An empirical study of credit shock transmission in a small open economy*

SUPPLEMENTARY MATERIAL

Nathan Bedock[†] Dalibor Stevanovic[‡§]

April 12, 2016

Abstract

This document contains supplementary material for the paper entitled "An empirical study of credit shock transmission in a small open economy". It contains: (i) further exploration of factor structure in data sets; (ii) more evidence on predictive content of credit spreads; (iii) additional VAR results, (iv) further FAVARMA robustness analysis, and (v) FAVAR analysis.

JEL Classification: E32, E44, C32

Keywords: Credit shock, structural factor analysis, factor-augmented VARMA.

---

*We thank the editor Francisco Ruge-Murcia and two anonymous referees for helpful comments. We thank Maxime Leroux for excellent research assistance. The second author acknowledges financial support from the Fonds de recherche sur la société et la culture (Québec) and the Social Sciences and Humanities Research Council.

[†]Montréal. e-mail: nathan@bonim.ca

[‡]Université du Québec à Montréal, Département des sciences économiques, 320, rue Ste-Catherine Est, Montréal, QC, H2X 1L7. e-mail: dstevanovic.econ@gmail.com

[§]Corresponding author

1 Further factor analysis of the data set

The Figures 1 - 2 show the R^2 between individual time series, grouped by category, and the eight common factors estimated as principal components.[1] The first factor is related to interest rates (CA and US) and to some housing series. The second explains a sizeable part of variance of output, employment and Canadian credit spreads. The third is clearly a price factor, while the forth seems related to stock market, exchange rates and credit measures. Explanatory power of subsequent factors is less and less by definition, but they are still important for some groups of series. Interestingly, only the eight explains some movements in net exports.

2 More evidence on predictive content of credit spreads

2.1 In-sample

Figures 3 - 6 summarize the predictive, in-sample, content of credit spreads for sectoral GDP and employment series. The results are for the autoregressive diffusion index model:

$$y_{t+h}^h = \alpha^h + \rho^h(L)y_t + \gamma^h(L)\hat{f}_t + \beta^h(L)CS_t + e_{t+h} \tag{1}$$

where $\hat{f}_t$ are K estimated factors from the subset of large macroeconomic data X_t. We fix the number of factors to 6, as suggested by the IC_{p2} criteria of Bai and Ng (2002). The model (1) is a version of the autoregressive diffusion index model considered in Stock and Watson (2002), augmented by the credit spread.

2.2 Out-of-sample

Figures 7 and 8 show the predictive content of credit spreads over time, 3 and 12 months ahead, for GDP and employment average annualized growth rates. It is measured as the MSPE ratio of ARDI+CS over the ARDI model.

Figures 9 - 12 present the MSPE ratio, for all sectoral GDP and employment series between each forecasting model containing a credit spread and the benchmark autoregressive direct specification.

[1] The factors are not individually identified and their interpretation depends on the rotation matrix. Here, a particular rotation is imposed by the principal component estimator and correlation between each factors and the observables is affected by this assumption.

3 Additional VAR results

Figure 13 and 14 show dynamic responses to US and Canadian credit shocks respectively, as estimated from a VAR model. The model consists of two blocks: US, containing CPI inflation (US-CPI), Industrial production growth (US-IP), Federal funds rate (US-R) and BAA credit spread (US-CS); and Canadian block which includes same but Canadian series (CPI, IP, R, CA-CS), where R is the 3-month T-bill, and CA-CS is the Canadian BBB Long credit spread. The identification is achieved by ordering the US block first. The US and Canadian credit shocks correspond to the 4th and 8th elements of the orthogonalized VAR residuals.

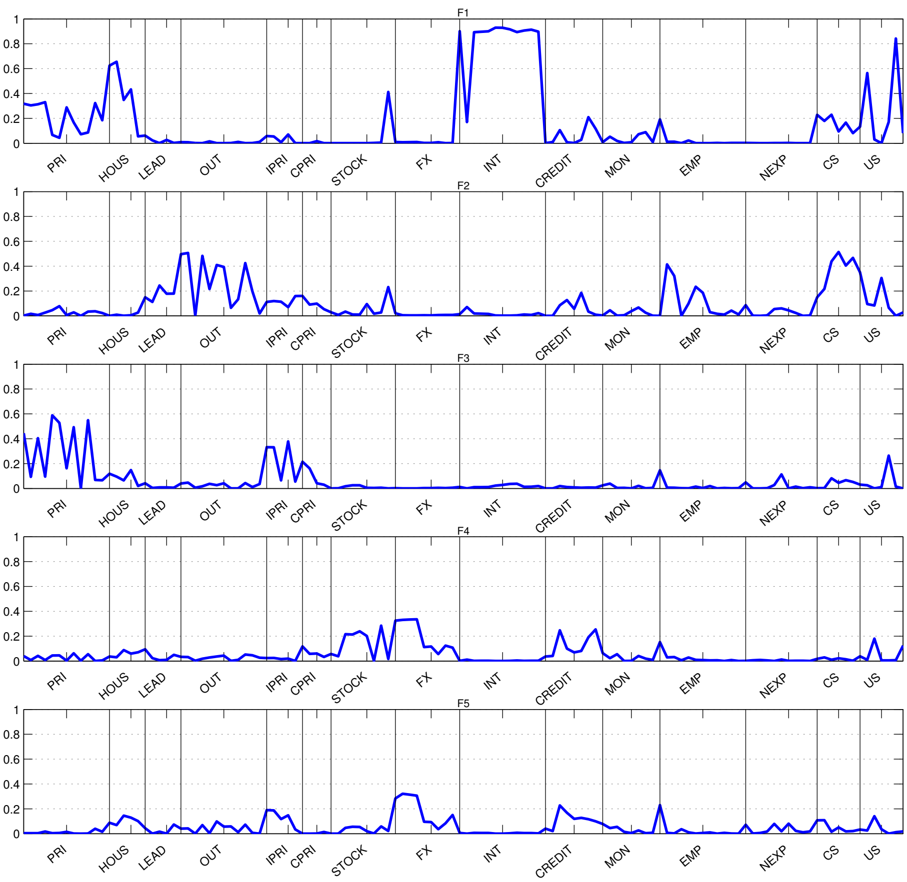
4 Further FAVARMA analysis

Figures 15 and 16 show dynamic responses to US and Canadian credit shocks as estimated by the benchmark FAVARMA model but where we use AAA and AA+ credit spreads instead of B category. Table 1 shows the corresponding variance decomposition. Figure 17 shows impulse responses to US credit shock identified using the BAA-AAA spread. Figure 18 plots the impulse responses after the US credit shock from the benchmark FAVARMA model but where the Federal Funds is placed just after the BAA credit spread, i.e. the US series ordering is the following: [US-CPI, US-IP, US-LOANS, US-CS, US-R]. Hence, the short rate is free to react contemporaneously to credit market. Table 2 resume the variance decomposition for last two FAVARMA specifications.

5 FAVAR analysis

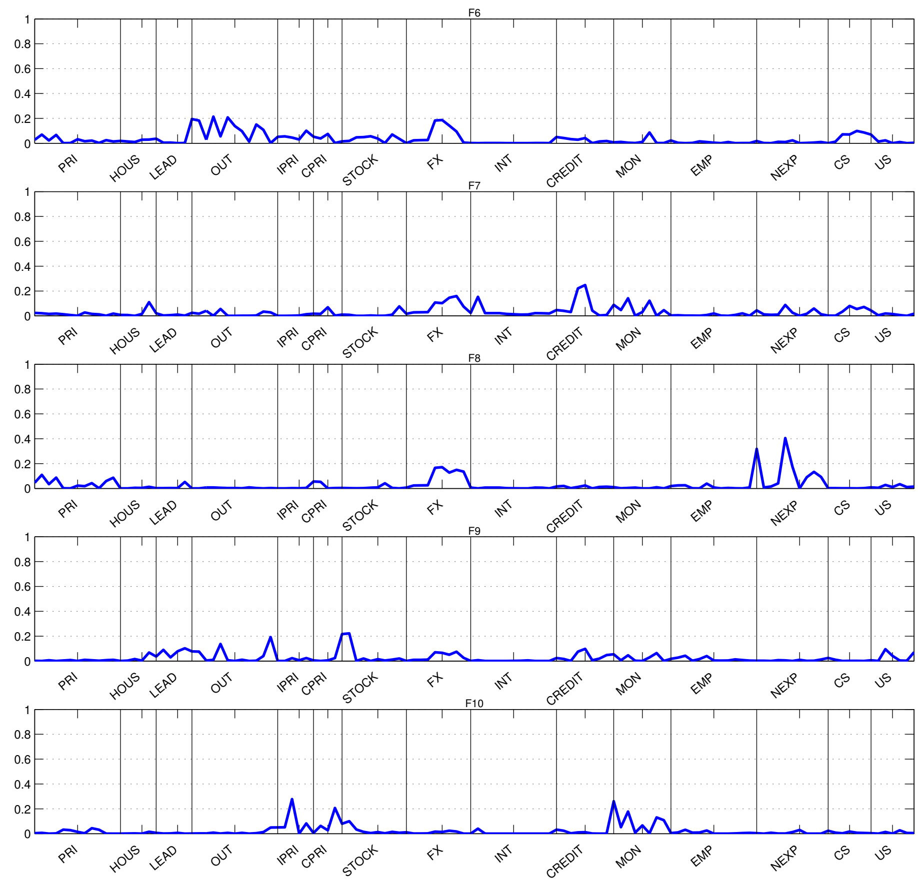
Finally, we compare the results from the FAVAR and FAVARMA models. Figures 19 and 20 show impulse responses to US and Canadian credit shocks as estimated from the FAVAR model where the factors' VAR lag order is fixed to 3, according to Akaike criterion (the BIC suggests only one lag). Figures 21 and 22 compare the impulse response coefficients, to US and CA shocks, of the benchmark FAVARMA model against FAVARs with VAR orders of 1, 2, 3 and 6. Table 3 presents the variance decomposition after both shocks as estimated from the FAVAR(3).

Figure 1: R^2 Between Factors and Individual Time Series, Grouped by Category



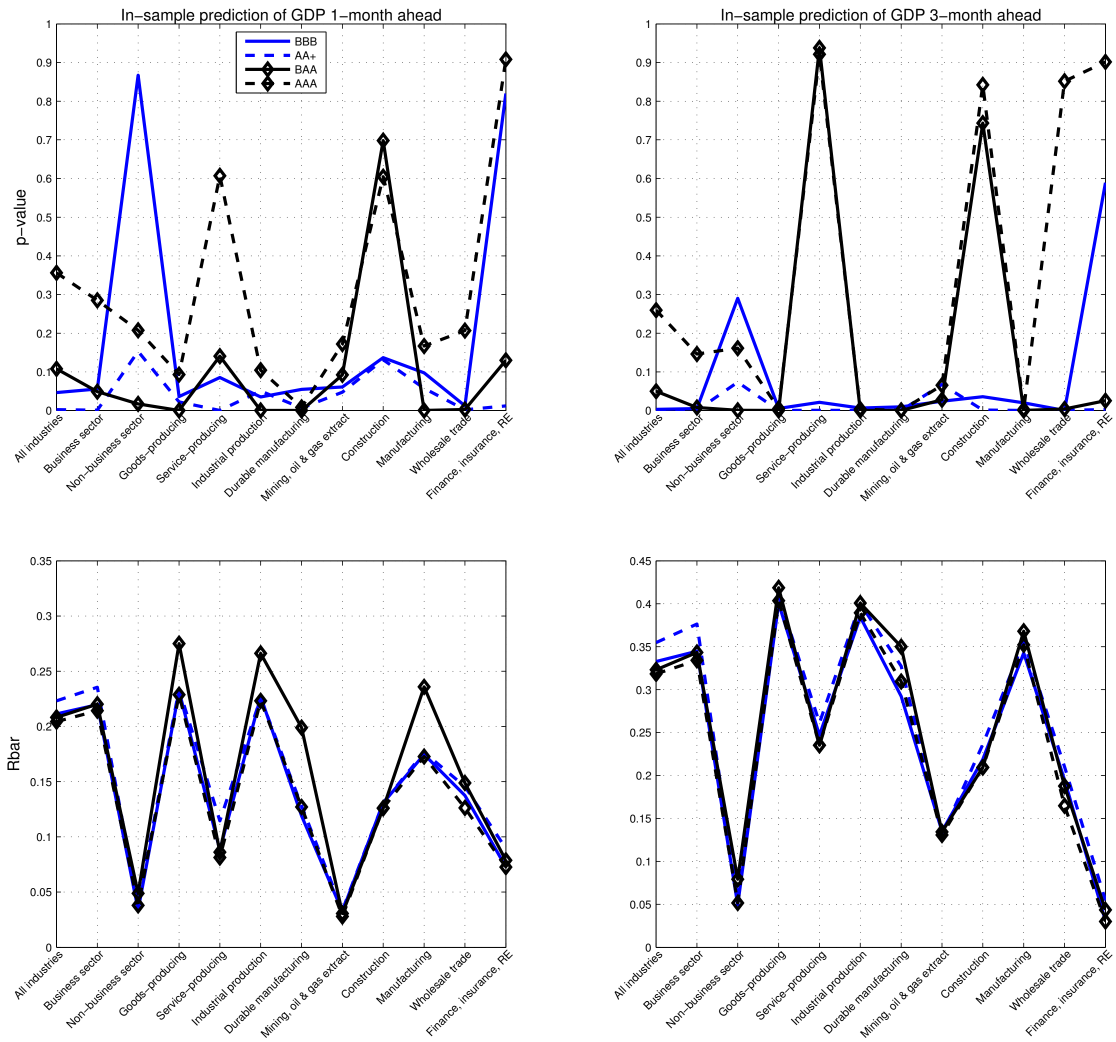
This Figure shows marginal R^2 of factors 1-5 estimated as principal components. The meaning of each category title is in the Appendix B in the main text.

Figure 2: R^2 Between Factors and Individual Time Series, Grouped by Category



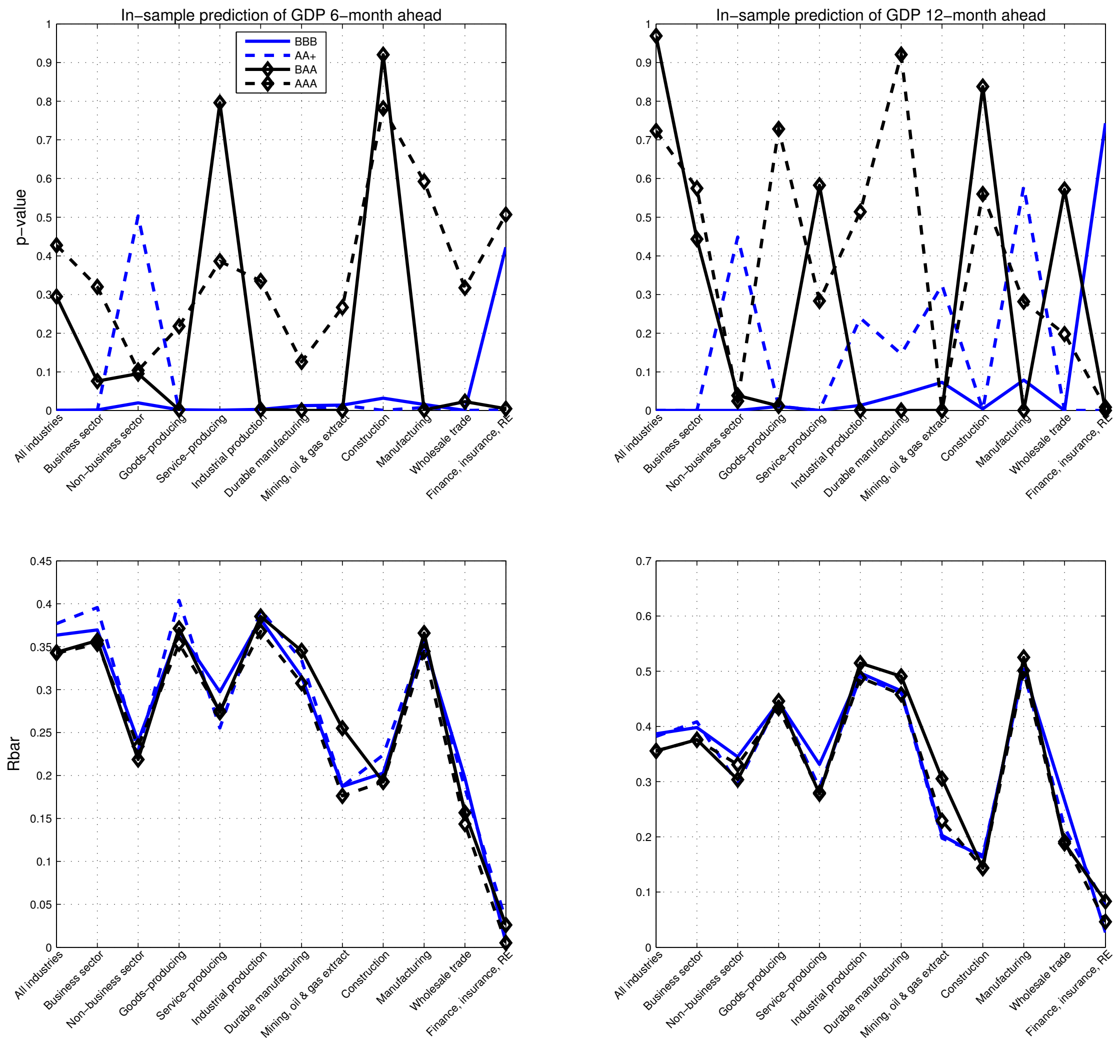
This Figure shows marginal R^2 of factors 6-10 estimated as principal components. The meaning of each category title is in the Appendix B in the main text.

Figure 3: In-sample predictive content of credit spreads (I)



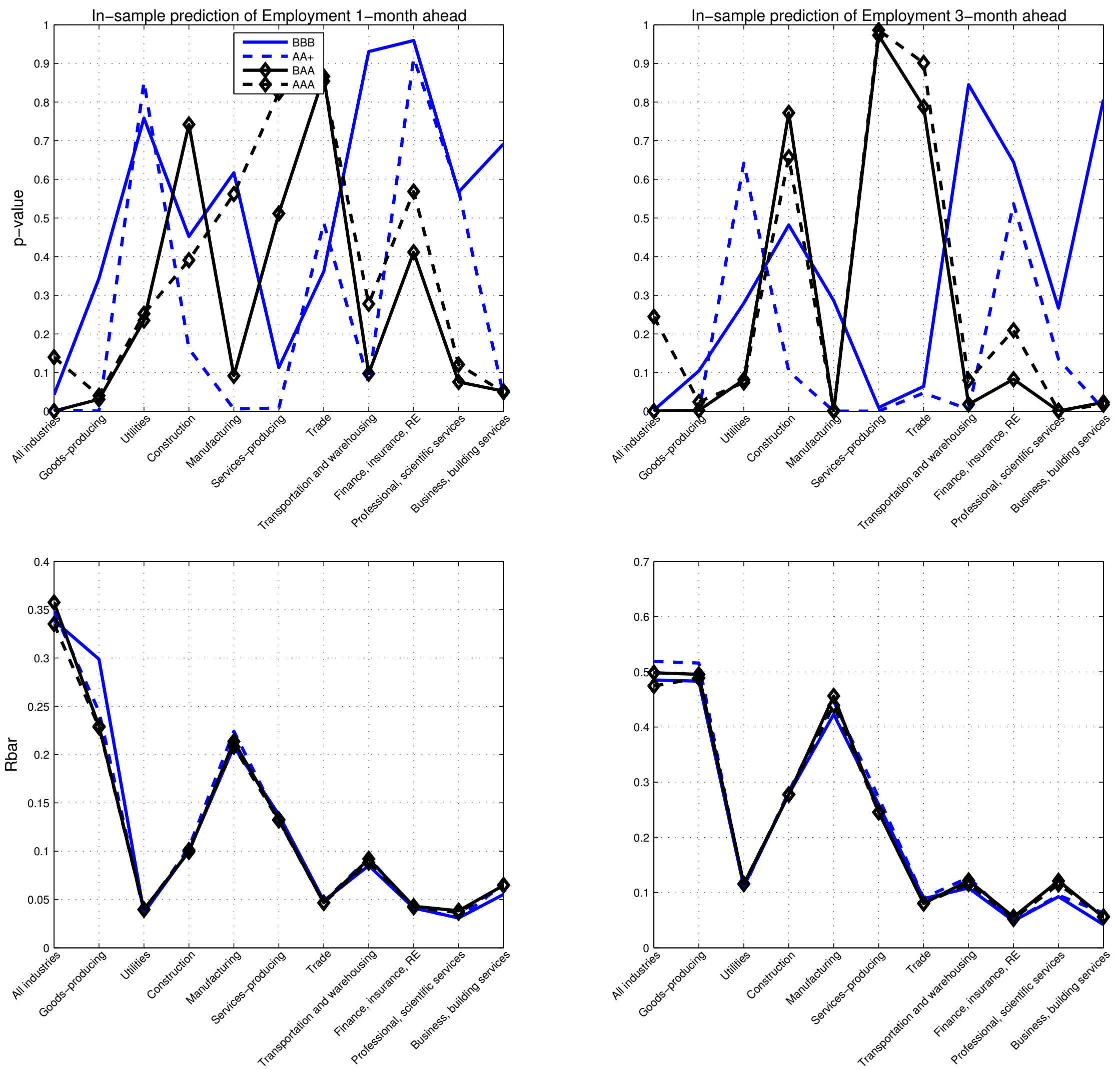
This Figure shows in-sample predictive content of credit spreads for sectoral GDP series at 1 and 3-month horizons. The top panels present the p-value of the test of the null hypothesis that $\beta^h(L) = 0$ *in equation (1). The bottom panels present the adjusted* R^2*.*

Figure 4: In-sample predictive content of credit spreads (II)



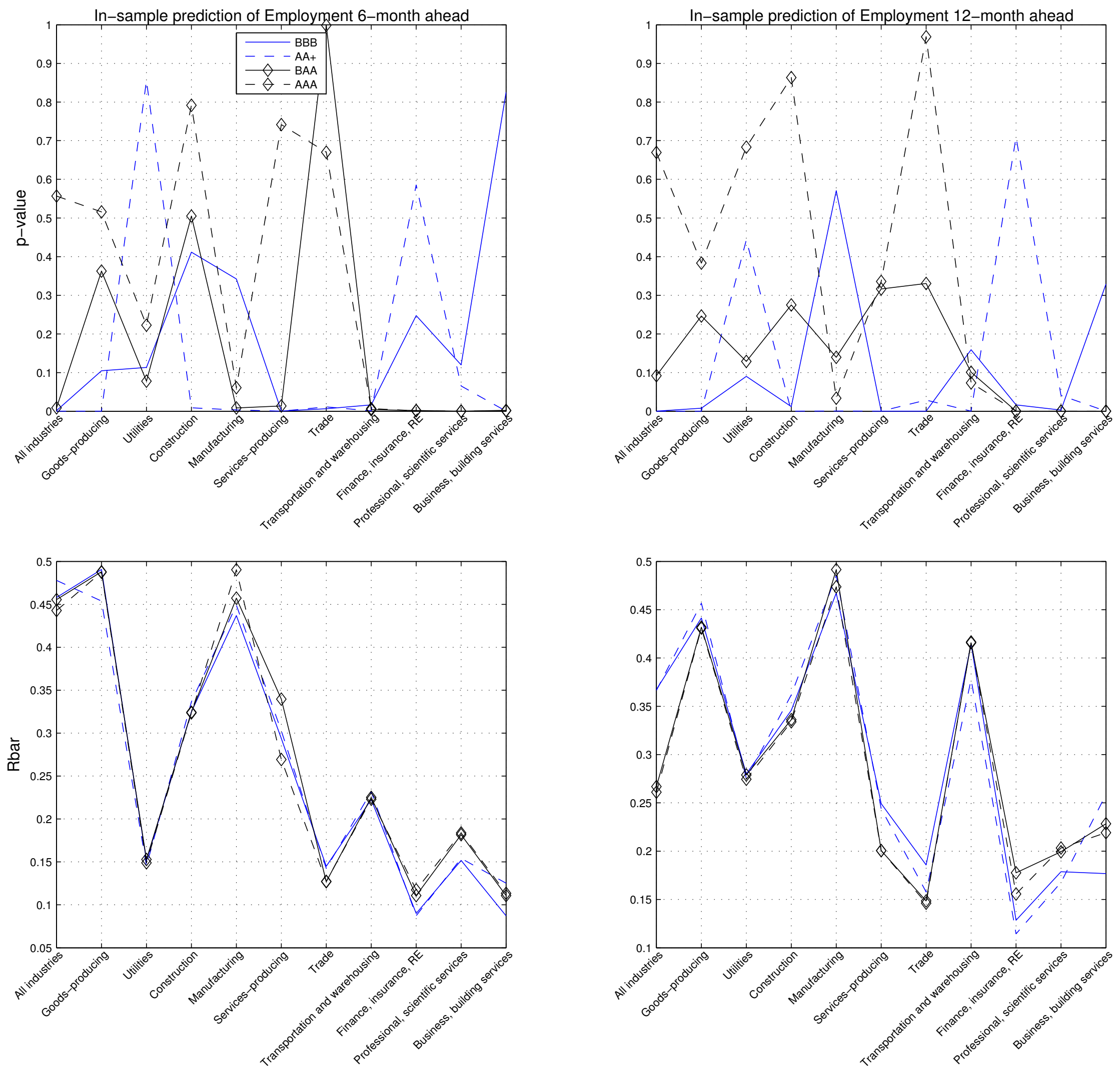
This Figure shows in-sample predictive content of credit spreads for sectoral GDP series at 6 and 12-month horizons. The top panels present the p-value of the test of the null hypothesis that $\beta^h(L) = 0$ *in equation (1). The bottom panels present the adjusted* R^2.

Figure 5: In-sample predictive content of credit spreads (III)



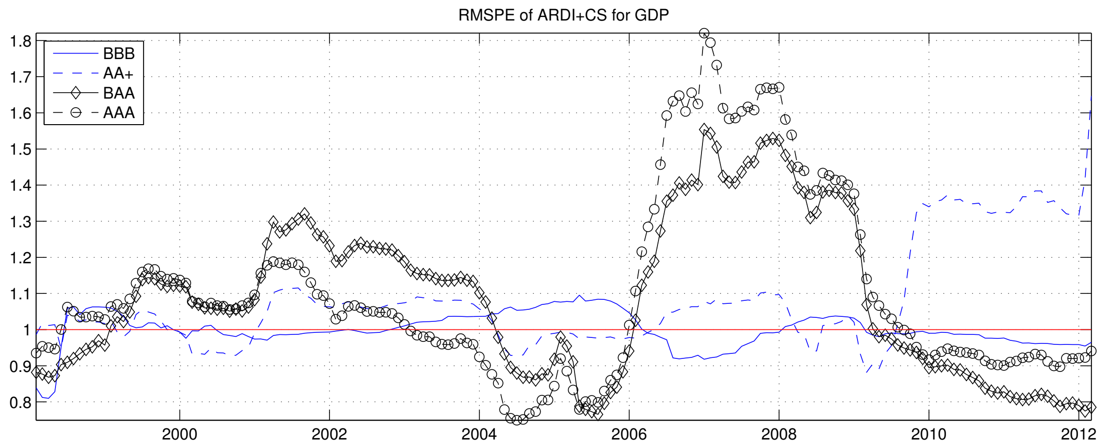
This Figure shows in-sample predictive content of credit spreads for sectoral employment series at 1 and 3-month horizons. The top panels present the p-value of the test of the null hypothesis that $\beta^h(L) = 0$ *in equation (1). The bottom panels present the adjusted* R^2.

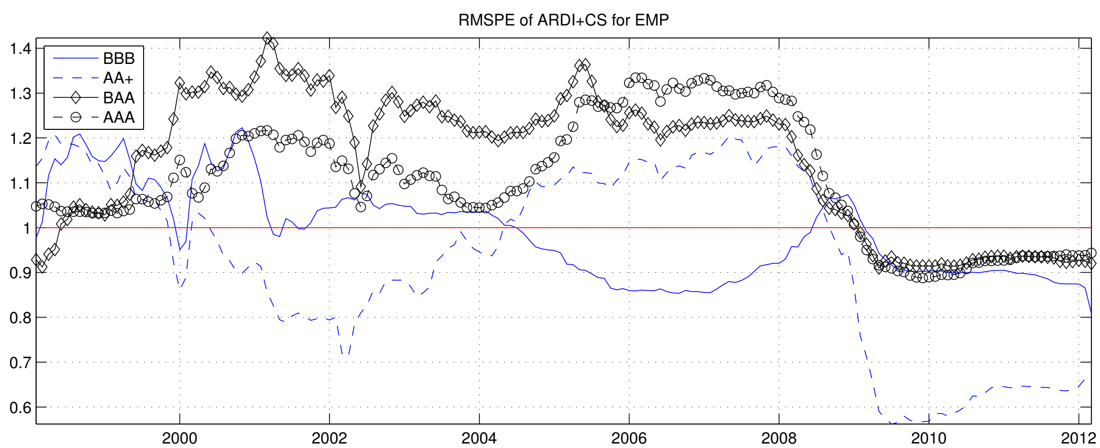
Figure 6: In-sample predictive content of credit spreads (IV)



This Figure shows in-sample predictive content of credit spreads for sectoral employment series at 6 and 12-month horizons. The top panels present the p-value of the test of the null hypothesis that $\beta^h(L) = 0$ in equation (1). The bottom panels present the adjusted R^2.

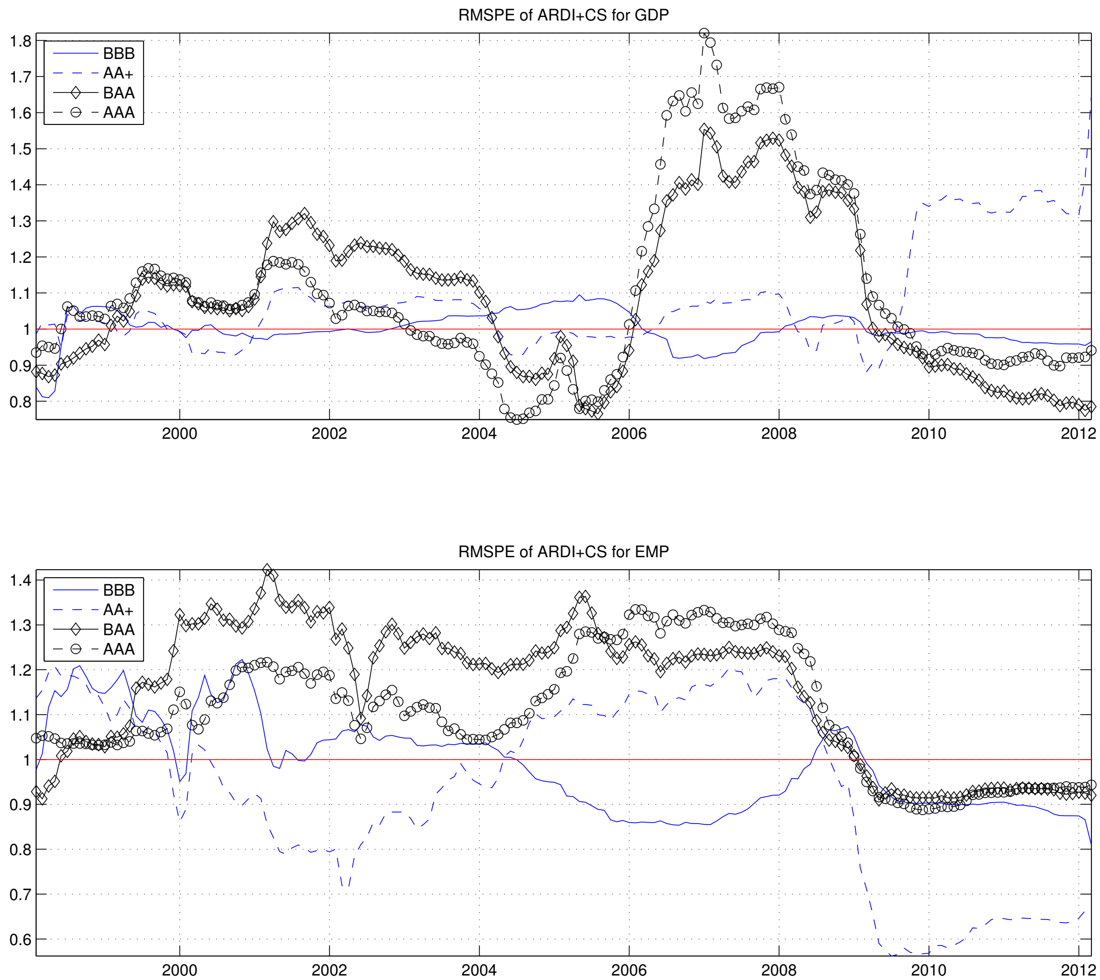
Figure 7: Out-of-sample performance of credit spreads over time at 3-month horizon





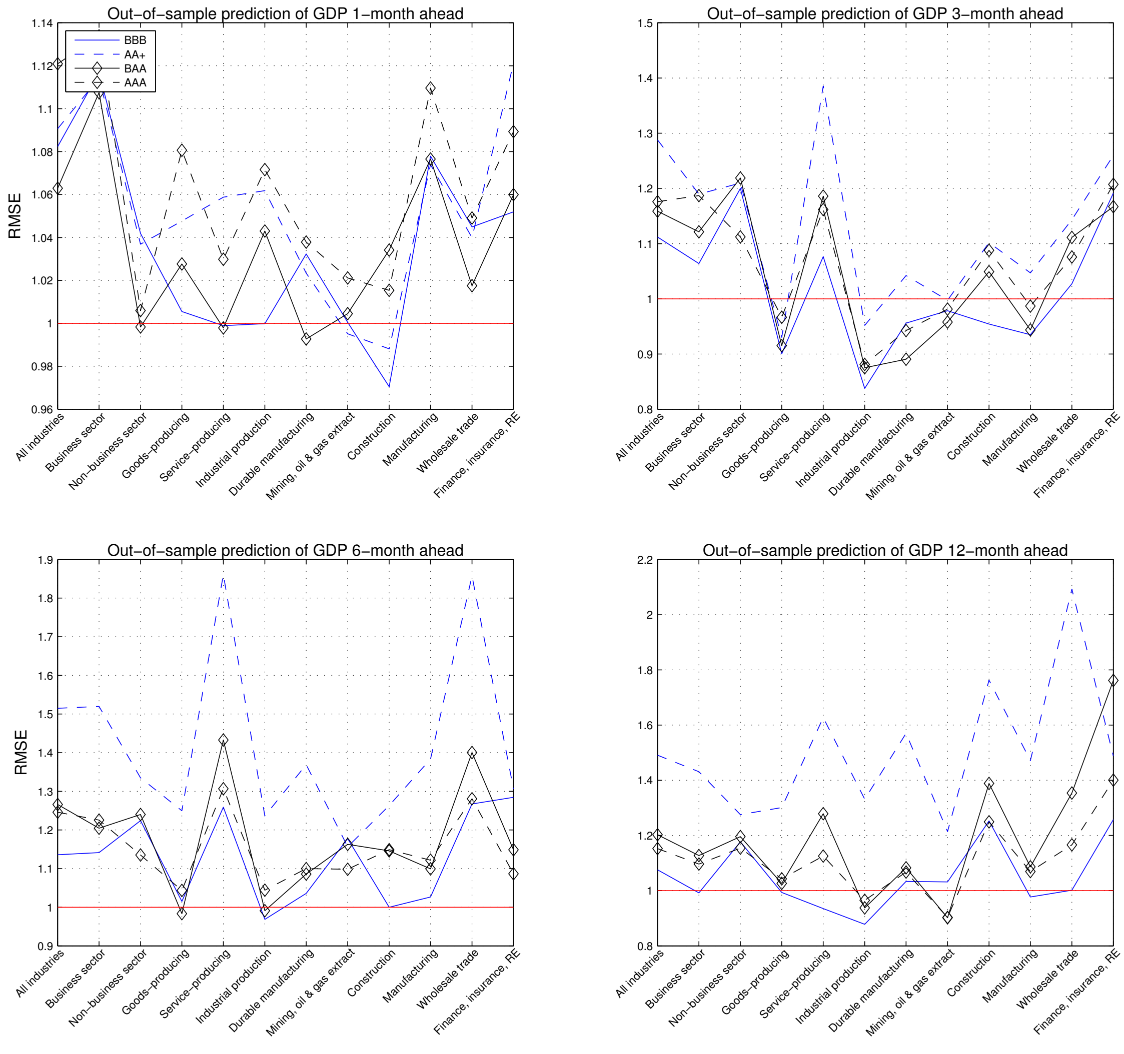
This Figure shows the MSPE of ARDI+CS models, for each credit spread relative to MSPE of the ARDI model. The ratio are calculated over 3-year rolling window. When the ratio is lower than 1, it means that adding a credit spread to ARDI model produce better forecast 3 months ahead in terms of MSPE. The top panel present results for industrial production average growth and the bottom for employment.

Figure 8: Out-of-sample performance of credit spreads over time at 12-month horizon



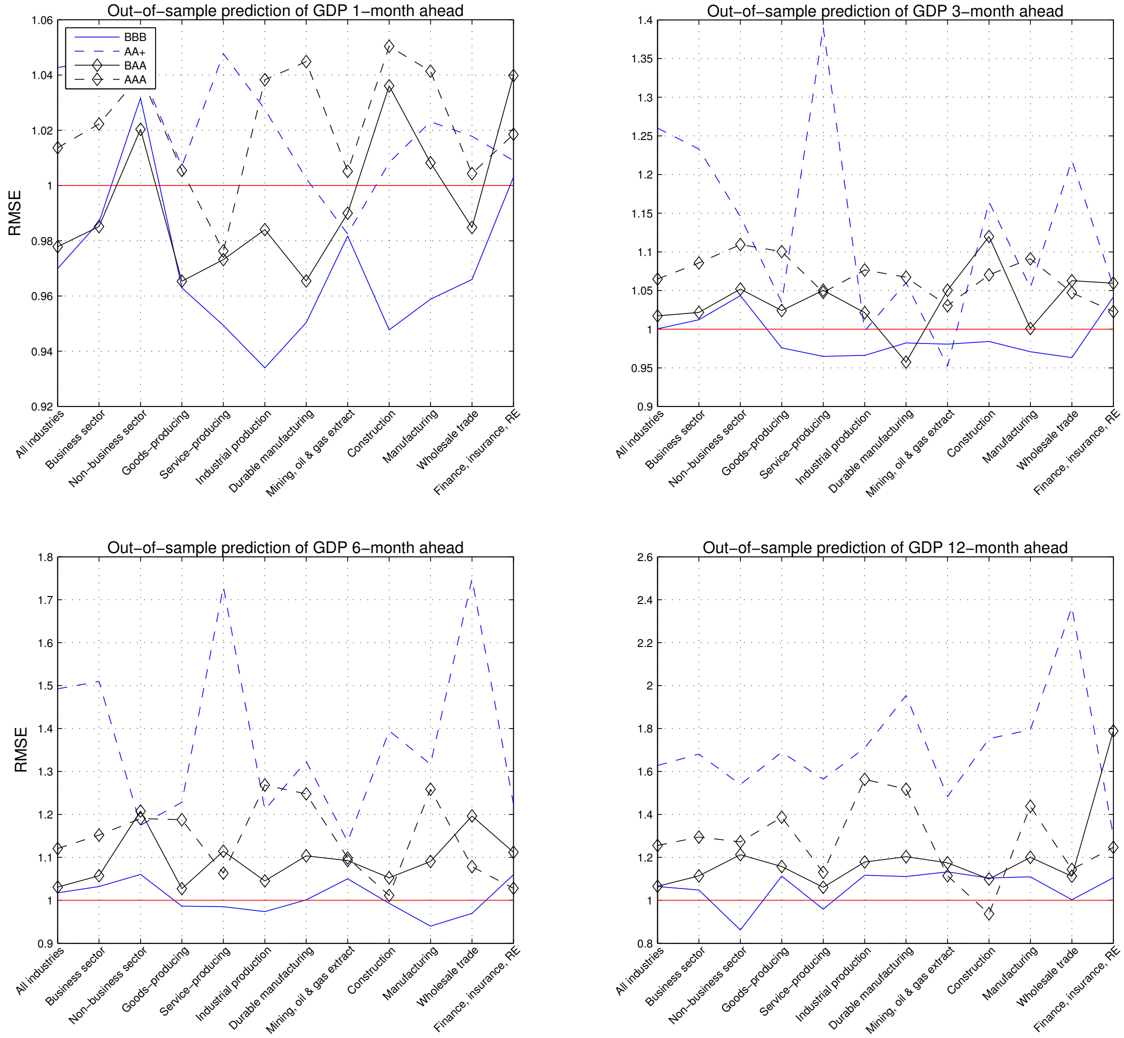
This Figure shows the MSPE of ARDI+CS models, for each credit spread relative to MSPE of the ARDI model. The ratio are calculated over 3-year rolling window. When the ratio is lower than 1, it means that adding a credit spread to ARDI model produce better forecast 12 months ahead in terms of MSPE. The top panel present results for industrial production average growth and the bottom for employment.

Figure 9: Relative MSPE for ARDI+CS: GDP sectors



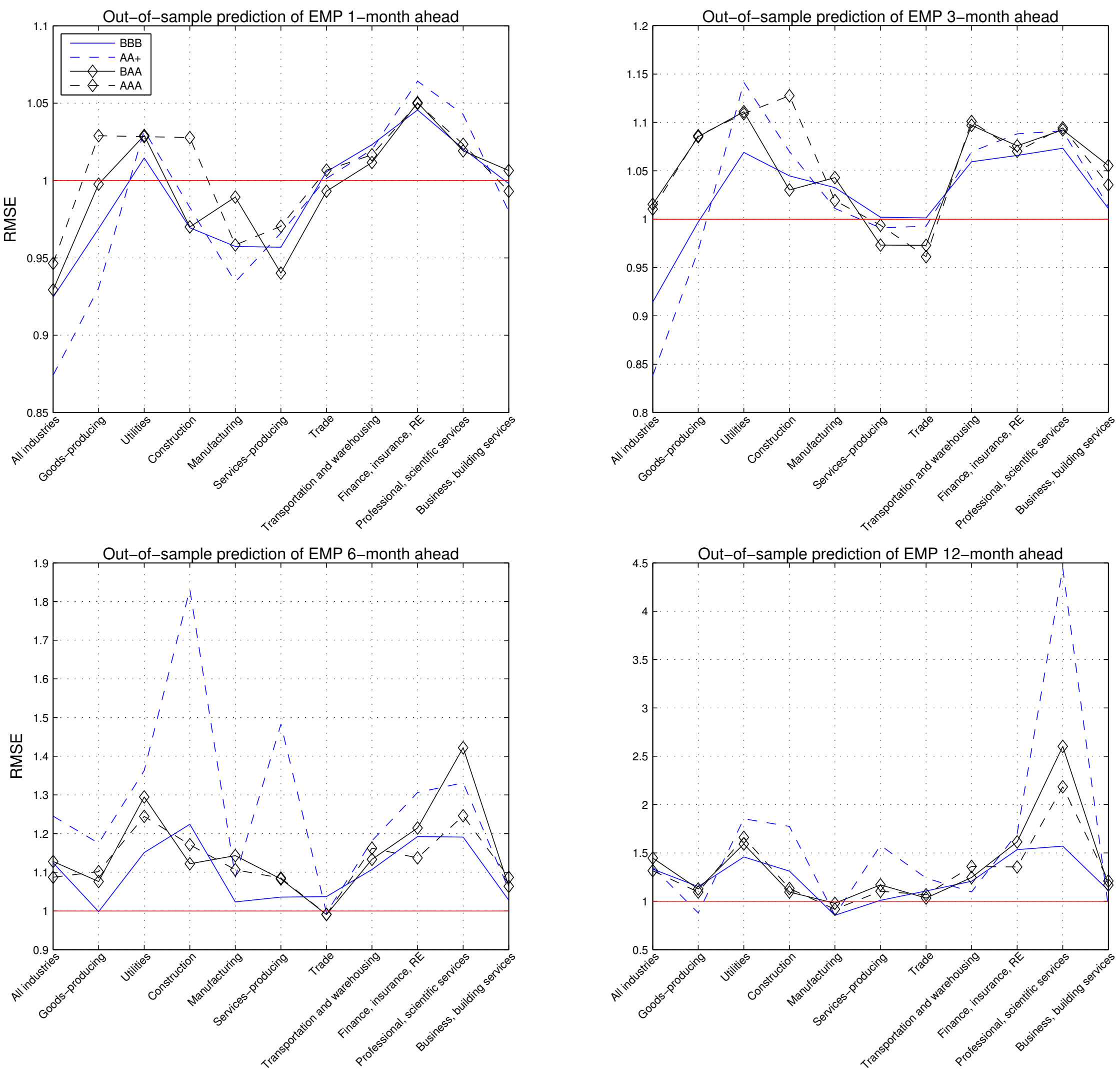
This Figure shows the MSPE of ARDI+CS models, for each credit spread relative to MSPE of the ARD model, for all GDP sectoral series. When the ratio is lower than 1, it means that adding a credit spread to ARDI model produces better forecast h months ahead in terms of MSPE.

Figure 10: Relative MSPE for ADL+CS: GDP sectors



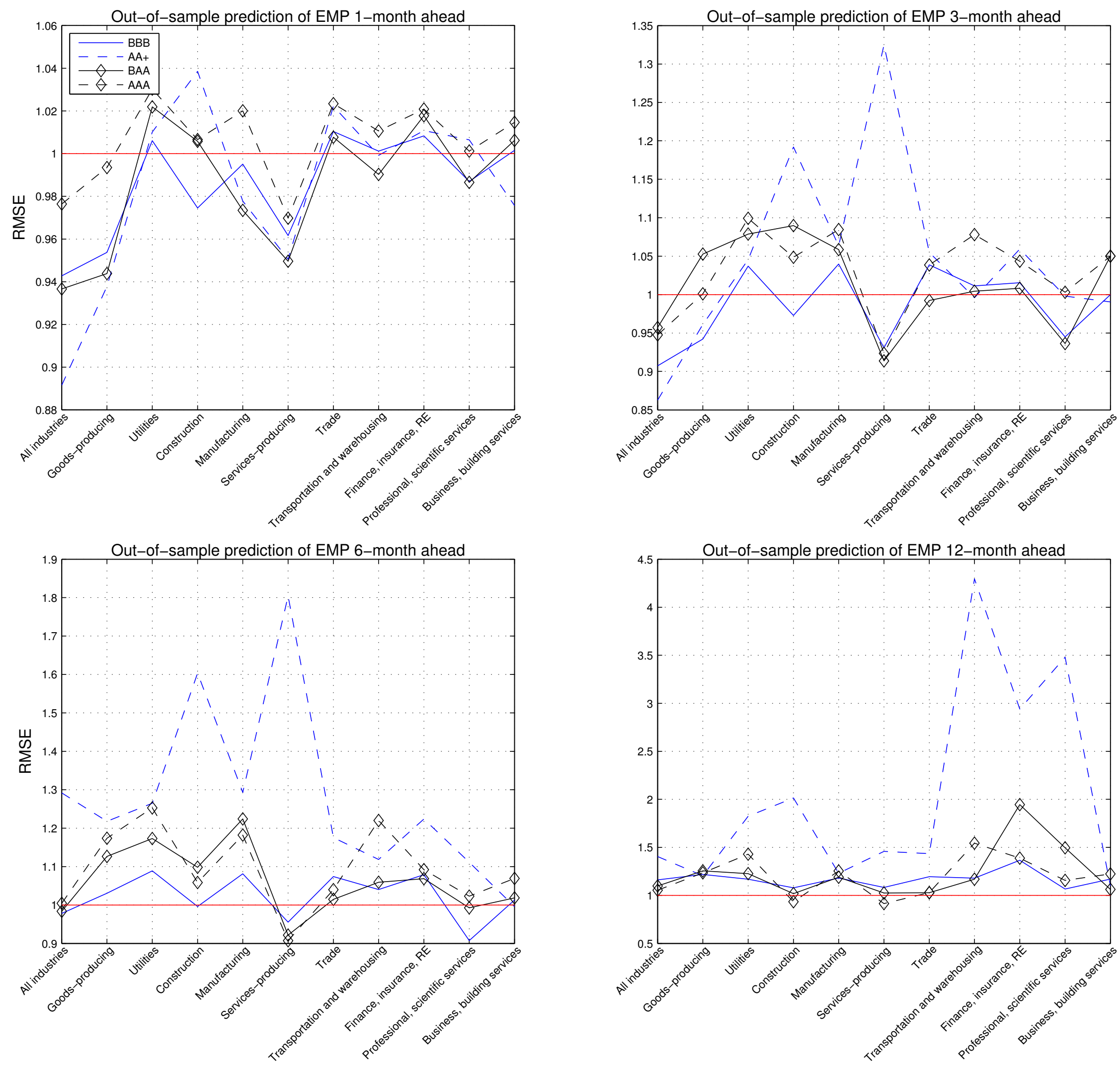
This Figure shows the MSPE of ADL+CS models, for each credit spread relative to MSPE of the ARD model, for all GDP sectoral series. When the ratio is lower than 1, it means that adding a credit spread to ARDI model produces better forecast h months ahead in terms of MSPE.

Figure 11: Relative MSPE for ARDI+CS: employment sectors



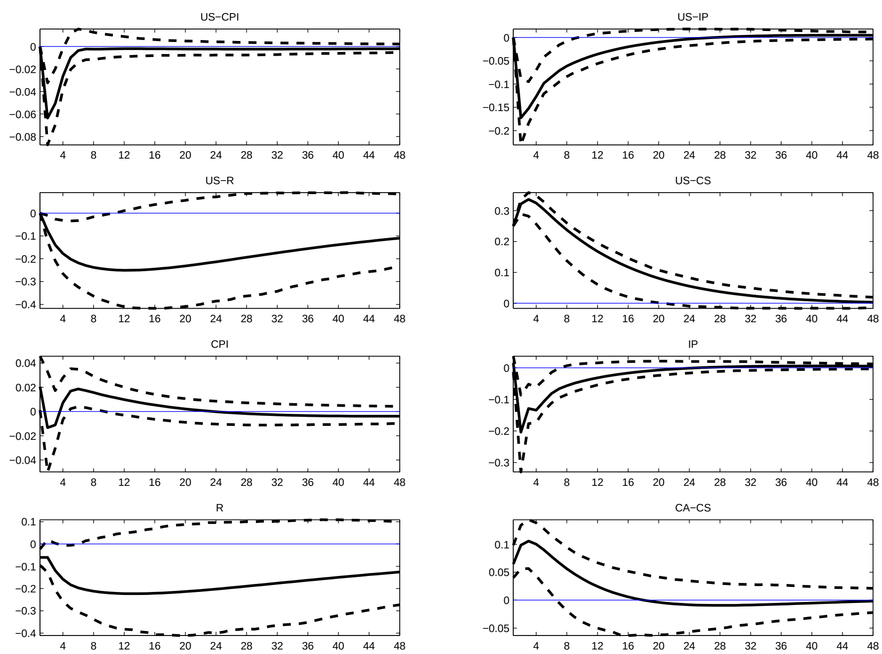
This Figure shows the MSPE of ARDI+CS models, for each credit spread relative to MSPE of the ARD model, for all employment sectoral series. When the ratio is lower than 1, it means that adding a credit spread to ARDI model produces better forecast h months ahead in terms of MSPE.

Figure 12: Relative MSPE for ADL+CS: employment sectors



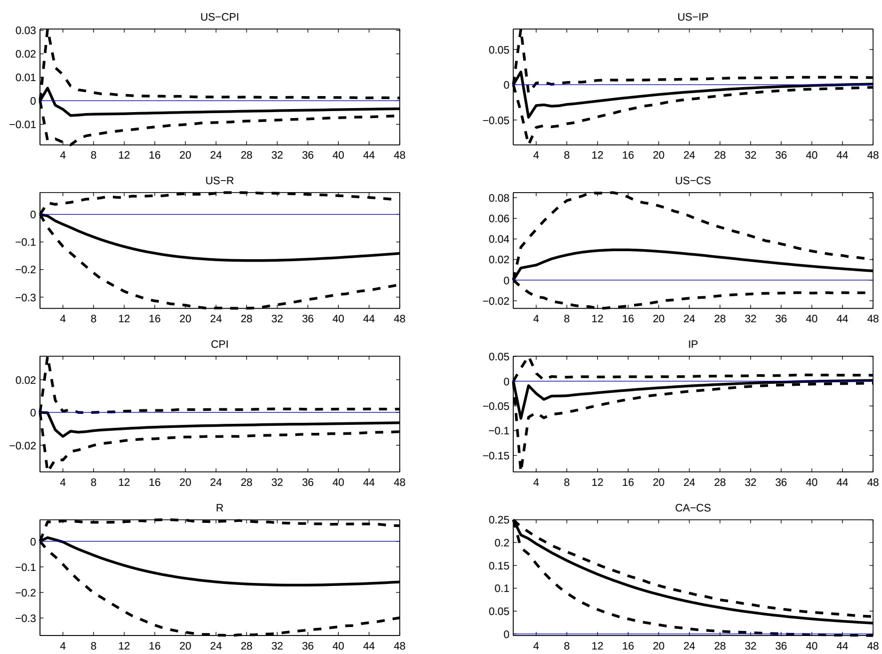
This Figure shows the MSPE of ADL+CS models, for each credit spread relative to MSPE of the ARD model, for all employment sectoral series. When the ratio is lower than 1, it means that adding a credit spread to ARDI model produces better forecast h months ahead in terms of MSPE.

Figure 13: SVAR evidence: dynamic response to US credit shock



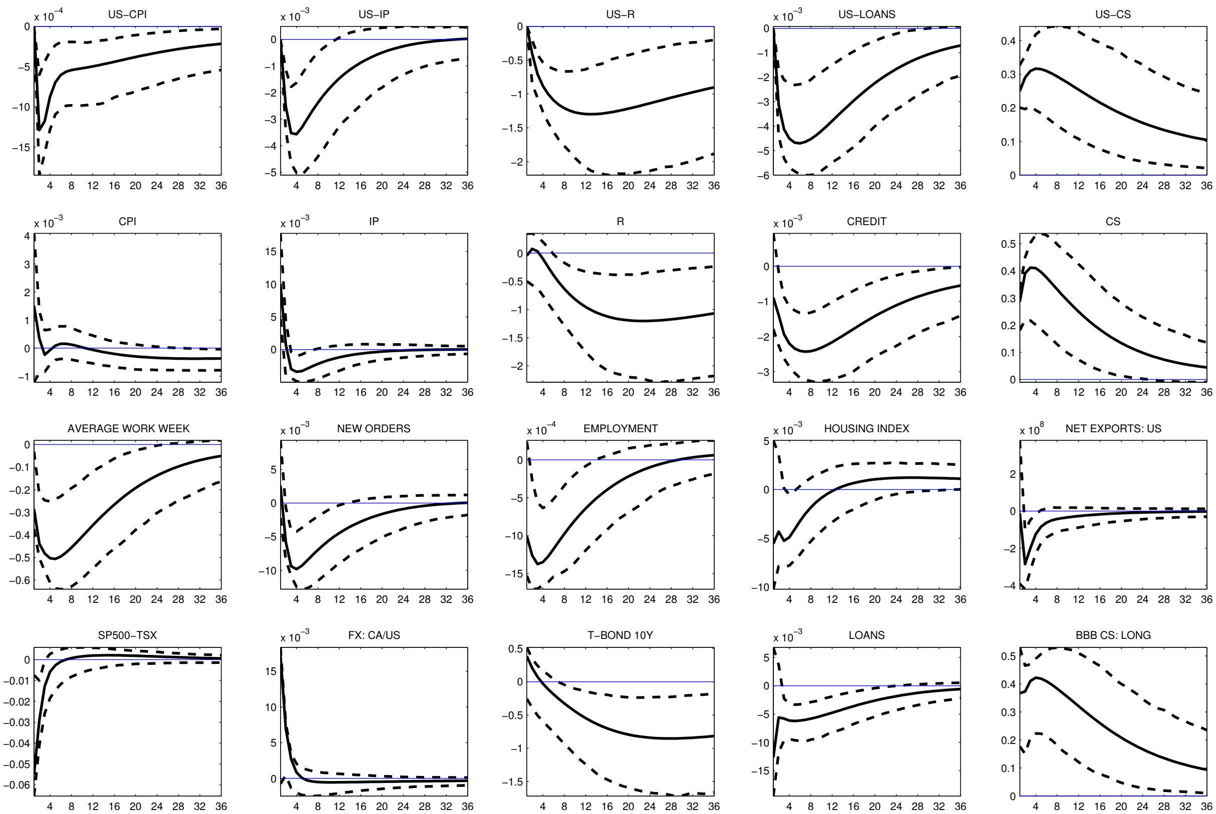
This Figure shows impulse response functions to the positive US credit shock estimated from a recursive VAR model. The dotted lines present 90% *confidence bands constructed after 5000 bootstrap replications.*

Figure 14: SVAR evidence: dynamic response to CA credit shock



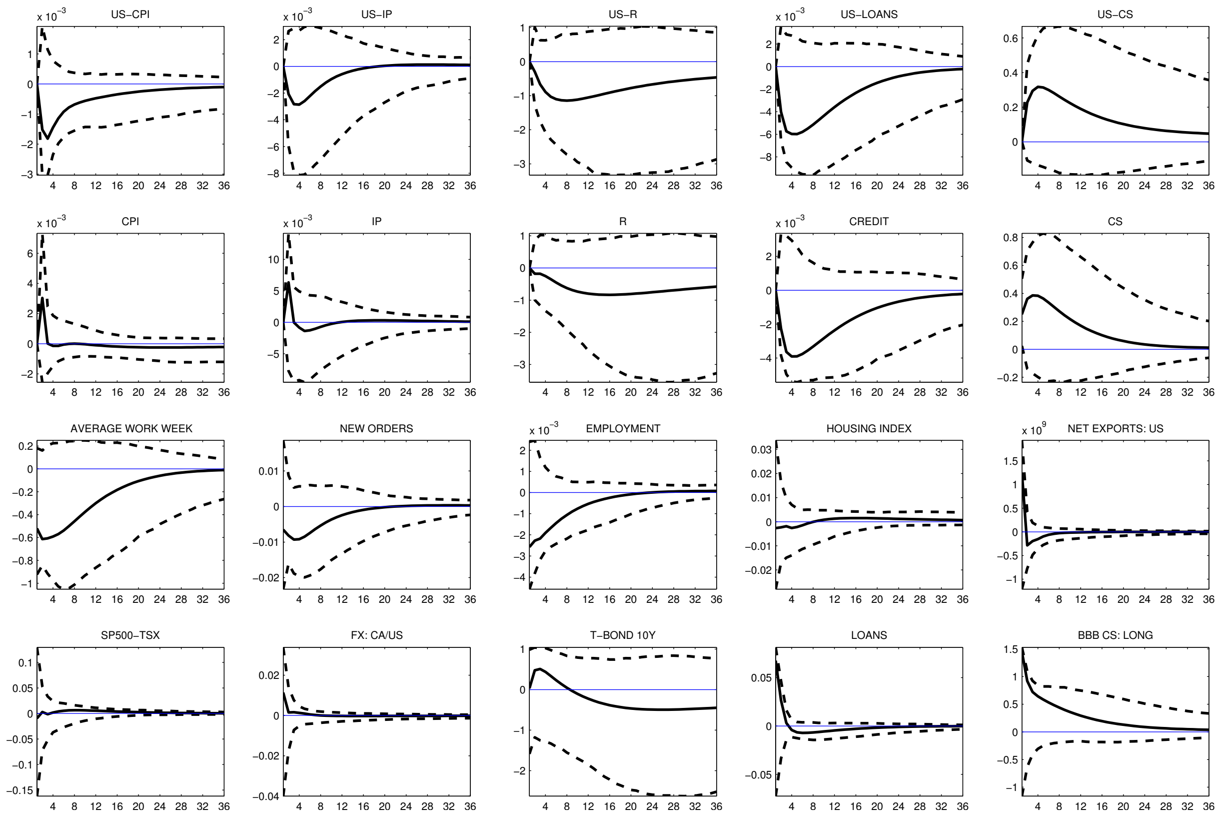
This Figure shows impulse response functions to the positive Canadian credit shock estimated from a recursive VAR model. The dotted lines present 90% *confidence bands constructed after 5000 bootstrap replications.*

Figure 15: FAVARMA evidence: dynamic response to US AAA credit shock



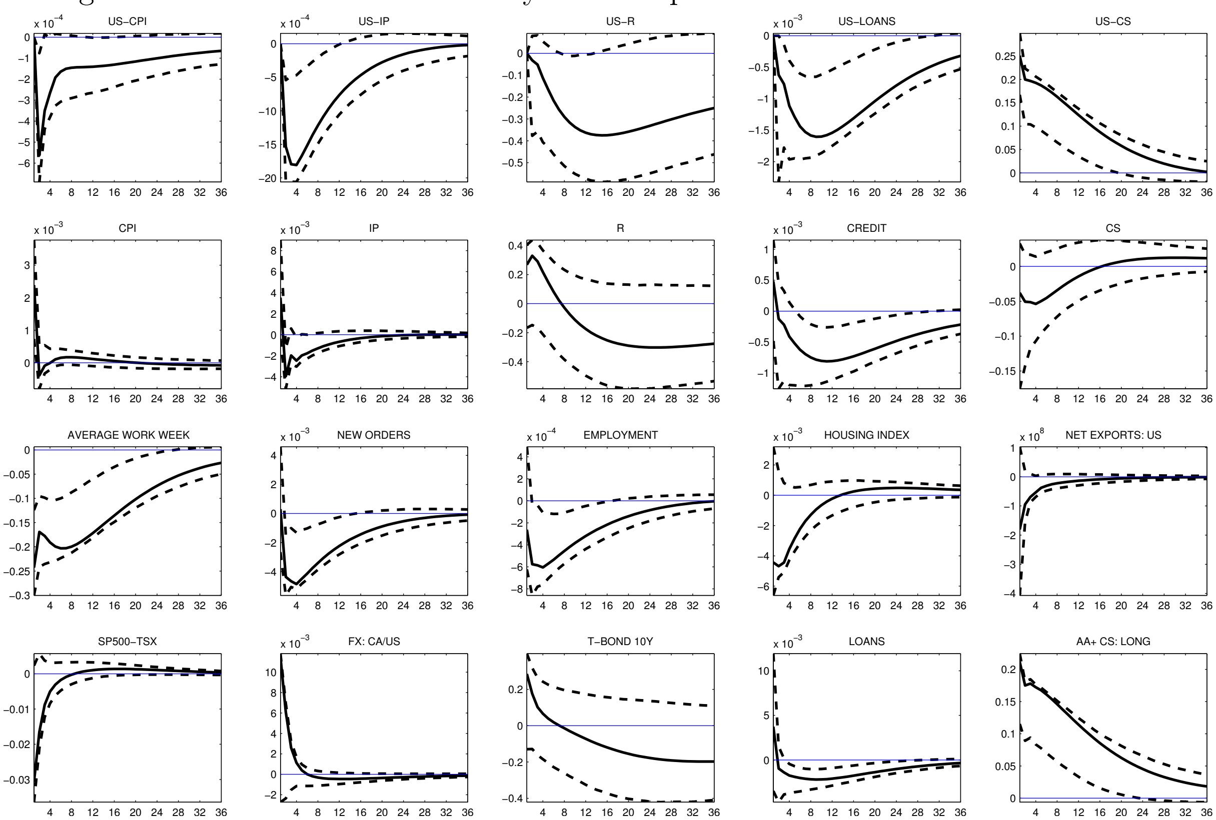
This Figure shows impulse response functions to the positive US credit shock estimated from the benchmark FAVARMA model. The US credit spread is the AAA, and the Canadian credit spread is the AA+ Long. The dotted lines present 90% *confidence bands constructed after 5000 bootstrap replications.*

Figure 16: FAVARMA evidence: dynamic response to CA AA+ credit shock



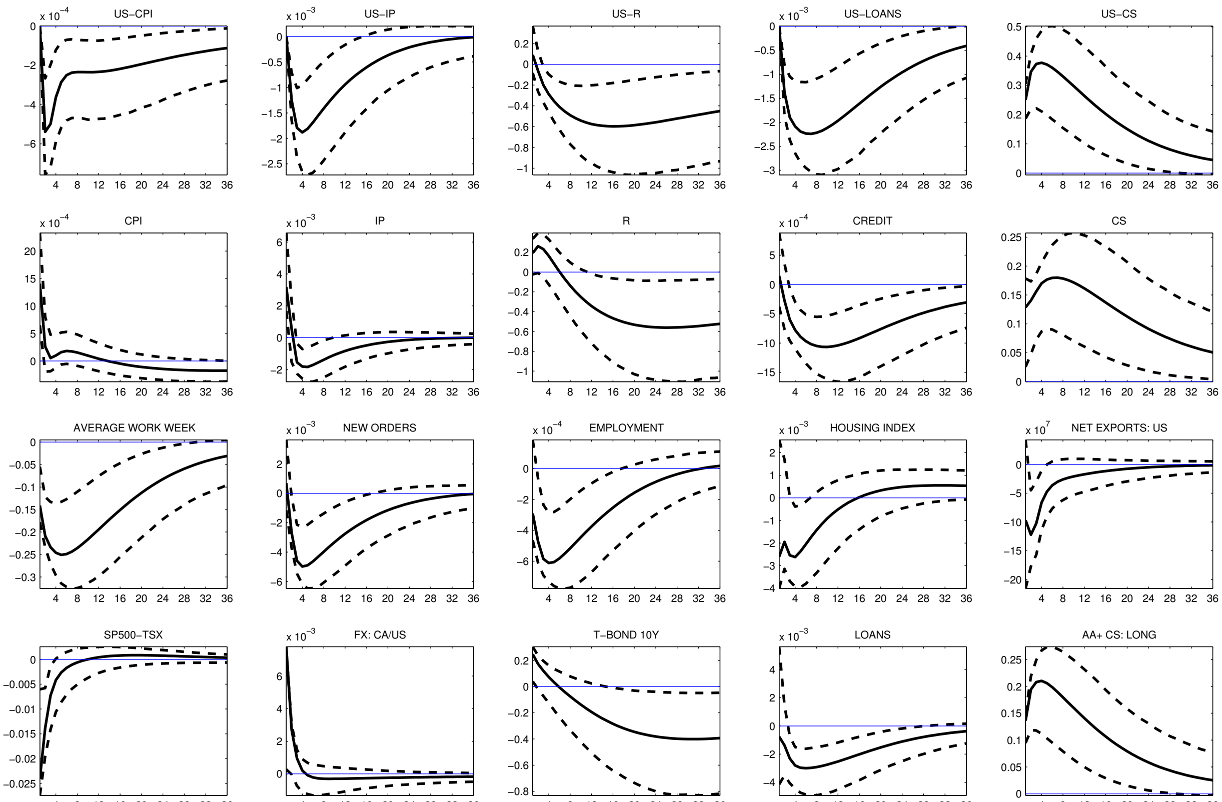
This Figure shows impulse response functions to the positive Canadian credit shock estimated from the benchmark FAVARMA model. The US credit spread is the AAA, and the Canadian credit spread is the AA+ Long. The dotted lines present 90% *confidence bands constructed after 5000 bootstrap replications.*

Figure 17: FAVARMA evidence: dynamic response to US BAA-AAA credit shock



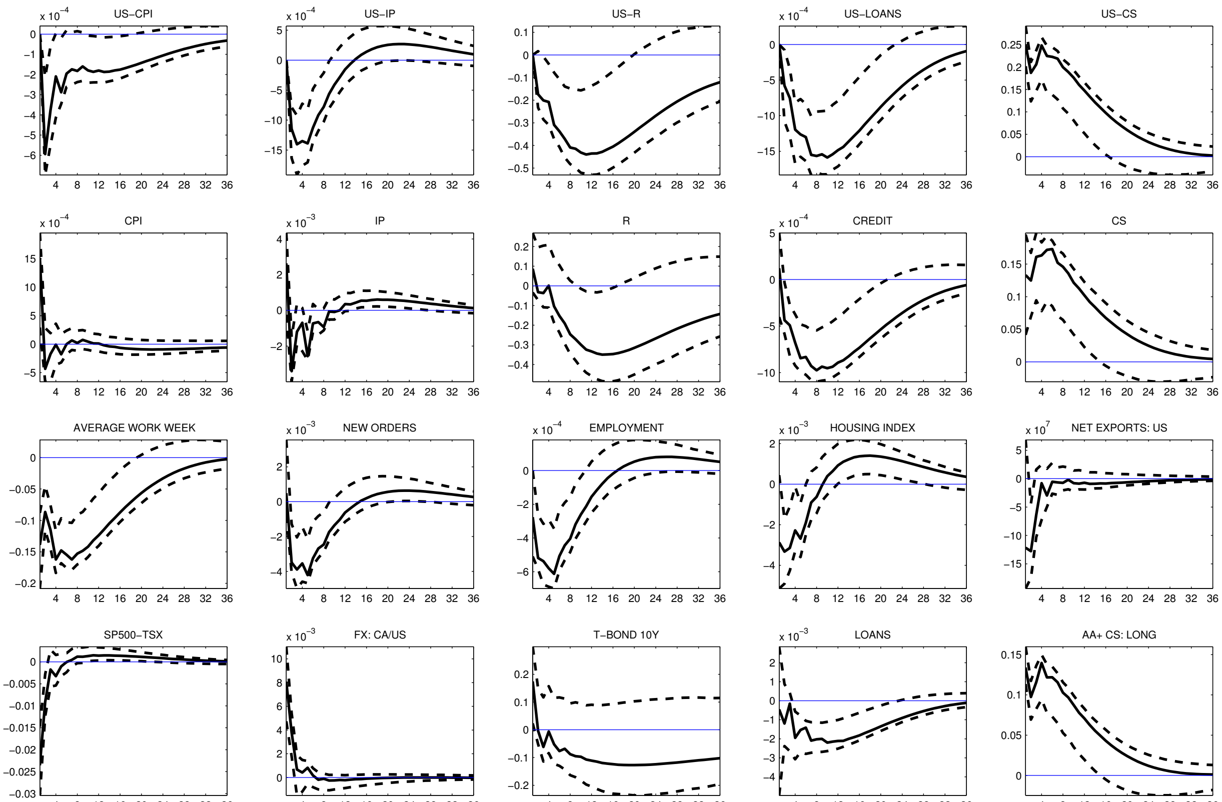
This Figure shows impulse response functions to the positive US credit shock estimated from the benchmark FAVARMA model. The US credit spread is the BAA-AAA, and the Canadian credit spread is the BBB-AA+ Long. The dotted lines present 90% *confidence bands constructed after 5000 bootstrap replications.*

Figure 18: FAVARMA evidence: dynamic response to US credit shock with another ordering



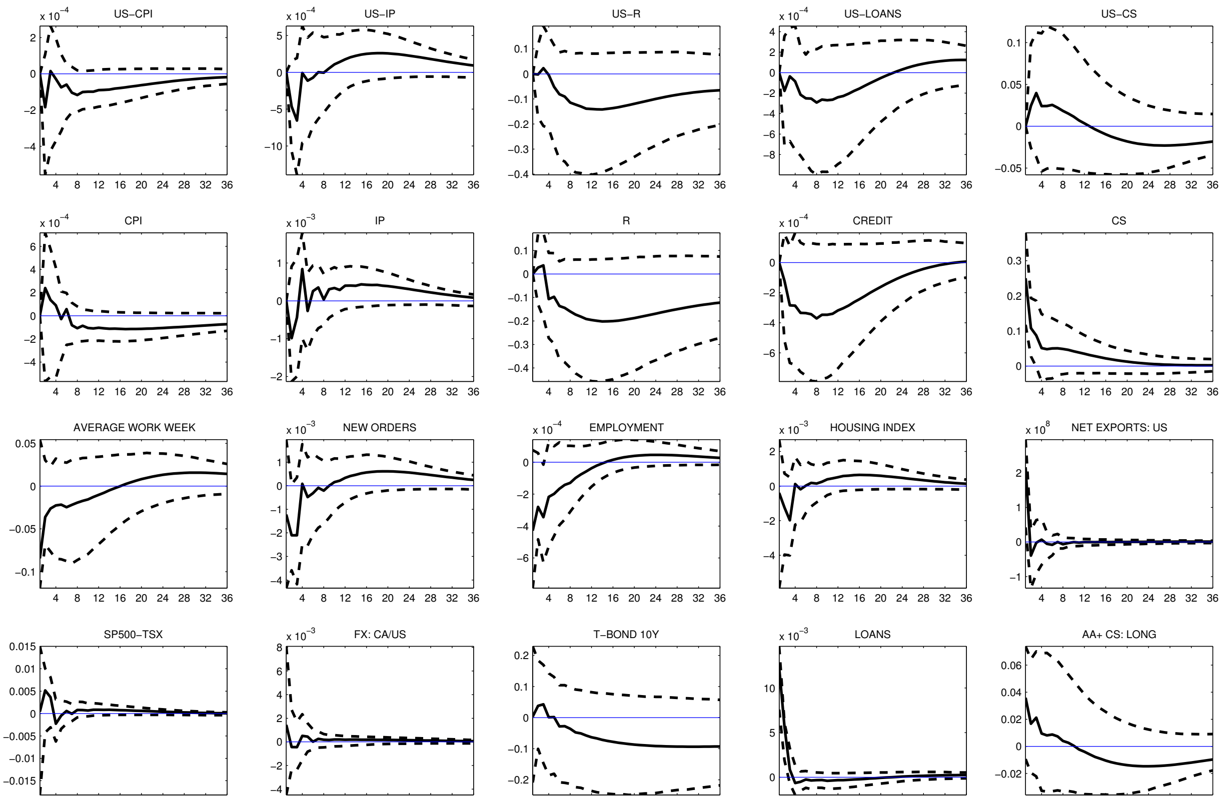
This Figure shows impulse response functions to the positive US credit shock estimated from the benchmark FAVARMA model but where the ordering between the Federal Funds Rate and US credit spread is inverted. The US credit spread is the BAA, and the Canadian credit spread is the BB+ Long. The dotted lines present 90% confidence bands constructed after 5000 bootstrap replications.

Figure 19: FAVAR evidence: dynamic response to US credit shock



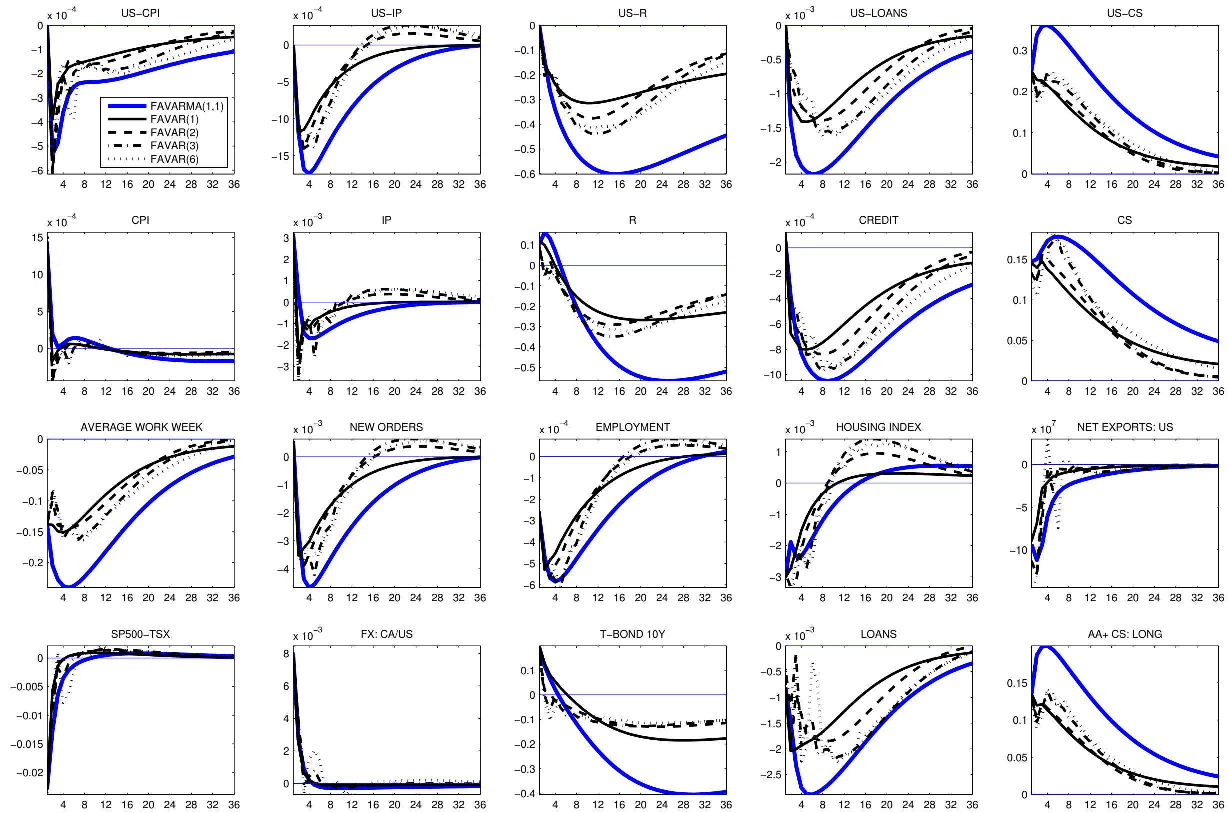
This Figure shows impulse response functions to the positive US credit shock estimated from the FAVAR model with the VAR(3) process for the factors. The US credit spread is the BAA, and the Canadian credit spread is the BB+ Long. The dotted lines present 90% *confidence bands constructed after 5000 bootstrap replications.*

Figure 20: FAVAR evidence: dynamic response to CA credit shock



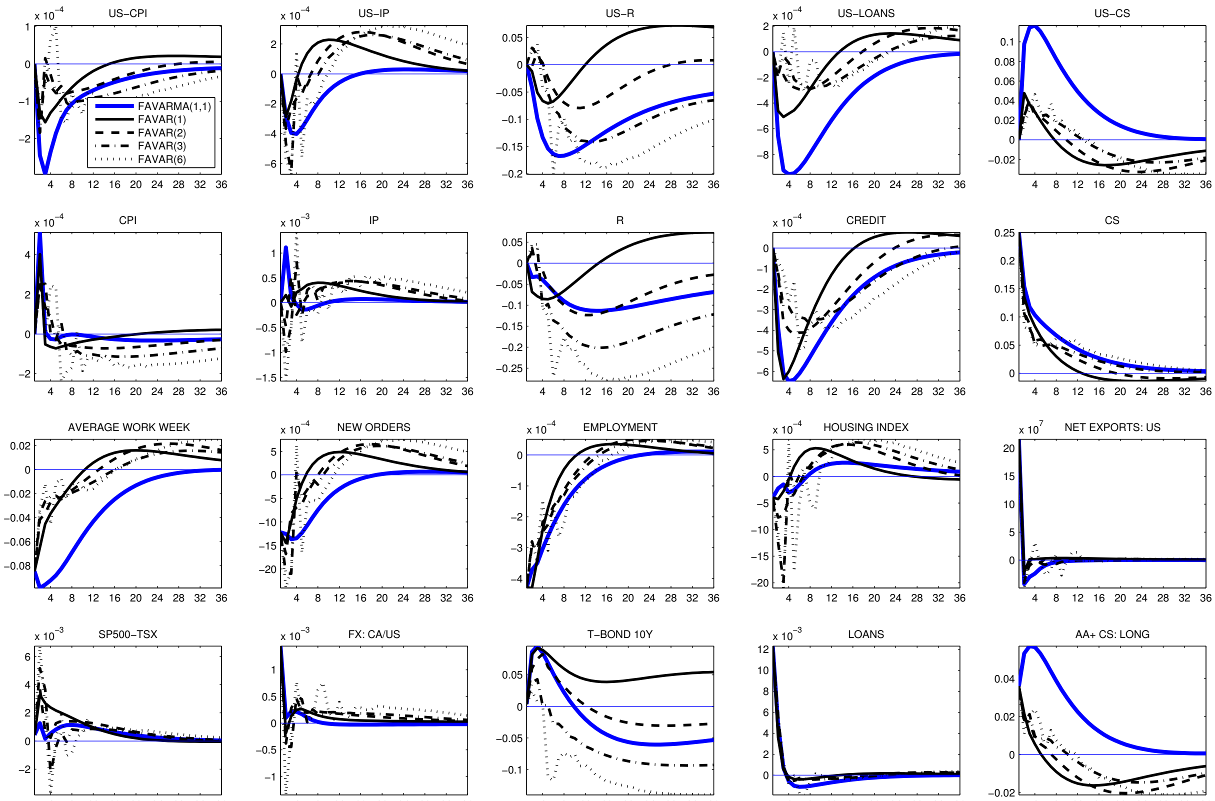
This Figure shows impulse response functions to the positive Canadian credit shock estimated from the FAVAR model with the VAR(3) process for the factors. The US credit spread is the BAA, and the Canadian credit spread is the BB+ Long. The dotted lines present 90% *confidence bands constructed after 5000 bootstrap replications.*

Figure 21: Comparison of FAVARMA and FAVAR evidence: dynamic response to US credit shock



This Figure compares impulse response functions to the positive US credit shock estimated from the benchmark FAVARMA model against the FAVAR models with factors' VAR orders of 1, 2, 3 and 6. The US credit spread is the BAA, and the Canadian credit spread is the BB+ Long.

Figure 22: Comparison of FAVARMA and FAVAR evidence: dynamic response to Canadian credit shock



This Figure compares impulse response functions to the positive Canadian credit shock estimated from the benchmark FAVARMA model against the FAVAR models with factors' VAR orders of 1, 2, 3 and 6. The US credit spread is the BAA, and the Canadian credit spread is the BB+ Long.

Table 1: FAVARMA robustness: Variance decomposition

Variables	US-CS: AAA-10y		
	$h = 3$	$h = 6$	$h = 36$
US-CPI	4,74	5,21	5,22
US-IP	10,69	10,54	10,54
US-R	6,74	11,98	12,11
US-LOANS	19,18	22,29	22,29
US-CS	54,75	45,62	45,22
CPI	1,63	1,68	1,69
IP	10,99	10,86	10,86
R	0,41	4,46	4,83
CREDIT	17,03	20,86	20,85
CS	47,62	40,54	40,51
AVERAGE WORK WEEK	47,82	42,15	42,13
NEW ORDERS	11,80	11,86	11,86
EMPLOYMENT	21,11	21,05	21,05
HOUSING INDEX	5,60	5,55	5,55
NET EXPORTS: US	2,56	2,58	2,58
SP500-TSX	23,24	23,19	23,19
FX: CA/US	17,18	17,17	17,17
T-BOND 10Y	1,53	4,40	4,89
LOANS	11,76	12,43	12,43
BBB+ CS: LONG	32,79	33,33	33,28

This Table presents the variance decomposition (in %) of the series of interest to US credit shocks as estimated from two FAVARMA model with the credit spread constructed as difference between AAA bonds and 10 year treasury.

Table 2: FAVARMA robustness: Variance decomposition

Variables	CS: BAA-AAA			FFR placed after CS		
	$h = 3$	$h = 6$	$h = 36$	$h = 3$	$h = 6$	$h = 36$
US-CPI	1,94	2,10	2,10	4,14	4,72	4,73
US-IP	10,69	11,56	11,56	16,30	17,07	17,07
US-R	0,66	2,86	2,96	3,27	10,08	10,44
US-LOANS	7,24	12,34	12,33	21,40	27,40	27,40
US-CS	64,53	60,62	60,56	72,98	64,72	64,69
CPI	8,81	8,77	8,76	7,55	7,55	7,56
IP	6,74	6,84	6,84	7,81	7,97	7,97
R	2,08	2,35	2,47	2,22	5,22	5,75
CREDIT	3,20	6,27	6,27	9,77	15,86	15,87
CS	1,16	1,21	1,22	25,73	29,22	29,21
AVG WORK WEEK	49,41	50,72	50,62	62,12	57,95	57,94
NEW ORDERS	10,42	11,48	11,48	15,69	16,89	16,89
EMPLOYMENT	10,52	11,78	11,78	18,90	20,35	20,35
HOUSING INDEX	7,07	7,02	7,02	7,33	7,34	7,35
NET EXPORTS: US	3,92	3,95	3,95	4,67	4,71	4,71
SP500-TSX	16,28	16,23	16,23	25,67	25,57	25,57
FX: CA/US	15,00	15,03	15,03	18,68	18,68	18,68
T-BOND 10Y	2,62	2,31	2,47	4,69	6,32	6,97
LOANS	2,87	3,77	3,77	3,56	5,06	5,06
AA+ CS: LONG	66,33	62,17	61,90	66,67	59,48	59,43

This Table presents the variance decomposition (in %) of the series of interest to US credit shocks as estimated from two FAVARMA models: (i) with the credit spread constructed as difference between BAA and AAA bonds; (ii) Federal funds rate placed just after the credit spread in the recursive ordering.

Table 3: FAVAR evidence: Variance decomposition

Variables	US credit shock			CA credit shock		
	$h = 3$	$h = 6$	$h = 36$	$h = 3$	$h = 6$	$h = 36$
US-CPI	5,64	6,09	6,09	0,26	0,36	0,36
US-IP	18,58	18,54	18,53	1,58	1,66	1,66
US-R	5,23	11,23	11,01	0,07	0,60	0,67
US-LOANS	10,93	21,59	21,56	0,23	0,42	0,42
US-CS	66,81	63,71	63,52	0,66	0,66	0,66
CPI	8,43	8,39	8,39	0,17	0,23	0,23
IP	13,31	13,24	13,24	0,42	0,50	0,50
R	0,58	4,44	4,40	0,22	1,22	1,31
CREDIT	11,22	19,56	19,54	1,35	1,97	1,97
CS	28,81	31,23	31,15	18,36	16,39	16,35
AVERAGE WORK WEEK	51,87	54,03	53,93	5,42	4,09	4,08
NEW ORDERS	19,38	19,53	19,53	3,03	2,97	2,97
EMPLOYMENT	22,95	23,57	23,56	6,43	6,14	6,14
HOUSING INDEX	12,48	12,79	12,79	1,30	1,37	1,37
NET EXPORTS: US	6,28	6,29	6,29	5,66	5,66	5,66
SP500-TSX	21,88	21,91	21,91	0,93	0,95	0,95
FX: CA/US	18,76	18,74	18,74	0,42	0,43	0,43
T-BOND 10Y	2,27	2,91	2,94	0,14	0,55	0,72
LOANS	1,02	2,71	2,71	31,42	30,63	30,63
AA+ CS: LONG	61,53	58,20	57,96	1,55	1,39	1,39

This Table presents the variance decomposition (in %) of the series of interest to US and Canadian credit shocks respectively, as estimated from the FAVAR model with factors VAR of order 3.