Sparse Factors, Streamlined Time-variation, and Twisted Yield Curves

Three Essays in Empirical Macroeconomics

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Contents

Introduction 9

1 Factor augmented VAR revisited - A sparse dynamic factor model approach 15

1.1 Introduction 16

1.2 Model specification and identification 19

1.2.1 The model 19

1.2.2 Implementing sparsity 21

1.2.3 Identification 22

1.3 Bayesian estimation 24

1.3.1 Likelihood and prior specification 24

1.3.2 Posterior sampler 25

1.3.3 Sampling the factors 26

1.3.4 Ex post mode identification 28

1.4 Application to the US economy 30

1.4.1 Data and prior specification 30

1.4.2 Results 31

1.4.3 Monetary policy 35

1.4.4 Term premium shock 40

1.4.5 Identification of interpretable shocks 42

1.5 Conclusion 45

Appendices 47

1.A Prior distributions 47

1.B Posterior distributions 47

1.B.1 The factor loadings λ^* 47

1.B.2 Sampling the factors: Covariance of initial states 49

1.B.3 The idiosyncratic components 50
1.B.4 The parameters for the factor dynamics 50
1.B.5 The error covariance matrix of factors Σ^* 51
1.C Identification of structural shocks by maximizing the explained share of the forecast error variance 53
1.D Tables 56
1.E Additonal figures 58
1.E.1 Choosing the number of factors 58
1.E.2 Additional impulse responses and variance decompositions . . 59
1.E.3 Factor loadings 61
1.F Data 64

2 Streamlining Time-varying VAR with a Factor Structure in the Parameters 71
2.1 Introduction 72
2.2 Model 75
2.2.1 Model specification 75
2.2.2 Separating the intercepts 79
2.2.3 Stability in TVP models 80
2.2.4 Prior specification 81
2.3 Bayesian inference 84
2.3.1 Posterior sampler 85
2.3.2 Sampling the time-varying factors 86
2.3.3 Factor loadings 87
2.3.4 Controlling time variation: Data augmentation 90
2.4 Monte Carlo study 91
2.4.1 Comparison to traditional TVP-VAR 92
2.5 Application to the Swiss economy 95
2.5.1 The impact of an appreciation shock 96
2.5.2 A small forecasting exercise 102
2.6 Application to historical inflation 103
2.7 Conclusion 108

Appendices 111
2.A Precision sampler 111

2.B Estimating prior hyperparameters 112
2.B.1 The scaling factors for the prior variances 113
2.C Convergence of sampler 114
2.C.1 Model for the Swiss economy 114
2.C.2 Model with historical inflation data 115

3 Shall We Twist? 117
3.1 Introduction 118
3.2 The 1960's – an important phase for U.S. monetary policy 121
3.2.1 The implementation of Operation Twist 124
3.2.2 Interest rates and yield spreads 133
3.2.3 Summing up 134
3.3 Theoretical foundation of Operation Twist 135
3.4 Methodology 136
3.4.1 Monte Carlo simulation 137
3.5 Estimated effects on the yield spreads 140
3.5.1 Potential size of the shock 145
3.5.2 Relative supply of long-term versus short-term securities . . . 148
3.5.3 Robustness 150
3.6 Conclusion 152

Appendices 155
3.A Alternative models 155
3.A.1 A model with stochastic volatility 155
3.A.2 A model with time varying parameters 159
3.B Additional tables 162
3.C Additional figures 164
3.D Data 176
3.D.1 FED balance sheet data 176
3.D.2 Treasury balance sheet data 176
3.D.3 Interest rate series and control variables 176

Bibliography 179

Introduction

We are living in a digitalized world in which the amount of data collected by public and private institutions is growing at an enormous pace. This data helps to improve our understanding of the current state of the economy, and the underlying structural relationships that lead to the economic outcomes we observe. To achieve both ends, we need econometric models that let us analyze the raw data in appropriate ways and are capable of handling the various difficulties that arise in this context. In the field of empirical macroeconomics the better availability and the improved quality of data together with the extraordinary developments in information technology have led to great advancement in the applied methodologies. This thesis covers recent developments in time series analysis and adds to them in several ways. The first chapter is about handling large data sets and conducting meaningful inference based on a large number of time series in a macroeconomic context. The second chapter addresses the question of parameter instability in an ever-changing world. It provides a traceable solution to relax the constant parameter assumption in a vector auto regression (VAR), the workhorse model of most macro-econometricians. The goal of the third chapter is to evaluate the impact of an unanticipated policy intervention jointly undertaken by the Federal Reserve Board and the U.S. Treasury in the early 1960s which strongly resembles unconventional measures implemented after the financial crisis in the late 2000s.

Factor models have become an important tool in empirical macroeconomics. They provide a solution to the curse of dimensionality whenever the researcher is confronted with a large number of time series where each of these time series possibly contains important information about a certain aspect of the economy, such as the business

cycle, the price level, or financial conditions. In such a situation, it is often impossible to conduct inference without first compressing the problem's dimension. Simply focusing on a smaller subset of the observable variables often leads to the problem of ignoring certain important features present in the data, and hence, this may distort the outcome of the empirical analysis. Factor analysis, in contrast, allows for dimension reduction without the loss of information, by summarizing the information content contained in the initial data set in a small number of latent variables, the so-called factors. However, it raises new issues concerning factor identification and makes the interpretation of the results more difficult. In the first chapter **"Factor augmented VAR revisited – A sparse dynamic factor model approach"** jointly written with Sylvia Kaufmann we address these issues by exploiting the sparsity in the factor loading matrix. We follow the approach of **?** who suggest augmenting standard small scale VAR models by adding latent factors extracted from a large dataset containing macro variables to the analysis and combine it with recent developments in the area of sparse factor models. Originated from gene expression analysis (**?**, **?**) sparse factor models are based on the simple idea that a single factor accounting for the co-movement of a certain group of variables is not necessarily related to all the other variables in the underlying data set. In the spirit of **?**, we estimate a sparse dynamic factor model for the FA part in the FAVAR approach using Bayesian estimation techniques based on a sparse hierarchical prior distribution. This allows us to discriminate explicitly between zero and non-zero factor loadings. The non-zero entries in the factor loading matrix identify the unobserved factors and simultaneously provide a meaningful economic interpretation for them. The factors are estimated independently of variable ordering, and their respective position and sign are determined by processing the posterior draws after model estimation.

Furthermore, we work with a generalized covariance matrix such that we can implement the strategies from the VAR literature for the identification of structural shocks in the FAVAR approach. We apply our methodology to a data set that consists of 224 variables describing the U.S. macro economy. We find overwhelming evidence in favor of a sparse representation of the factor loading matrix. With our proposed factor identification strategy we successfully identify seven latent factors. Due to

the respective positions of the relevant non-zero factor laodings, they all possess an economically meaningful interpretation. Despite the high degree of sparsity, the estimated common component accounts for a large fraction of the variation in the data. In a structural exercise we study the impact of an unanticipated hike of the monetary policy rate and an unanticipated increase in the term premium factor on the economy.

Capturing instabilities in the economic environment or in the behavior of economic agents is a challenging problem in modern macroeconometric analysis. During the Great Moderation volatility of major economic variables strongly declined. More recently, central banks who were constrained by the lower bound on nominal interest rates shifted from conventional to unconventional monetary policy measures. Altogether, such occurrences call into question the assumption of fixed parameters present in most traditional econometric models. Instead, the relationships that describe an economy might well be evolving over time as the behavior of economic agents is likely to adapt to changes of the "rules of the game", such as policy changes or modifications of the institutional settings. This point was famously emphasized in the Lucas critique (**?**). Using a battery of tests **?** provide evidence of instability for a substantial number of U.S. macroeconomic time series which might be linked to variation in the structural relationships. If that is the case, this would naturally lead to shifts in the reduced form parameters of macroeconometric models, such as vector auto regressions. A widely used method to approach this issue are time-varying parameter (TVP) models often in combination with stochastic volatility such as the TVP-VAR models proposed by **?** or **?**. In the second chapter **"Streamlining Time-varying VAR with a Factor Structure in the Parameters"** I follow a new strand of the literature taking advantage of the fact that the time-varying behavior of the various parameters in these models over time tends to be very similar. This observation allows to rely on similar techniques, as those described in the first chapter, to reduce the dimension of the model's state space. In contrast to the approach described in the first chapter, the factor structure is not imposed upon the observable data, but upon the unobserved, time-varying model parameters. The contribution of the second chapter is twofold. First a version of a TVP-VAR

with a factor structure in its parameters is developed and second a novel sampler that includes Bayesian shrinkage priors to estimate the model is proposed. In sum, this leads to a convenient way to capture parameter instabilities by allowing for time-variation wherever necessary but in a well structured way. This reduces model complexity and offers a remedy for the over-fitting problem that typically occurs in such models. In a Monte Carlo study with simulated data the proposed sampler shows its ability to correctly estimate the degree of time-variation and to correctly distinguish between truly constant and truly time-varying parameters.
In an application for Switzerland the model is estimated with monthly data to study the effect of an appreciation shock on the economy and its evolution over time, especially during the lower bound period for the nominal interest rate. Although the estimated time-variation in the coefficients is muted, the model captures a stark drop in the effect of the exchange rate shock on the nominal interest rate once it has been lowered to basically zero. The response of the remaining variables also changed but to a much lesser extent. A forecasting exercise based on the same dataset further reveals a superior forecasting performance of the proposed model compared to the traditional TVP-VAR model. A second application is based on historical inflation data for the United Kingdom, Norway, Sweden and the United States covering almost 200 years of history. This example nicely emphasizes the role of time-variation among model parameters when working with observations covering such a long time span.

An important task in the field of macroeconomics is to evaluate the success of policy interventions. An example are the unconventional measures adopted by central banks around the globe in the face of the low interest rate environment in the aftermath of the Great Recession. However, isolating the effect of a single policy intervention in such turbulent times is like a Herculean task. Having a closer look at the monetary history of the United States reveals that measures such as balance sheet restructuring are not completely new but have already been used earlier. The U.S. in fact experienced a similar situation in the early 1960s. In the third chapter **"Shall we twist?"** coauthored with Sophie Altermatt we investigate the events

linked to Operation Twist, which can be seen as the origin of quantitative easing, and the success thereof.

When the Kennedy administration took office in January 1961 it wanted to provide further stimulus for the economy that was still recovering from the recent recession. The Federal Reserve System (FED) however, was unwilling to lower short-term interest rates because of a surge in gold outflows from the U.S. towards Europe. These outflows originated from the institutional setting of the Bretton Woods exchange rate system that was in place at that time. As providing monetary stimulus through conventional policy measures (lowering short-term interest rates) was not an option, novel, unconventional ways had to be found instead. The solution came in form of a plan that was later known under the name Operation Twist. It foresaw a coordination between the Treasury and the FED to lower the longer end of the yield curve by restructuring the composition of their respective balance sheets. The idea was to change the relative supply of short- and long-term government bonds and exert downward pressure on long-term yields while simultaneously producing upward pressure on short-term yields. As a result, the intervention should compress the spread between the long and the short end of the yield curve.

To gain a better understanding of the actions that took place under Operation Twist we collected a dataset that covers balance sheet data on the FED's and the Treasury's positions of government securities. We then estimate an autoregressive distributed lag model for the spreads between bond yields for various longer maturities and the 3-month Treasury bill rate. This approach is in the spirit of **?**, who were among the first to analyze Operation Twist.

To study the effect of Operation Twist, we focus on the residuals of the estimated model. In the absence of an Operation Twist effect the residuals are expected to be symmetrically distributed around zero over the whole sample period. If on the contrary Operation Twist affected the spreads, we expect to observe an asymmetry towards negative errors during the Operation Twist phase. To detect such an asymmetry, we compute the cumulated sum of the residuals starting in February 1961, when Operation Twist was publicly announced for the first time. To properly account for uncertainty around our estimates, we compute bootstrapped confidence

bands under the null hypothesis of no spread compression. Our main findings are, that based on the balance sheet data the actions under Operation Twist taken by the FED and the Treasury were of moderate size at best. Nonetheless our econometric analysis points towards weakly significant compression in most of the analyzed spreads. We interpret our results as a mild success of Operation Twist, however, a better coordination between the Treasury and the FED would likely have boosted its effect.

Chapter 1

Factor augmented VAR revisited - A sparse dynamic factor model approach*

with **Sylvia Kaufmann**, Study Center Gerzensee

Abstract

We combine the factor augmented VAR framework with recently developed estimation and identification procedures for sparse dynamic factor models. Working with a sparse hierarchical prior distribution allows us to discriminate between zero and non-zero factor loadings. The non-zero loadings identify the unobserved factors and provide a meaningful economic interpretation for them. Applying our methodology to US macroeconomic data reveals indeed a high degree of sparsity in the data. We use the estimated FAVAR to study the effect of a monetary policy shock and a shock to the term premium. Factors and specific variables show sensible responses to the identified shocks.

Link

Beyeler Simon and Sylvia Kaufmann (2016): "Factor augmented VAR revisited - A sparse dynamic factor model approach", Study Center Gerzensee Workingpaper, 16.08.

* We thank Luca Benati, Mark Watson and seminar participants at the University of Bern and Newcastle University Business School for valuable comments and discussions.

Chapter 2

Streamlining Time-varying VAR with a Factor Structure in the Parameters*

Abstract

I introduce a factor structure on the parameters of a Bayesian TVP-VAR to reduce the dimension of the model's state space. To further limit the scope of over-fitting the estimation of the factor loadings uses a new generation of shrinkage priors. A Monte Carlo study illustrates the ability of the proposed sampler to well distinguish between time varying and constant parameters. In an application with Swiss data the model proves useful to capture changes in the economy's dynamics due to the lower bound on nominal interest rates.

Link

Beyeler Simon (2019): "Streamlining Time-varying VAR with a Factor Structure in the Parameters", Study Center Gerzensee Workingpaper, 19.03.

* I would like to thank Sylvia Kaufmann, Luca Benati, Mark Watson, Christian Schumacher, and Rodney Strachan for valuable comments and discussions.

Chapter 3

Shall We Twist?

with **Sophie Altermatt**, University of Bern

Abstract

In recent monetary history, central banks around the world have started to introduce unconventional monetary policy measures, such as extending or restructuring the asset side of their balance sheet. The origin of these monetary policy tools goes back to an intervention by the U.S. Federal Reserve System under the Kennedy administration in 1961 known as Operation Twist. Operation Twist serves as a perfect laboratory to study the effectiveness of such balance sheet policies, because interest rates neither were at their lower bound nor was the economy in a historical turmoil. We assess the actions of the FED and the Treasury under Operation Twist based on balance sheet data and evaluate their success using modern time series techniques. We find that, although being of rather moderate size, the joint policy actions were effective in compressing the long-short spreads of the Treasury bond rates.

Link

Altermatt Sophie and Simon Beyeler (2018): "Shall we twist?", University of Bern Discussion papers, 18-25.

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Bern, 23. Januar 2019

Simon Beyeler