International spill-overs of uncertainty shocks: Evidence from a FAVAR*

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Abstract

This paper analyses the international spill-overs of uncertainty shocks originating in the US to the New Zealand economy. We propose an open economy, structural factor-augmented vector autoregression (FAVAR) model that allows us to identify the impact of shocks to uncertainty in the US. We first show that unexpected increases in uncertainty are isomorphic to negative demand shocks in the US. Second we find that the US specific uncertainty shock is associated with synchronized downturns in the rest of the world and falling international commodity prices. Last, we investigate the direct and indirect transmission channels of uncertainty shocks as the FAVAR approach provides us with a detailed characterization of sectorial dynamics in New Zealand.

*The views expressed here are the views of the authors and do not necessarily reflect the views of our employers, the Reserve Bank of New Zealand or the New Zealand Treasury. Özer Karagedikli (corresponding author), Reserve Bank of New Zealand, PO Box 600, Wellington, New Zealand. ozer.karagedikli@rbnz.govt.nz.
1 Introduction

The degree of monetary and fiscal stimulus that has been used in the U.S. economy are at unprecedented levels. Similar stimulus have also been in place in many other countries in the world, the UK, the Euro area and Japan for example. Despite these, the recovery in the US economy has been slow at best. Unemployment rate has stubbornly been above 8 per cent for example. Many economists/commentators have put forward the uncertainty about future economic conditions as the main factor behind very slow nature of the recovery. At the same time, the uncertainty stemming from the US economy may be of relevance for small open economies.

We examine the international dimensions of uncertainty shocks by analysing the international transmission of uncertainty shocks to small open economies by using a factor-augmented vectorautoregression. In particular, we identify uncertainty shocks originating in the US, the largest economy in the world, and how it transmits to the rest of the world, in particular to small open economies. Our paper fills in two gaps in this literature where the effects of uncertainty shocks are examined: First, for the US economy, we test the effects of uncertainty shock in a data-rich environment by using a factor-augmented vectorautoregression (FAVAR, see Bernanke et al 2005 among others). Second, we examine the international transmission of uncertainty shocks hitting the US economy again using the same “data-rich” approach. The data-rich, the FAVAR, has a number of advantages over a small “limited information” VAR on top of its ability to cover a large amount of information.

Because the FAVAR uses a large amount of information that enables us to examines the different channels through which the uncertainty shock might be transmitting to the US economy as well to the world and to small open economies, like New Zealand. Bloom and Fernandez-Villaverde (2012) reviews the different channels through which uncertainty may affect the economy for example. The empirical, mostly VAR, evidence does not go into the details a data-rich environment may uncover in terms of the channels that transmit the shock. For example, we know little about the extend to which the expectations of the households and firms are affected by the uncertainty shock. Our data set information from labour markets for example as well as “forward looking” survey measures which can help us to distinguish the relative importance of these different channels in transmitting the shock. To our knowledge this expectations channel has not been investigated previously in the context of uncertainty literature, which we do believe might be of great importance. For example, in response to an uncertainty shock people’s expectations about future growth prospects might be falling or firms' intentions to hire might be falling. The data rich approach to the empirical analysis of the uncertainty shock would enable us to discriminate between different channels proposed in the literature.

We find that overall, the uncertainty shock acts like a demand shock, similar to Leduc and Lui (2012)
where the effects on the US economy are not negligible. However, the effects of the uncertainty shock does not stay within the boundaries of the US economy: It has significant implications for the growth in the world economy, commodity prices, and small open economies. We find that the GDP growth slows down in most economies and most commodity prices fall in response to an uncertainty shock. The responses of a small open economy like New Zealand is also interesting: New Zealand is affected both from demand perspective for its commodity products as well as the prices of its commodities. As a result, unemployment in New Zealand increases by and the GDP growth falls. The interest rates fall in response to this shock, while the nominal exchange rate depreciates significantly, which is consistent with the fallen commodity prices (Chen and Rogoff 2003) and lower interest rates in New Zealand than the US.

The remainder of the paper is structured as follows: Section 2 briefly discusses the literature, section 3 introduces the empirical framework, and discusses estimation and identification, section 4 presents and discusses the results. Section 5 presents the robustness results and section 6 concludes.

2 Literature review

Uncertainty and its effects can be dated back to seminal analysis of Pyndyk (1991) in which they showed that in uncertain times the effects of irreversibility in investment generates option value in waiting and hence reduces investment. Bloom (2009) in a seminal work re-vitalised the issue in a macro context. Although the earlier literature showed the effects on investment, the effects of uncertainty on broader set of macroeconomic variables was unknown.

Bloom (2009) presents simulations from a model where higher uncertainty causes firms to pause their hiring and investment which leads to a decline in economic activity. Fernández-Villaverde, Guerrón-Quintana, Rubio-Ramírez and Uribe (2009), by using a non-linear small open economy DSGE model, provides an important channel through which changes in real interest rate volatility can affect small open economies that use foreign debt to smooth consumption and to hedge against idiosyncratic productivity shocks. As real interest rate volatility/uncertainty increases these small open economies which borrow to smooth their consumption become increasingly exposed to variations in marginal utility of borrowing. As a consequence they reduce their level of foreign debt/borrowing by reducing consumption. As a result these countries experience a major slowdown and re-balancing in their economies.

On the empirical side, there are a number of papers that have tested the effects of uncertainty on measures of real activity, inflation and financial markets (Alexopoulos and Cohen (2009), Bloom (2009),

1See Leahy and Whitehead (1996) for an empirical investigation of uncertainty at firm level.
Bachmann, Elstner and Sims (2011), Baker, Bloom and Davis (2011), Kose and Torennies (2012) and Mumtaz and Theodoridis (2012)).

From a theoretical, and also empirical, perspective one of the hotly debated issue is whether the uncertainty shocks act like an aggregate demand shock or a different kind of shock, for example, like an aggregate supply shock. This issue is of great importance for the policymakers as the latter would leave an inflation targeting central bank with a trade off between output and inflation stabilisation. Moreover, an aggregate demand kind of shock would require interest rates to be cut while the aggregate supply kind shock (a negative technology) shock would probably require interest rates to rise.

Leduc and Lui (2012) combine a standard New Keynesian DSGE model with search and matching type labour markets to allow for frictions in the labour markets. Based on their model they argue that in a model with sticky prices an uncertainty shock unambiguously acts like an aggregate demand shock: real activity declines, unemployment increases, inflation falls and interest rates fall. These results are irrespective of the effects on the potential growth. In the sticky price world, the effects of uncertainty shock are amplified during recessions due to fluctuations in the relative price of intermediate goods or the markup in the retail sector. Leduc and Lui (2012) also provide VAR evidence for the US and the UK and using different measures of uncertainty and identification structure that uncertainty shock acts like an aggregate demand shock.

Mumtaz and Theodoridis (2012) is closest to our paper, where by using non-linear techniques they analyse the effects of uncertainty shocks originating in the US economy on the UK economy. They find that an increase to the volatility of the shock to the US GDP leads to a decline in the UK GDP growth and an increase in the UK inflation. They find that shocks that generate marginal cost uncertainty (for example a wage mark-up and productivity) in the foreign economy can generate this kind of results.

Basu and Bundwick (2011) for example show that in an RBC model higher uncertainty lowers consumption and creates incentives for households to work harder as the given wage rate. As a result the potential output increases. At the same time the frictions in the labour markets lead to a different channel through which uncertainty shock affects potential output (Leduc and Lui 2012): In their model the long term employment relationship between the firm and the workers represents some value. As a result in response to an uncertainty shock the value of this relationship declines and hence the incentive for firms to post vacancies. Consequently, the job finding rate declines and unemployment increases.

Another major issue in the uncertainty literature is the measure of uncertainty and how to measure it. Probably there are different kinds of uncertainties, for example an uncertainty about the future demand is different that the uncertainty about the future supply of oil or commodities, or uncertainty
about the fiscal position of a government. For this reason different researchers have resorted to different measures of it. Most of this literature use an observed measure of uncertainty. For example the VIX index, which measures the implied volatility in the S&P 500 stock price index is a commonly used one. In addition to this, a particular question from the Michigan Survey of Consumers is used. Mumtaz and Theodoridis (2012) use the changes in the stochastic volatility term in their time-varying stochastic volatility VAR as a measure of uncertainty for example.

3 Empirical Framework: Model, Estimation and Identification

The VAR approach to measuring the effects of different shocks have appeared to produce a lot of useful information on the structural questions researchers and policymakers have in mind. However, the VAR approach has had some major criticism as well. One of the major criticisms of the VAR approach to identification of shocks is the low dimensionality of the information sets used in these so-called “limited information” VARs. Most small open economy VARs include a handful of variables. However, the actual economy includes a much larger information. A related criticism from use of such limited information in VARs where the researchers/policymakers can only observe the effects of the shocks on the same limited number of variables. Researchers and policymakers would probably like to see the effects of the shocks on a number of different variables. This is particularly important given small number of variables would all have their own idiosyncracies.

The FAVAR approach combines the old SVAR approach with estimated unobserved factors stemming from the more recent dynamic factor literature. The recent dynamic factor model literature argues that a large number of series can be summarised by a small number of factors, which is an attempt to overcome the criticism discussed above. Therefore the factor approach helps in reduction of dimensionality with large data sets. Our factor augmented vector autoregression model (FAVAR) uses the general setup of Bernanke et al. (2005). Since the factors we estimate are unobserved and have to be inferred from the data, the model can naturally be represented in a state space form in the following way:

\[
\begin{bmatrix}
    F_t \\
    Y_t
\end{bmatrix} = \beta(L) \begin{bmatrix}
    F_{t-1} \\
    Y_{t-1}
\end{bmatrix} + u_t, \tag{1}
\]

where \( F_t \) is a set of unobserved factors, and \( Y \) are a observed variables, interest rate and the exchange rate in our case. \( \beta(L) \) is a conformable lag polynomial of order \( p \) and \( u_t \) is the reduced form residuals. The structural disturbances follow \( u_t = \Omega^{1/2} \varepsilon_t \), with \( \varepsilon \sim N(0, 1) \) and \( \Omega = A_0(A_0)' \).

The observation equation of the system is:
\[ X_{i,t} = \Lambda^F F_t + \Lambda^Y Y_t + e_t, \] (2)

where \( X_t \) is a N x 1 vector, \( \Lambda^F \) and \( \Lambda^Y \) are N x K and N x 1 matrixes of factor loadings. Finally \( e_t \) is a N x 1 vector of idiosyncratic, zero mean, disturbances.

The first equation is the transition equation in the state space representation while the second equation is the observation equation. The seminal work of Bernanke et al. (2005) introduced this framework and used it to analyse the effects of a shock to the monetary policy (Fed Funds rates, in their case) in the transition equation and its transmission to each variable in the \( X_{i,t} \) matrix.

The large data set, \( X_{i,t} = [X_{f,i,t} X_{d,i,t}] \) contains our data set, \( X^f \) refers to the foreign data-set, which includes economic variables from the US and from the world. The reason for this is that we will be allowing the uncertainty index (VIX index, in our baseline model) to respond to economic/financial developments in the US and also in the world. \( X^d \) refers to the domestic, New Zealand, data set. We first extract factors from both of these data sets separately.

We estimate the factors using the principal component approach. One important question in the use of principal component of course is the number of the principal components. Statistical tests such as Bai and Ng (2002) provide criteria to determine the number of factors present in the dataset \( X \). However, as Bernanke et al. (2005) argue, this criterion does not address the question of how many factors to include in the VAR in order to identify the shock that we are interested in. We will be discussing these in the factors section.

We estimate models with five foreign factors and three domestic factors. However, we should caution that our sample size is rather limited on the time series dimension (1994Q3 through 2012Q1) which implies that the model may suffer from degrees of freedom issues when an additional factor (variable) is added to the VAR. After estimating the principal components, we place them in the VAR along with the observed uncertainty variable, the VIX index.\(^2\)

Identification in a FAVAR involves the identification of the factors and the associated loadings, and also the identification of the shocks. In our two step estimation with principal components we use the standard identification technique in principal components: We can either choose to restrict the loadings by \( \Lambda^F \Lambda^F/N = I \) or restrict the factors by \( F'F/T = I \). Either approach would deliver the common principal components that are orthogonal.

For the identification of the uncertainty shock we use a in the VAR we use a Cholesky identification scheme. The variables are ordered in the following order: VIX index, international factors and domes-

\(^2\)We also test for other measures of uncertainty measures and present them in robustness section (section ??).
tic factors, which assumes that the VIX index is the most exogenous one given when the VIX index is determined the market participants (where the implied volatility is determined) do not have information about the current quarter information for the other variables. However, some of the variables in the international block are so-called “fast moving” asset price variables and might be affecting the VIX. For robustness of our results, we order VIX after the international factors, and we also use the Bernanke et al. (2005) slow moving/fast moving identification. We also impose the block exogeneity where the domestic factors do not affect the VIX and the international factors.

4 Results

In this section we present the results from our estimation. In section we present and discuss the estimated factors. In section 4.2 we present impulse responses of the US variables to a one standard deviation shock to the level of VIX index. Sections 4.2 and 4.4 present the impulse responses for the world and the New Zealand variables respectively. In subsection 4.5 we present the forecast error variance decompositions and finally in subsection 4.6 we present the historical decomposition for some variables.

4.1 Factors

Figure 1 plots the estimated factors. Aside from splitting our factors into foreign and domestic factors to allow us to impose structure on the VAR, we are agnostic of the factors and let “the data decide”. Alternative approaches would be to loosely group the data as activity variables, price variables etc and take factors, or by country, as US variables, European variables etc, but it is unclear a priori which is the best way to group the data hence we adopt our entirely agonistic approach.

Consistent with our data driven approach we examine the eigenvalues from the eigenvalue-eigenvector decomposition of the sample co-variance to determine the number of factors. Visually inspecting Figure 2 shows that 2 domestic factors and 5 domestic factors is where we begin to observe gradient changes in the scree plot; this represents the point where the remaining variance in the data explained by additional factors is small and therefore little to gain from adding more factors.

Factors are entirely statistical phenomena by construction, never-the-less it is useful to examine their correlations with observed variables to give them some economic meaning and help us understand our results. The first foreign factor is correlated (around 0.5) with various foreign GDP variables, as well as long dated interest rates. The second factor is highly correlated with commodity prices, while the third factor is correlated with nominal exchange rates. Factor four appears to be correlated
with inflation variables; whilst the fifth factor appears to be European specific (being correlated with European exports, capacity utilisation and both the real and nominal exchange rate).

It is also informative to see how much of the variance in some key series are explained by the factors using the R-squared, which is shown in table 1. For quarterly growth in GDP the factors explain as little as 19% for Australia to around 75% for the Euro area; with the R-squared for Canada, U.K. and U.S. all being in the mid- to high-sixties. A considerable proportion of world commodity prices is explained by the factors (82%), which is encouraging given this is a likely channel through which an uncertainty shock would be transmitted to New Zealand and therefore it is important that this channel can be captured by our model. The heterogeneity of R-squared numbers we observed across countries for GDP is also present for nominal exchange rates and inflation. Our factors generally explain between 55% and 78% of individual country exchange rates, with the exception of Japan where they only explain 19%. Japan (22%), along with Canada (44%), is also on the outlier for inflation, with the R-squared in the other countries generally being between 62% and 76%. The R-squared for short term interest rates ranges between 70% for Japan and 84% for the US.

Table 2 reports the R-Squared for some key New Zealand variables. The domestic factors explain more than half the variance in 90 day rates, GDP, unemployment rate and the exchange rate; the R-squared on inflation is also reasonably high at 49%. These reasonably high R-squared values give us a degree of comfort that the domestic factors are capturing the New Zealand economy well.

4.2 Impulse responses - US Economy

Figure 3 shows the impact of a one standard deviation uncertainty shock on key US variables. Following the shock GDP immediately falls, as does the unemployment rate, with the shock taking about a year to dissipate. Reflecting the fall in output (as well as the appreciation of the US exchange rate (Figure 6) inflation in the US falls and the FED funds is cut 150 basis points. The appreciation of the exchange rate is consistent with a model of international risk sharing, where a shock to consumption in the US (brought about through more household saving owing to precaution owing to increased uncertainty) would see an appreciation in the exchange rate to make imported consumption goods cheaper. Alternatively it is consistent with the common perception in financial markets that the US dollar is a safe haven currency and thus in times of increased uncertainty capital flows out of currencies perceived to be more risky to the US dollar. Leduc and Liu (2012) on the basis on their DSGE and VAR modelling concluded that uncertainty shocks in the US look like aggregate demand shock. Our results, using a slightly different framework, a FAVAR, confirm this result with output, inflation and interest rates falling and unemployment rising - dynamics all consistent with a demand shock.
In terms of the sub-components of GDP, figure 4 shows private investment falls by more than consumption. Gilchrist, Sim and Zarkrajsek (2010) decompose individual firm equity variability into firm specific and macroeconomic uncertainty. This macroeconomic uncertainty then enters a VAR with observed macroeconomic variables such as business investment, GDP and the fed funds rate. They find business investment responses more than GDP, as we do.

The mortgage loan rate spread (over the funds rate) increases (figure 6) indicating that the increased uncertainty sees lending institutions require more of a risk premium. The fall in the Fed Funds rate is still more than the increase in the spread however meaning households in the US economy still face lower borrowing rates. However falls in house prices sees residential investment decrease. The fall in house prices can be explained by lower incomes suppressing the demand for new houses or, perhaps more plausibly, if one views house prices as an asset price, reflecting the deterioration in the prospects for US economy.

4.3 Impulse Responses - World Economy

Turning to the impact on other economies, the shock has the largest impact on Japanese GDP, while the impact on Canadian, European and UK GDP is similar in magnitude to the impact on US GDP. Interestingly Australian GDP is not affected much at all, although Australian industrial production shows similar falls as other countries’ GDP (5). The discrepancy between Australian industrial production and GDP may reflect export of services, which would have been boosted by the large depreciation in the Australian effective exchange rate (6). In fact it is interesting to note that all the traditional commodity currencies (Chen and Rogoff, 2003) depreciate (Canada, Australia and New Zealand) consistent with commodity prices falling; this finding supports. As expected the increase in uncertainty sees a fall in stock markets around the world (figure 7).

Despite the large relative fall in Japanese GDP, the fall in Japanese CPI is moderate relative to other countries. This reflects the fact that the Yen actually appreciates on a trade weighted basis. However all the major Japanese macroeconomic variables had low R-squared relative to other countries’ equivalents so care needs to be taken in interpreting Japanese results.

4.4 Impulse Responses - New Zealand Economy

Turning to the New Zealand results, the shock affects New Zealand’s GDP with a lag but the order of magnitude of the impact similar to US and the other advanced economies (excluding Japan and Australia). The magnitude of the interest rate fall is much larger in New Zealand than in other advanced economies and this explains the fall in the exchange rate, through the uncovered interest
parity condition. Inflation does not fall as much as the US, consistent with the depreciation in the exchange rate generating tradables inflation offsetting less non-tradables inflation owing to more of an output gap. Karagedikli and Price (2012) show that if New Zealand was hit by a foreign demand shock output, inflation and interest and exchange rates all fall, as we find here. Extending the Leduc and Liu (2012) analogy, foreign uncertainty shocks to the New Zealand economy are like foreign demand shocks.

Consistent with the dynamics observed in the US, private consumption is less affected than private investment. Breaking the sub-components of investment out we see both transport equipment and computer investment is affected the most. Given transport equipment investment is generally large, deferrable (able to be put off and existing equipment able to be used for longer) and generally imported (and thus sensitive to the value of the dollar, which depreciates here making imports more expensive) this is understandable. Computers are also generally imported and deferrable, which may explain their large relative fall.

The fall in gross earnings is less than the aggregated fall in private consumption and the CPI (a proxy for nominal consumption) meaning, all else equal, household savings increased - a dynamic consistent with precautionary saving. The new customer floating mortgage rate falls by less than 90 day rate indicating the shock, as in the US, sees a risk premium to lending applied by New Zealand banks. However the mortgage rate and the borrowing rate of Small-Medium Enterprises (SME) still fall around 150 and 90 basis points respectively meaning that the fall in private sector credit we observe reflects, at least in part, a fall in demand from the private sector for credit.

New Zealand falls against all the major currencies except Australia. Given New Zealand the commodity currency nature of New Zealand and the fact that the interest rates fall by more than its major trading partners this would be expected. The reason the New Zealand does not fall against the Australian dollar might reflect the fact, as mentioned above, both currencies are considered commodity currencies and as we saw above that commodity prices fell which would affect both the New Zealand and Australian dollars.\(^3\)

### 4.5 Variance decomposition

The variance decomposition seeks to decompose the forecasting error variance of any particular variable at different time horizons, by its source. Table 3 presents the variance decomposition of the VIX owing to the VIX itself, and shows most of the forecast variance of the VIX is indeed to itself. This is what

\(^3\)The fact that both these currencies respond to the same shock in similar way might well be the reason why the New Zealand - Australia exchange rate, a freely floating exchange rate, is one of the least volatile currency pairs in the world, in terms of its peak to through volatility.
one would expect, uncertainty is inherently a psychological phenomenon and is unlikely to be affected by macroeconomic variables.

### 4.6 Historical Decomposition

### 5 Robustness

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### 6 Conclusions

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### References


7 Tables

Table 1: Explanatory Power of Factors for Selected Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>R square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Australia: Gross Domestic Product (SA, Mil.Chn,Q3:09-Q2:10,A$)</td>
<td>19%</td>
</tr>
<tr>
<td>EA 17: Gross Domestic Product (SA/WDA, Mil.Chn.2005.Euros)</td>
<td>75%</td>
</tr>
<tr>
<td>Canada: Gross Domestic Product (SAAR, Mil.Chn.2002.C8)</td>
<td>65%</td>
</tr>
<tr>
<td>China: Gross Domestic Product (SA, Bil.2000.Yuan)</td>
<td>29%</td>
</tr>
<tr>
<td>World: Commodity Price Index: All Commodities (2005=100)</td>
<td>82%</td>
</tr>
<tr>
<td>World: Non-fuel Primary Commodities Index (2005=100)</td>
<td>67%</td>
</tr>
<tr>
<td>World: Commodity Price Index: Agricultural Raw Materials (2005=100)</td>
<td>59%</td>
</tr>
<tr>
<td>World: Commodity Price Index: Food &amp; Beverage (2005=100)</td>
<td>47%</td>
</tr>
<tr>
<td>United States: Nominal Effective Exchange Rate (Avg, NSA,2005=100)</td>
<td>78%</td>
</tr>
<tr>
<td>Australia: Nominal Effective Exchange Rate (2005=100)</td>
<td>74%</td>
</tr>
<tr>
<td>Euro Area: Nominal Effective Exchange Rate (Avg, NSA,2005=100)</td>
<td>55%</td>
</tr>
<tr>
<td>Canada: Nominal Effective Exchange Rate (Avg, NSA,2005=100)</td>
<td>61%</td>
</tr>
<tr>
<td>Japan: Nominal Effective Exchange Rate (Avg, NSA,2005=100)</td>
<td>19%</td>
</tr>
<tr>
<td>United Kingdom: Nominal Effective Exchange Rate (Avg, NSA,2005=100)</td>
<td>57%</td>
</tr>
<tr>
<td>US Federal funds rate</td>
<td>84%</td>
</tr>
<tr>
<td>Australia: 3-Month Bank Accepted Bills (AVG, %)</td>
<td>80%</td>
</tr>
<tr>
<td>EA17 3 month rate</td>
<td>91%</td>
</tr>
<tr>
<td>Canada: 3-month Treasury Bill yield (Haver)</td>
<td>84%</td>
</tr>
<tr>
<td>Japan: Call Rate: Uncollateralized 3-Month (EOP, %)</td>
<td>70%</td>
</tr>
<tr>
<td>Canada: Consumer Price Index (SA, 2002=100)</td>
<td>44%</td>
</tr>
<tr>
<td>EA 11-17: Monetary Union: Index of Consumer Prices(SA/H, 2005=100)</td>
<td>66%</td>
</tr>
<tr>
<td>Japan: Consumer Price Index (SA/H, 2010=100)</td>
<td>22%</td>
</tr>
<tr>
<td>U.K.: Harmonized Index of Consumer Prices [HICP] (SA, 2005=100)</td>
<td>62%</td>
</tr>
<tr>
<td>U.S.: Consumer Price Index (SA, 1982-84=100)</td>
<td>72%</td>
</tr>
<tr>
<td>China: Consumer Price Index (SA, 2005=100)</td>
<td>76%</td>
</tr>
</tbody>
</table>

Table 2: Explained Variation - Domestic Variables

<table>
<thead>
<tr>
<th>Variable</th>
<th>R squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>CPI</td>
<td>49%</td>
</tr>
<tr>
<td>Interest rate</td>
<td>90%</td>
</tr>
<tr>
<td>GDP</td>
<td>68%</td>
</tr>
<tr>
<td>Unemployment rate</td>
<td>90%</td>
</tr>
<tr>
<td>TWI</td>
<td>64%</td>
</tr>
<tr>
<td>NZ/USD</td>
<td>57%</td>
</tr>
</tbody>
</table>

Table 3: FEVD - Percent of variance decomposition of VIX owing to VIX

<table>
<thead>
<tr>
<th>Horizon</th>
<th>FEVD</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>100%</td>
</tr>
<tr>
<td>5</td>
<td>96%</td>
</tr>
<tr>
<td>15</td>
<td>96%</td>
</tr>
<tr>
<td>20</td>
<td>90%</td>
</tr>
</tbody>
</table>
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Figure 4: Key US Macro Variables
Figure 5: GDP Across the World
Figure 6: Exchange Rates

- US
- Australia
- EA17
- Canada
- Japan
- UK
Figure 7: Stock Market

Figure 8: Key NZ Macro Variables
Figure 9: Selected NZ Macro Variables

- CPI
- 90-Day Rate
- Real GDP
- Unemployment Rate
- Nominal Trade Weighted Exchange Rate

Figure 10: Selected NZ Macro Variables

- House Price Index
- Gross earnings
- Private sector credit
- Private consumption
- Private investment
Figure 11: Selected NZ Macro Variables

Figure 12: New Zealand dollar cross rates
Appendix

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