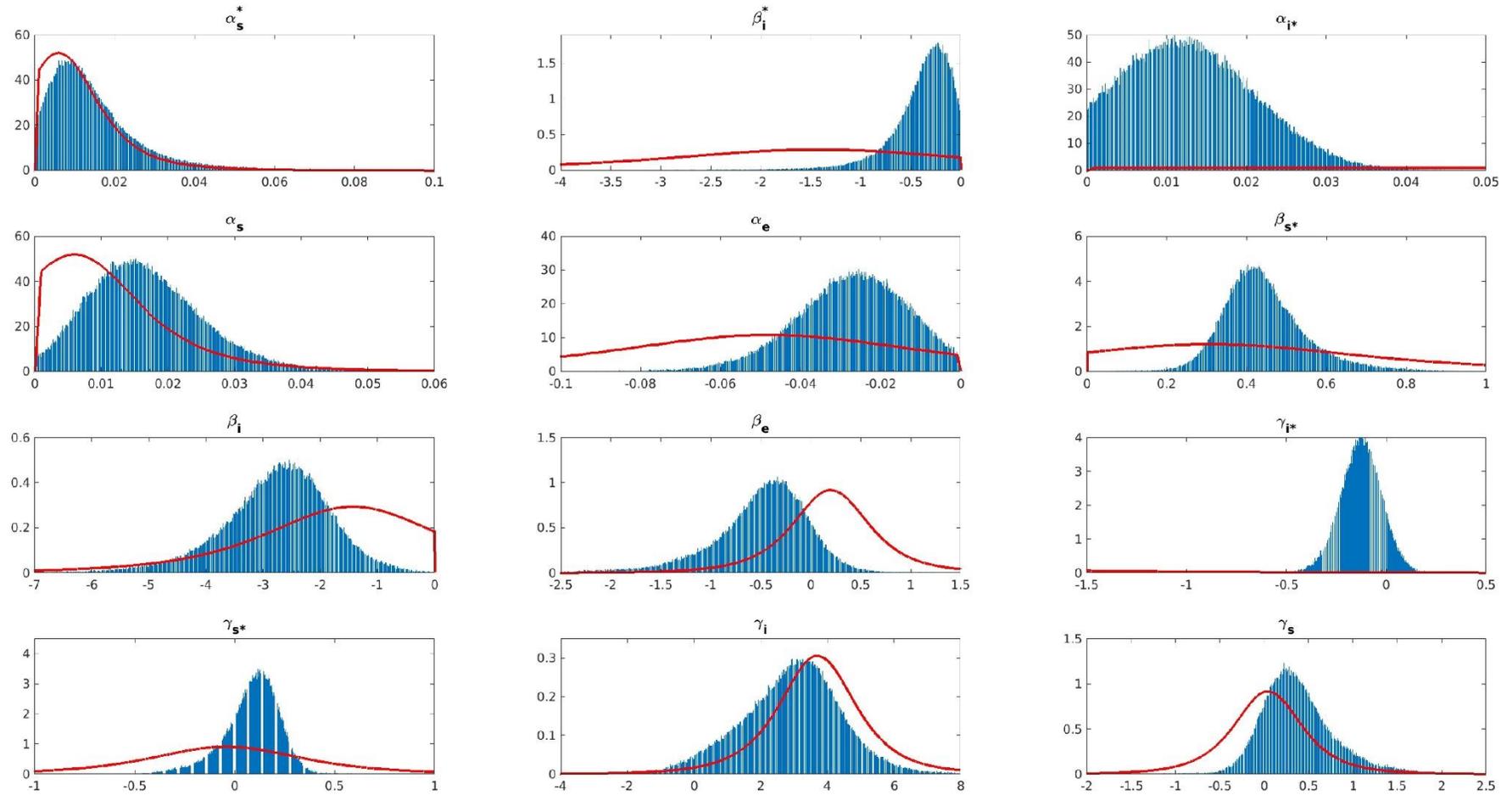
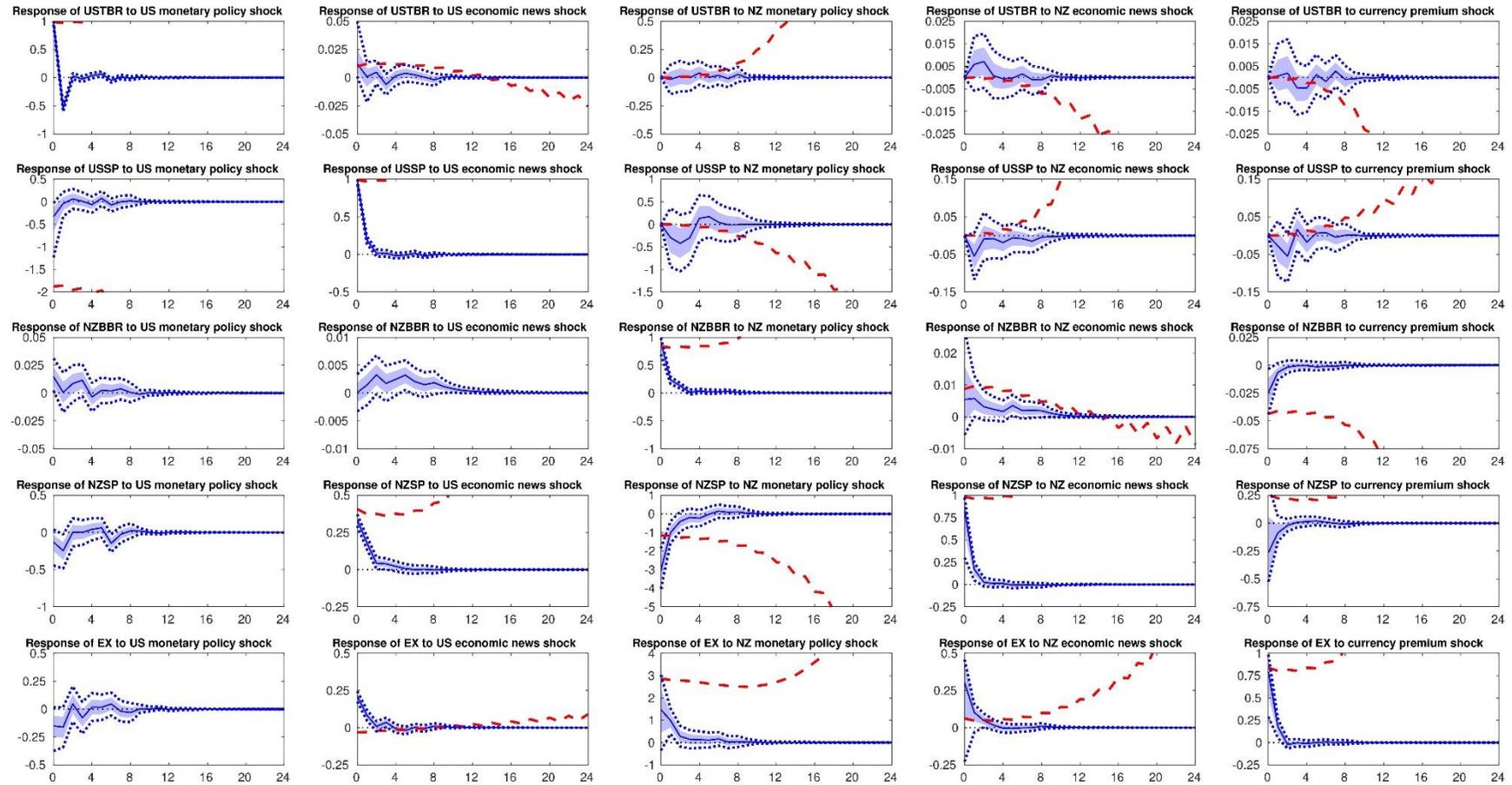


Figure 4 Prior and posterior distributions



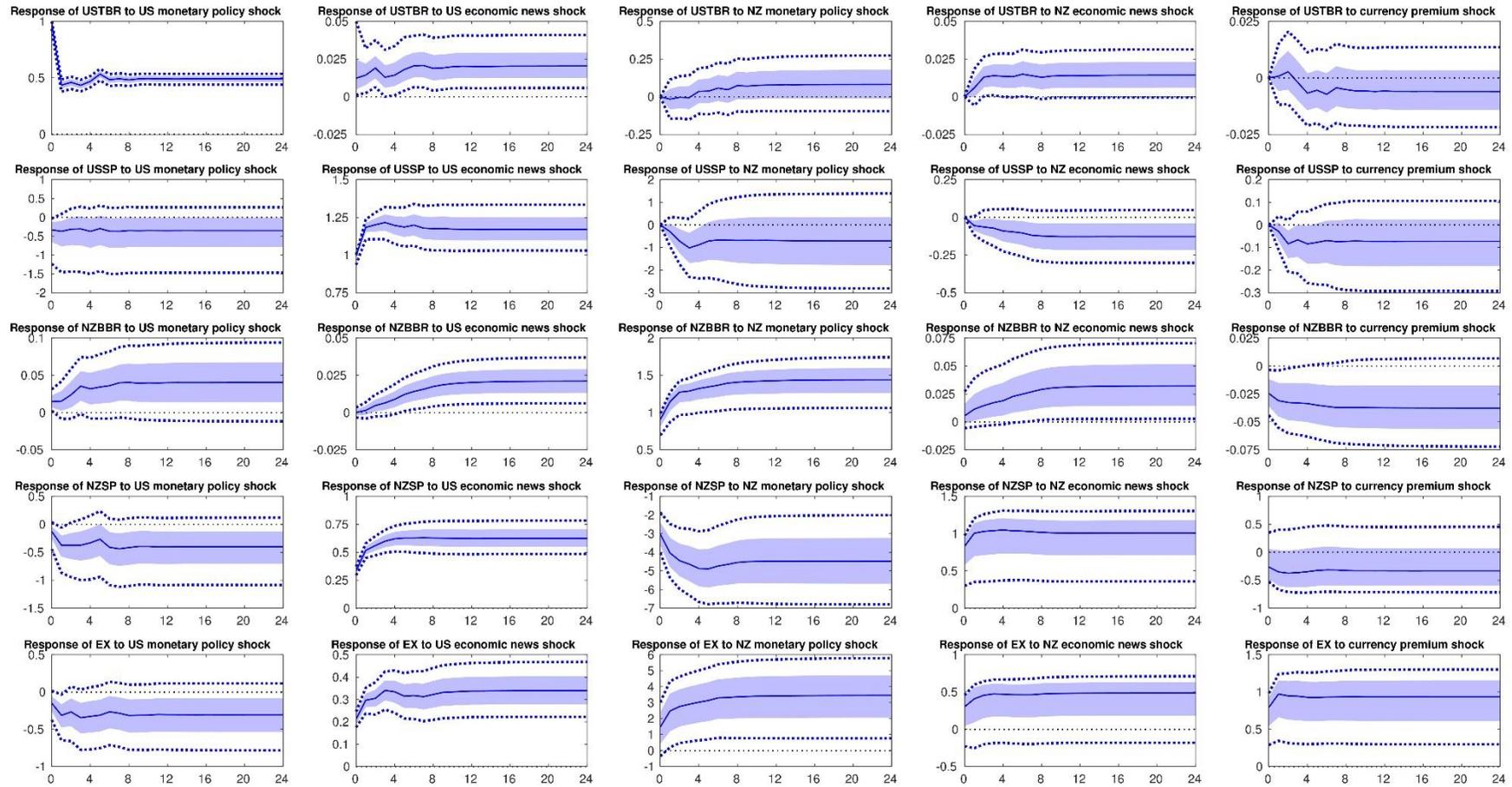
Note: Prior distribution (red lines) and posterior distributions (blue histogram) for contemporaneous coefficients.

Figure 5 Structural impulse-response functions and prior median



Note: Structural impulse-response functions. Solid blue lines: posterior median. Shaded region: 68% posterior credibility set. Dotted blue lines: 95% posterior credibility set. Dashed red lines: prior median. USTBR: US 3-month Treasury bill rate, USSP: US stock price, NZBBR: New Zealand 3-month Bank bill rate, NZSP: New Zealand stock price, EX: exchange rate of NZD against USD.

Figure 6 Cumulative impulse-response functions



Note: Cumulative impulse-response functions. Solid blue lines: posterior median. Shaded region: 68% posterior credibility set. Dotted blue lines: 95% posterior credibility set. USTBR: US 3-month Treasury bill rate, USSP: US stock price, NZBBR: New Zealand 3-month Bank bill rate, NZSP: New Zealand stock price, EX: exchange rate of NZD against USD.

Appendix

I present below briefly how the algorithm is implemented in this study. The fundamental prior assumptions follow Baumeister and Hamilton (2015).

The structural model has the following form:

$$\mathbf{A}\mathbf{y}_t = \mathbf{B}\mathbf{x}_{t-1} + \mathbf{u}_t \quad (\text{A4.1})$$

for \mathbf{y}_t an $(n \times 1)$ vector of observed variables, \mathbf{A} an $(n \times n)$ matrix of the contemporaneous structural relations, \mathbf{x}_{t-1} a $(k \times 1)$ vector (with $k = mn + 1$) consisting of a constant and m lags of \mathbf{y} ($\mathbf{x}'_{t-1} = (\mathbf{y}'_{t-1}, \mathbf{y}'_{t-2}, \dots, \mathbf{y}'_{t-m}, \mathbf{1})'$), and \mathbf{u}_t an $(n \times 1)$ vector of structural residuals assumed to be independent and identically distributed (i.i.d.) $N(\mathbf{0}, \mathbf{D})$ and mutually uncorrelated (\mathbf{D} diagonal). In this study, I set m to 8 lags.

The prior information about the contemporaneous structural coefficients is represented in the form of an arbitrary prior distribution $p(\mathbf{A})$, incorporating exclusion restrictions, sign restrictions, and informative prior beliefs about elements of \mathbf{A} . I also assume that there are no restrictions on the lag coefficients in \mathbf{B} other than the prior beliefs about the distribution $p(\mathbf{B}|\mathbf{D}, \mathbf{A})$. Then the overall prior distribution of the parameters of the matrices \mathbf{A} , \mathbf{B} , and \mathbf{D} is:

$$p(\mathbf{A}, \mathbf{D}, \mathbf{B}) = p(\mathbf{A}) p(\mathbf{D}|\mathbf{A}) p(\mathbf{B}|\mathbf{D}, \mathbf{A})$$

Prior for $p(\mathbf{A})$: I assign the prior $p(\mathbf{A})$ as truncated t-distributions with 3 degrees of freedom for the unknown elements of \mathbf{A} . The prior modes, scales, and sign restrictions in the baseline model are presented in Table 1.

Prior for $p(\mathbf{D}|\mathbf{A})$: The prior beliefs about structural variance reflect in part the scale of the underlying data. Let d_{ii} denote the (i, i) diagonal elements of the structural variance matrix \mathbf{D} and be independent across equations, so $p(\mathbf{D}|\mathbf{A}) = \prod_{i=1}^n p(d_{ii}|\mathbf{A})$ with the reciprocals of diagonal elements of \mathbf{D} following Gamma distribution $d_{ii}^{-1}|\mathbf{A} \sim \Gamma(\kappa, \tau_i(\mathbf{A}))$, where κ is the parameter and $\tau_i(\mathbf{A}) = \kappa a'_i \hat{S} a_i$. Here, a'_i denotes the i th row of \mathbf{A} and \hat{S} is the variance-covariance matrix of residuals from estimating the univariate AR(m) models for the endogenous variables. I follow Baumeister and Hamilton (2015) by setting $\kappa = 2$, which in turn puts a weight on the prior equivalent to $2\kappa = 4$ observations of data. The prior mean for d_{ii}^{-1} is κ/τ_i , which is chosen to equal the reciprocal of the i th diagonal element of $\mathbf{A}\hat{S}\mathbf{A}'$. The prior variance of d_{ii}^{-1} is κ/τ_i^2 .

Prior for $p(\mathbf{B}|\mathbf{D}, \mathbf{A})$: Let b'_i denote the i th row of the matrix \mathbf{B} and be independent across equations, so $p(\mathbf{B}|\mathbf{D}, \mathbf{A}) = \prod_{i=1}^n p(b_i|\mathbf{D}, \mathbf{A})$. Assuming that $b_i|\mathbf{D}, \mathbf{A} \sim N(m_i, d_{ii}M_i)$, so m_i denotes the prior mean for b_i and $d_{ii}M_i$ denotes the prior variance associated with this prior. I allow m_i and M_i to be functions of \mathbf{A} but not of \mathbf{D} . I set the prior mean $m_i = \eta' a_i$ with $\eta_{n \times k} = (0_{n \times 1} \ 0_{n \times nm})$ because I expect all variables (in first-differences) to have zero persistence; i.e., I impose no long-run restrictions for all equations. I also put more confidence in my prior beliefs that coefficients on higher-order lags are zero, represented by smaller diagonal elements for M_i associated with higher lags. Let $v'_{1(1 \times m)} = (\frac{1}{12\lambda_1}, \frac{1}{22\lambda_1}, \dots, \frac{1}{m2\lambda_1})$ and $v'_{2(1 \times n)} = (s_{11}^{-1}, s_{22}^{-1}, \dots, s_{nn}^{-1})'$ where $\sqrt{s_{ii}}$ denotes the estimated standard deviation of a univariate eighth-order autoregression fit to variable i . Then I form $v_3 = \lambda_0^2 \begin{bmatrix} v_1 \otimes v_2 \\ \lambda_3^2 \end{bmatrix}$ and the covariance matrix M_i is taken as a diagonal matrix whose row r column r element is the r th element of v_3 : $M_{i,rr} = v_{3r}$. I set the hyperparameters following Baumeister and Hamilton (2015): $\lambda_1 = 1$ (which governs how quickly the prior for lagged coefficients tightens to zero as the lag m increases), $\lambda_3 = 100$ (which makes the prior on the constant term essentially irrelevant), and $\lambda_0 = 0.1$ (which summarizes the overall confidence in the prior).

I follow Baumeister and Hamilton (2015) to calculate the target function which is built based on the joint distribution of \mathbf{A} , \mathbf{B} , and \mathbf{D} conditional on the data, and use a random walk Metropolis-Hastings algorithm to generate draws of \mathbf{A} , \mathbf{B} , \mathbf{D} from the posterior distribution, with the scalar tuning parameter set to get an acceptance ratio of 30%. In this chapter, I set the tuning parameter to 0.45 and the acceptance ratio is 29.14%. The results are based on 2,000,000 draws with 1,000,000 burn-in draws.

Table A.1 Data sources

Variable	Source	Starting daily data
US 3-month Treasury bill rate, % per annum	https://fred.stlouisfed.org	4/01/1954 -
US Effective Fed Funds rate, % per annum	https://fred.stlouisfed.org	3/07/2000 -
S&P 500 index, nominal USD (S&P500): The stock market index that measures the stock performance of 500 large companies listed on stock exchanges in the United States.	Datastream (code: S&PCOMP)	4/03/1957 -
New Zealand 3-month Bank bill rate, % per annum	Reserve Bank of New Zealand	4/01/1985 -
New Zealand Official Cash rate, % per annum	Reserve Bank of New Zealand	17/03/1999 -

S&P/NZX 10 index (NZSE10), nominal NZD: The index measures the performance of 10 of the largest New Zealand listed companies within the S&P/NZX 50 index.	Datastream (code: NZ10CAP)	30/06/1988 -
S&P/NZX All index (NZSE), nominal NZD: The index is considered the total market indicator for the New Zealand equity market. It comprises all eligible securities quoted on the NZX Main Board. Constituents are not screened for liquidity.	Datastream (code: NZSEALL)	3/01/1990 -
S&P/NZX MidCap index (NZSEMC), nominal NZD: The index is designed to measure the performance of New Zealand's core mid-cap equity market. The eligible universe is drawn from the constituents of the S&P/NZX 50 Index, excluding those that are also constituents of the S&P/NZX 10 index.	Datastream (code: NZMCAPC)	7/04/1997 -
S&P/NZX SmallCap index (NZSESC), nominal NZD: The index is designed to measure the performance of New Zealand's smaller listed companies that sit outside of the S&P/NZX 50 index.	Datastream (code: NZSMCIC)	28/12/1990 -
S&P/NZX 50 Portfolio index (S&P50NZ), nominal NZD: The index comprises the same constituents as the S&P/NZX 50 index, but with a 5% cap on the float-adjusted market capitalization weights of the constituents.	Datastream (code: NZ50CAP)	29/12/2000 -
MSCI New Zealand index (MSCINZ), nominal NZD: The MSCINZ is designed to measure the performance of the large and mid cap segments of the New Zealand market. With 7 constituents, the index covers approximately 85% of the free float-adjusted market capitalization in New Zealand.	Datastream (code: MSNZEAL)	31/12/1981 -
Nominal exchange rate of New Zealand dollar against US dollar	Reserve Bank of New Zealand	1/06/1973 -

Table A.2 Detailed unit root test results

Test	Type	Variable	Test statistic	1%	5%	10%	Result	Break
ADF	level, constant	USTBR	-2.69	-3.43	-2.86	-2.57	I(1)	
ADF	level, constant	log(S&P500)	-0.91	-3.43	-2.86	-2.57	I(1)	
ADF	level, constant	NZBBR	-2.33	-3.43	-2.86	-2.57	I(1)	
ADF	level, constant	log(NZSE)	0.09	-3.43	-2.86	-2.57	I(1)	
ADF	level, constant	log(NZDUSD)	-1.77	-3.43	-2.86	-2.57	I(1)	
ADF	level, trend	USTBR	-3.56	-3.96	-3.41	-3.12	I(0)	
ADF	level, trend	log(S&P500)	-1.79	-3.96	-3.41	-3.12	I(1)	
ADF	level, trend	NZBBR	-2.62	-3.96	-3.41	-3.12	I(1)	
ADF	level, trend	log(NZSE)	-1.78	-3.96	-3.41	-3.12	I(1)	
ADF	level, trend	log(NZDUSD)	-2.16	-3.96	-3.41	-3.12	I(1)	
ADF	1st-difference, none	USTBR	-44.85	-2.58	-1.95	-1.62	I(0)	
ADF	1st-difference, none	log(S&P500)	-26.24	-2.58	-1.95	-1.62	I(0)	
ADF	1st-difference, none	NZBBR	-21.77	-2.58	-1.95	-1.62	I(0)	
ADF	1st-difference, none	log(NZSE)	-24.25	-2.58	-1.95	-1.62	I(0)	
ADF	1st-difference, none	log(NZDUSD)	-26.35	-2.58	-1.95	-1.62	I(0)	
PP	level, constant	USTBR	-2.64	-3.44	-2.864	-2.57	I(1)	
PP	level, constant	log(S&P500)	-0.81	-3.44	-2.864	-2.57	I(1)	
PP	level, constant	NZBBR	-2.41	-3.44	-2.864	-2.57	I(1)	
PP	level, constant	log(NZSE)	0.16	-3.44	-2.864	-2.57	I(1)	
PP	level, constant	log(NZDUSD)	-1.68	-3.44	-2.864	-2.57	I(1)	
PP	level, trend	USTBR	-3.76	-3.97	-3.42	-3.13	I(0)	
PP	level, trend	log(S&P500)	-1.7	-3.97	-3.42	-3.13	I(1)	
PP	level, trend	NZBBR	-2.78	-3.97	-3.42	-3.13	I(1)	
PP	level, trend	log(NZSE)	-1.76	-3.97	-3.42	-3.13	I(1)	
PP	level, trend	log(NZDUSD)	-2.02	-3.97	-3.42	-3.13	I(1)	
PP	1st-difference, constant	USTBR	-95.58	-3.44	-2.86	-2.57	I(0)	
PP	1st-difference, constant	log(S&P500)	-34.38	-3.44	-2.86	-2.57	I(0)	
PP	1st-difference, constant	NZBBR	-31.65	-3.44	-2.86	-2.57	I(0)	
PP	1st-difference, constant	log(NZSE)	-30.9	-3.44	-2.86	-2.57	I(0)	
PP	1st-difference, constant	log(NZDUSD)	-31.72	-3.44	-2.86	-2.57	I(0)	
KPSS	level, constant	USTBR	12.37	0.74	0.46	0.35	I(1)	
KPSS	level, constant	log(S&P500)	15.55	0.74	0.46	0.35	I(1)	
KPSS	level, constant	NZBBR	12.4	0.74	0.46	0.35	I(1)	
KPSS	level, constant	log(NZSE)	12.56	0.74	0.46	0.35	I(1)	
KPSS	level, constant	log(NZDUSD)	8.01	0.74	0.46	0.35	I(1)	
KPSS	level, constant and trend	USTBR	0.7	0.22	0.15	0.12	I(1)	
KPSS	level, constant and trend	log(S&P500)	1.98	0.22	0.15	0.12	I(1)	

KPSS	level, constant and trend	NZBBR	0.55	0.22	0.15	0.12	I(1)	
KPSS	level, constant and trend	log(NZSE)	1.18	0.22	0.15	0.12	I(1)	
KPSS	level, constant and trend	log(NZDUSD)	1.21	0.22	0.15	0.12	I(1)	
KPSS	1st-difference, constant	USTBR	.11	0.74	0.46	0.35	I(0)	
KPSS	1st-difference, constant	log(S&P500)	.12	0.74	0.46	0.35	I(0)	
KPSS	1st-difference, constant	NZBBR	.17	0.74	0.46	0.35	I(0)	
KPSS	1st-difference, constant	log(NZSE)	.22	0.74	0.46	0.35	I(0)	
KPSS	1st-difference, constant	log(NZDUSD)	.08	0.74	0.46	0.35	I(0)	
ZA	level, constant	USTBR	-4.27	-5.34	-4.8	-4.58	I(1)	15/12/2000
ZA	level, constant	log(S&P500)	-2.77	-5.34	-4.8	-4.58	I(1)	12/10/2007
ZA	level, constant	NZBBR	-3.9	-5.34	-4.8	-4.58	I(1)	03/10/2008
ZA	level, constant	log(NZSE)	-3.3	-5.34	-4.8	-4.58	I(1)	19/10/2007
ZA	level, constant	log(NZDUSD)	-3.28	-5.34	-4.8	-4.58	I(1)	27/09/2002
ZA	level, trend	USTBR	-4.03	-4.93	-4.42	-4.11	I(1)	16/05/2014
ZA	level, trend	log(S&P500)	-2.18	-4.93	-4.42	-4.11	I(1)	02/02/1996
ZA	level, trend	NZBBR	-3.13	-4.93	-4.42	-4.11	I(1)	21/12/1990
ZA	level, trend	log(NZSE)	-2.63	-4.93	-4.42	-4.11	I(1)	23/12/2011
ZA	level, trend	log(NZDUSD)	-2.43	-4.93	-4.42	-4.11	I(1)	13/09/2013
ZA	level, constant and trend	USTBR	-4.67	-5.57	-5.08	-4.82	I(1)	02/11/2007
ZA	level, constant and trend	log(S&P500)	-3.36	-5.57	-5.08	-4.82	I(1)	01/09/2000
ZA	level, constant and trend	NZBBR	-3.89	-5.57	-5.08	-4.82	I(1)	03/10/2008
ZA	level, constant and trend	log(NZSE)	-4.86	-5.57	-5.08	-4.82	I(1)	28/12/2007
ZA	level, constant and trend	log(NZDUSD)	-3.36	-5.57	-5.08	-4.82	I(1)	09/08/2002
ZA	1st-difference, constant	USTBR	-44.96	-5.34	-4.8	-4.58	I(0)	
ZA	1st-difference, constant	log(S&P500)	-26.81	-5.34	-4.8	-4.58	I(0)	
ZA	1st-difference, constant	NZBBR	-22.17	-5.34	-4.8	-4.58	I(0)	
ZA	1st-difference, constant	log(NZSE)	-24.76	-5.34	-4.8	-4.58	I(0)	
ZA	1st-difference, constant	log(NZDUSD)	-26.57	-5.34	-4.8	-4.58	I(0)	

Note: Table reports the test statistics and critical values at 1%, 5%, and 10% levels of significance in the ADF, the PP, the KPSS, and the ZA unit root tests for five series, including US 3-month Treasury bill rate (USTBR), natural log of the S&P500 index (log(S&P500)), New Zealand 3-month Bank bill rate (NZBBR), natural log of New Zealand stock price index (log(NZSE)), and natural log of nominal bilateral exchange rate of NZD against USD (log(NZDUSD)). The sampled period is 12/01/1990 – 27/12/2019 using all available data. Column Result indicates the series is non-stationarity (I(1)) or stationary (I(0)) at 5% level of significance. The last column reports the suggested break dates in the ZA test.

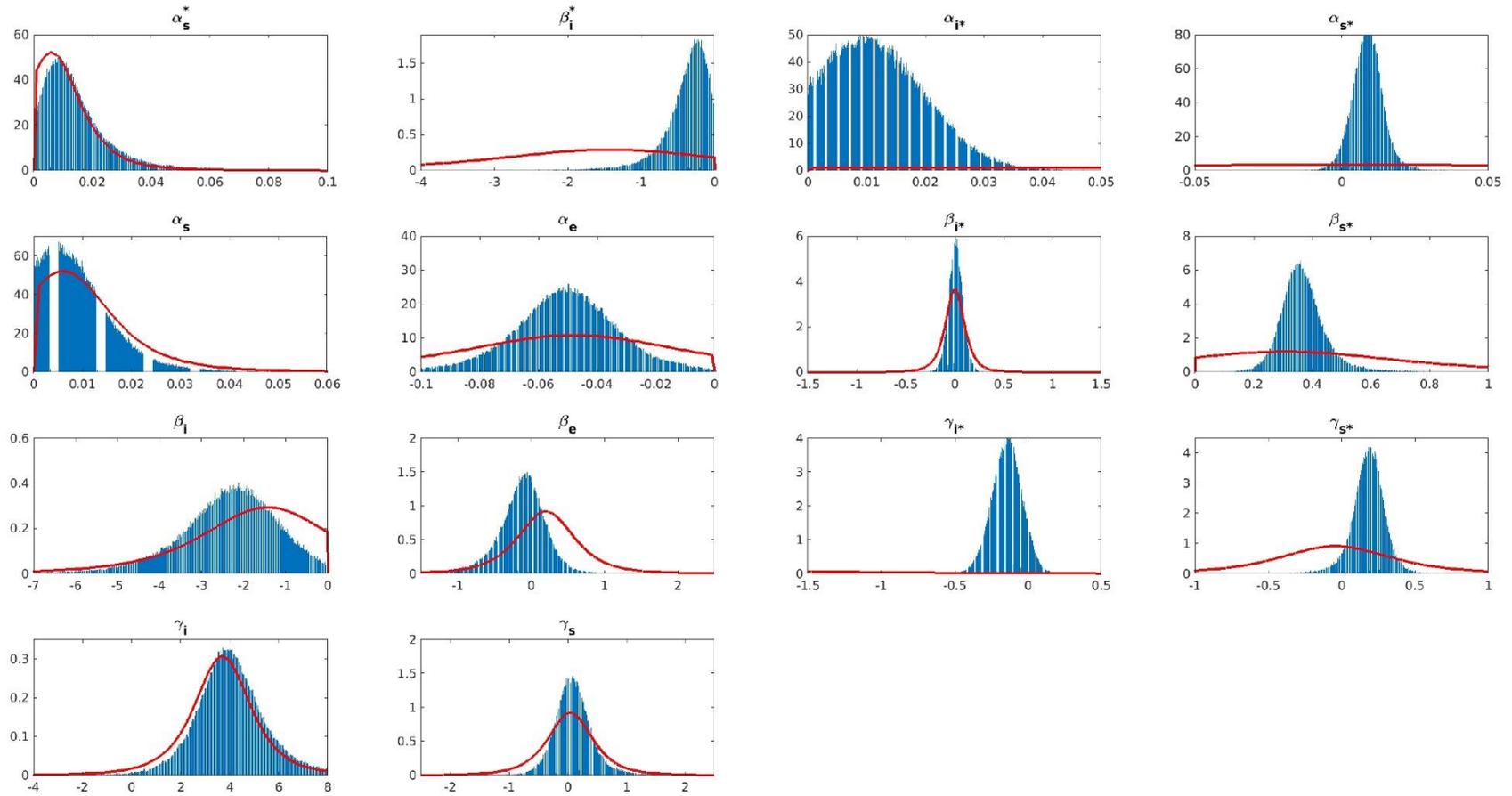
ADF test: Null hypothesis: Series is non-stationary; Alternative hypothesis: Series is stationary. Reject the null hypothesis if test-statistic is larger than the critical values at 5% significance in absolute term. PP test: Null hypothesis: Series is non-stationary; Alternative hypothesis: Series is stationary. Reject the null hypothesis if test-statistic is larger than the critical values at 5% significance in absolute term. KPSS test: Null hypothesis: Series is stationary; Alternative hypothesis: Series is non-stationary. Reject the null hypothesis if test-statistic is larger than the critical values at 5% significance in absolute term. ZA test: Null hypothesis: the series has a unit root with structural break(s); Alternative hypothesis: Series are stationary with break(s). Reject the null hypothesis if t-value statistic is lower than the critical value at 5% significance (left tailed test).

Table A.3 Short-run impact of NZD exchange rate on New Zealand stock price: Simple OLS estimations

<i>Dependent variable: $\Delta LNZSE$</i>	(1)	(2)	(3)	(4)
L. $\Delta LNZSE$	0.251*** (0.040)	0.249*** (0.040)	0.250*** (0.040)	0.241*** (0.040)
L2. $\Delta LNZSE$	-0.026 (0.037)	-0.028 (0.037)	-0.027 (0.037)	-0.029 (0.037)
L3. $\Delta LNZSE$	0.026 (0.033)	0.024 (0.033)	0.024 (0.033)	0.022 (0.033)
L4. $\Delta LNZSE$	0.017 (0.032)	0.015 (0.032)	0.015 (0.032)	0.014 (0.032)
L5. $\Delta LNZSE$	-0.056** (0.028)	-0.058** (0.028)	-0.057** (0.028)	-0.057** (0.028)
L. $\Delta LNZDUSD$	0.052* (0.032)	0.052* (0.031)	0.052* (0.032)	
$\Delta LNZDUSD$	0.218*** (0.042)	0.217*** (0.042)	0.217*** (0.042)	0.210*** (0.040)
D1		-0.002 (0.001)		
D2			-0.002 (0.001)	
D3				0.003** (0.001)
Time trend		0.000 (0.000)	0.000 (0.000)	-0.000 (0.000)
Observations	1596	1596	1596	1596
R-squared	0.100	0.102	0.101	0.101

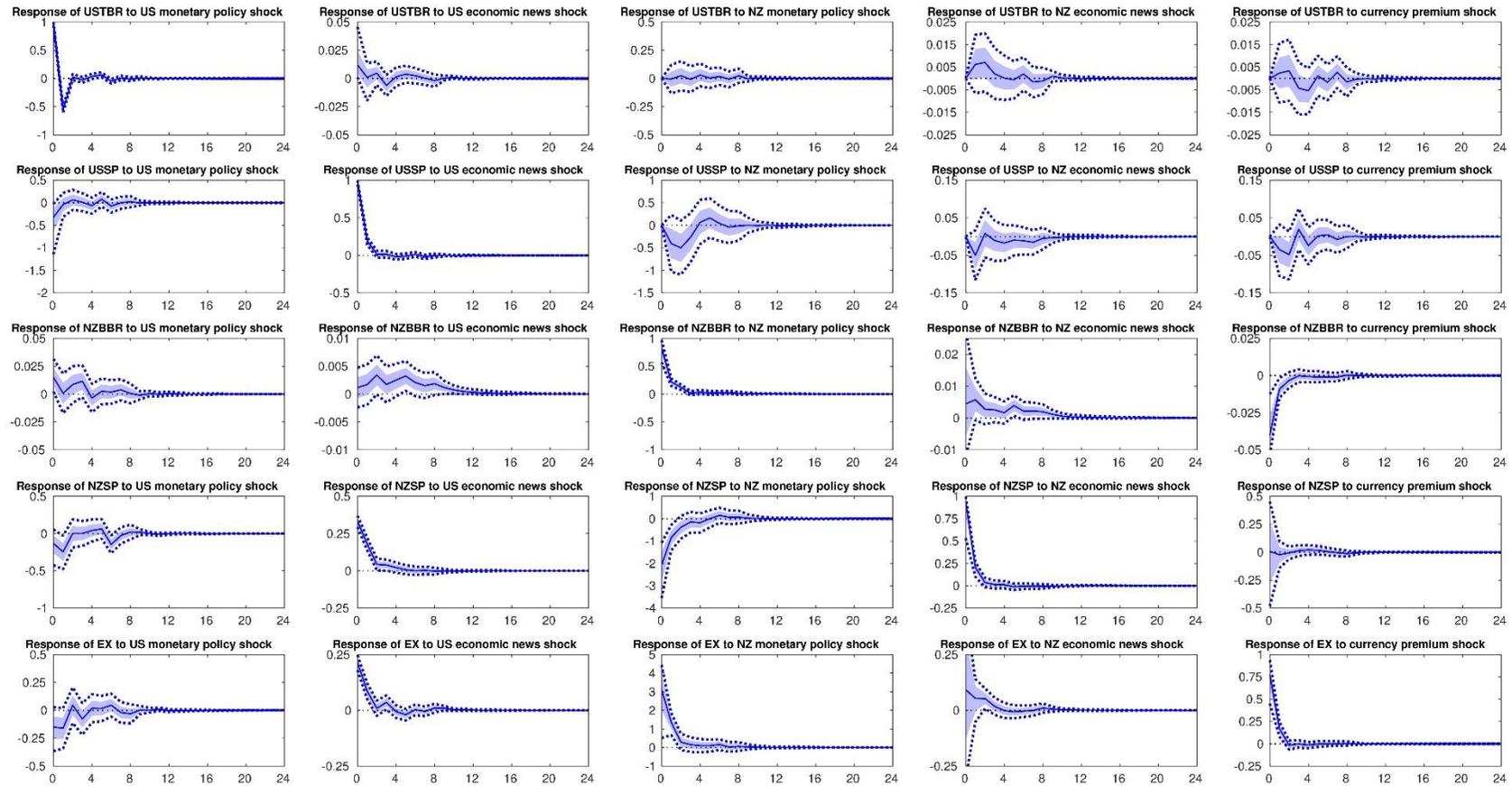
Note: $\Delta LNZSE$ and $\Delta LNZDUSD$ are log-differences of the New Zealand stock price and exchange rate of NZD against USD; the dummy variables: $D1$ gets 1 since 19/10/2007 and 0 otherwise, $D2$ gets 1 since 28/12/2007 and 0 otherwise, or $D3$ gets 1 since 23/12/2011 and 0 otherwise. The variables $L.\Delta LNZSE$, $L2.\Delta LNZSE$, etc. are the lags of dependent variables. Standard errors are in parentheses. ***, **, *: 1%, 5%, 10% significance.

Figure A.1 Allowing international cross-market effects: Prior and posterior distributions



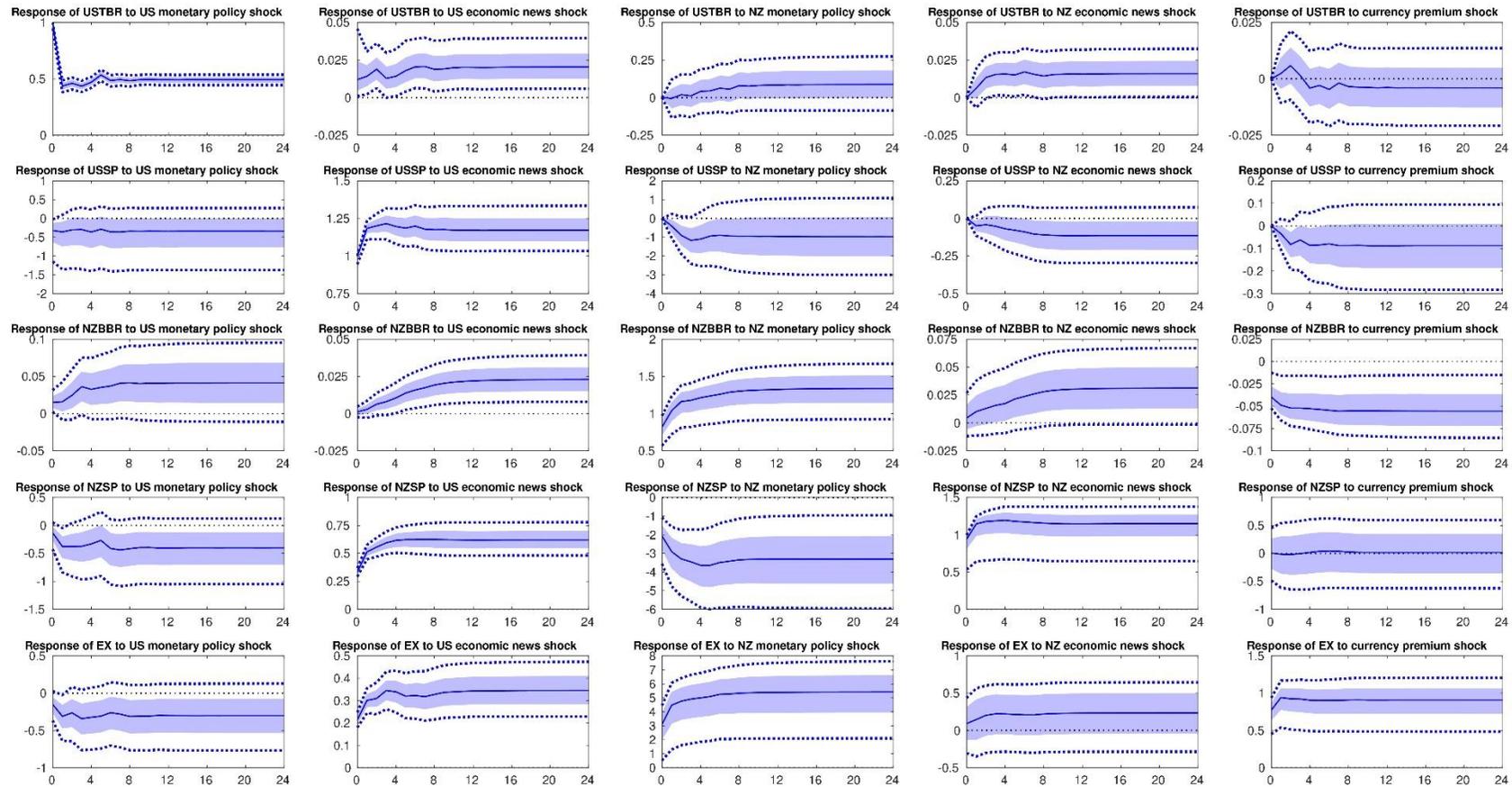
Note: Prior distribution (red lines) and posterior distributions (blue histogram) for contemporaneous coefficients.

Figure A.2 Allowing international cross-market effects: Structural impulse-response functions and prior median



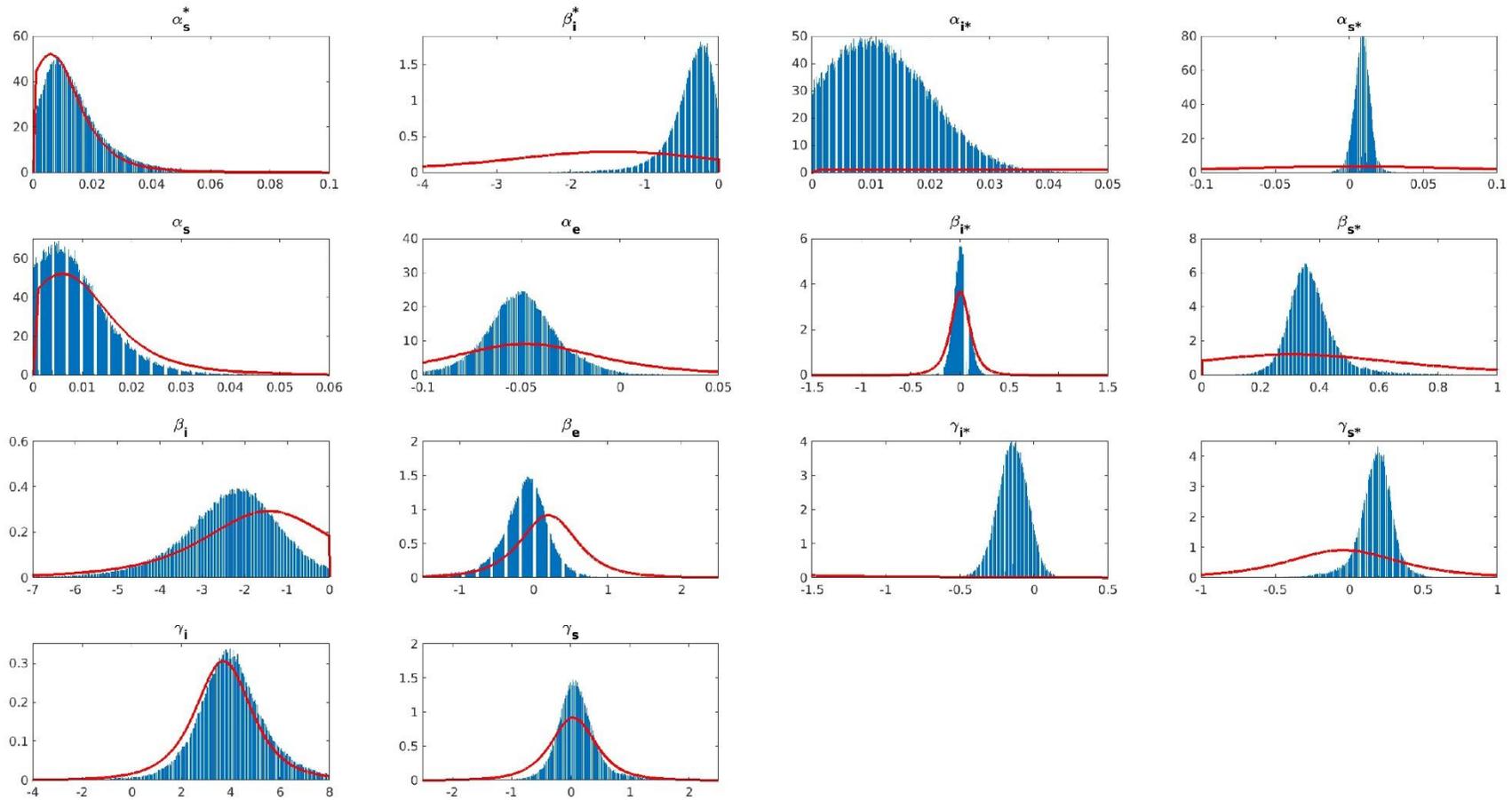
Note: Structural impulse-response functions. Solid blue lines: posterior median. Shaded region: 68% posterior credibility set. Dotted blue lines: 95% posterior credibility set. USTBR: US 3-month Treasury bill rate, USSP: US stock price, NZBBR: New Zealand 3-month Bank bill rate, NZSP: New Zealand stock price, EX: exchange rate of NZD against USD.

Figure A.3 Allowing international cross-market effects: Cumulative impulse-response functions



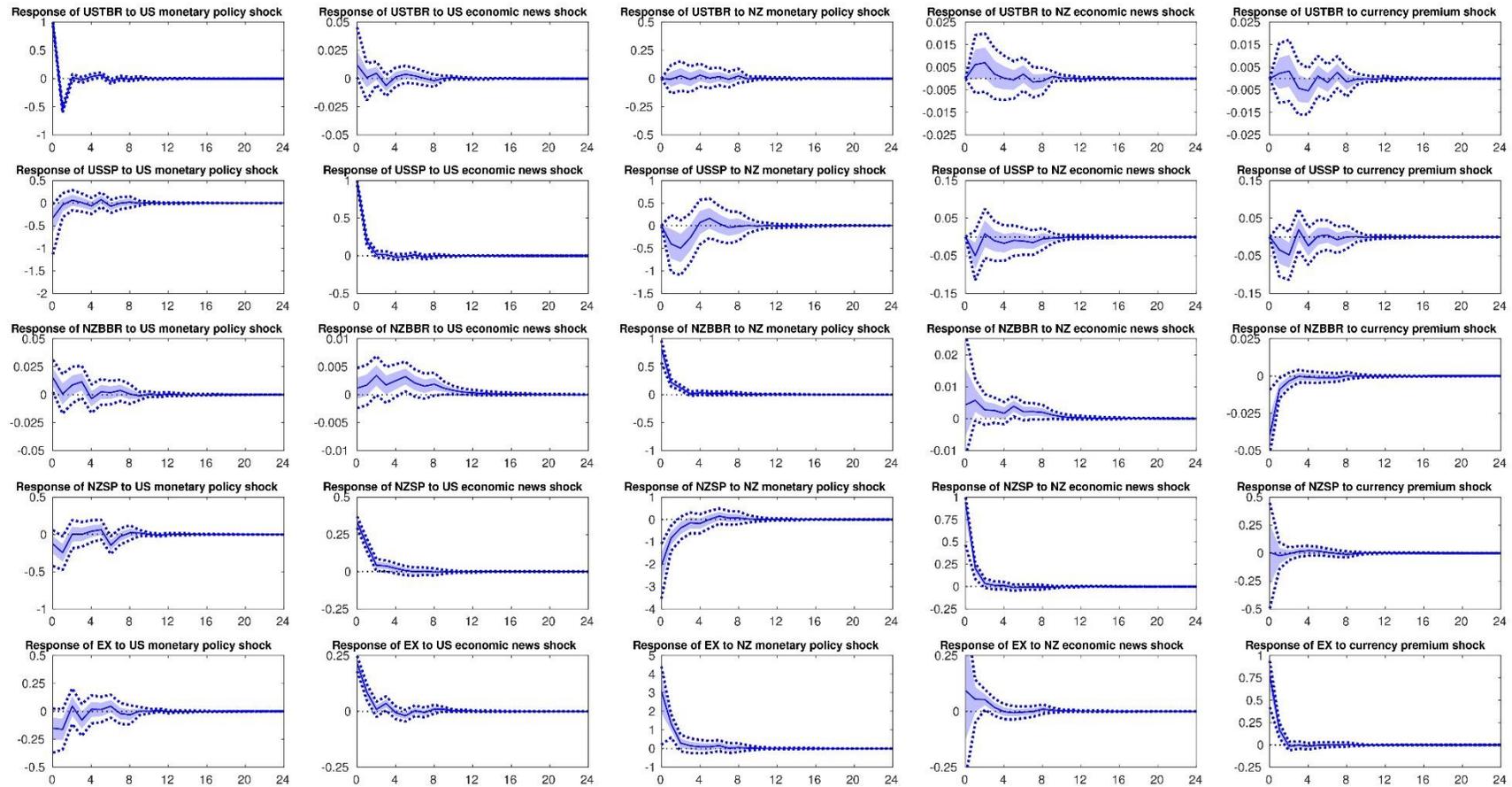
Note: Cumulative impulse-response functions. Solid blue lines: posterior median. Shaded region: 68% posterior credibility set. Dotted blue lines: 95% posterior credibility set. USTBR: US 3-month Treasury bill rate, USSP: US stock price, NZBBR: New Zealand 3-month Bank bill rate, NZSP: New Zealand stock price, EX: exchange rate of NZD against USD.

Figure A.4 Allowing international cross-market effects and relaxing effect of exchange rate on interest rate: Prior and posterior distributions



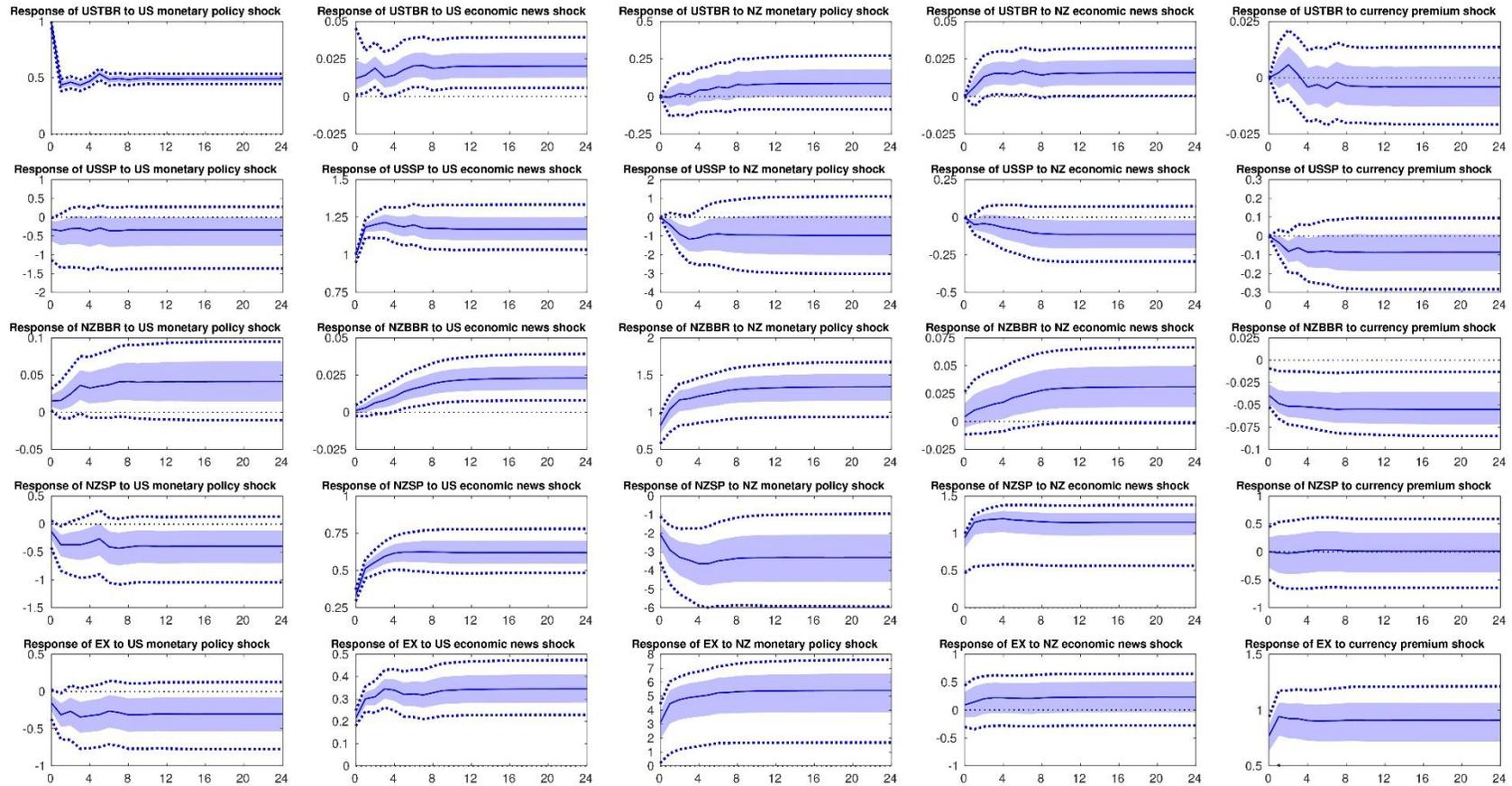
Note: Prior distribution (red lines) and posterior distributions (blue histogram) for contemporaneous coefficients.

Figure A.5 Allowing international cross-market effects and relaxing effect of exchange rate on interest rate: Structural impulse-response functions and prior median



Note: Structural impulse-response functions. Solid blue lines: posterior median. Shaded region: 68% posterior credibility set. Dotted blue lines: 95% posterior credibility set. USTBR: US 3-month Treasury bill rate, USSP: US stock price, NZBBR: New Zealand 3-month Bank bill rate, NZSP: New Zealand stock price, EX: exchange rate of NZD against USD.

Figure A.6 Allowing international cross-market effects and relaxing effect of exchange rate on interest rate: Cumulative impulse-response functions



Note: Cumulative impulse-response functions. Solid blue lines: posterior median. Shaded region: 68% posterior credibility set. Dotted blue lines: 95% posterior credibility set. USTBR: US 3-month Treasury bill rate, USSP: US stock price, NZBBR: New Zealand 3-month Bank bill rate, NZSP: New Zealand stock price, EX: exchange rate of NZD against USD.

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