Finance and Economics Discussion Series
Divisions of Research & Statistics and Monetary Affairs
Federal Reserve Board, Washington, D.C.

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2017-066

Please cite this paper as:
Shin, Minchul, Boyuan Zhang, Molin Zhong, and Dong Jin Lee (2017). "Measuring International Uncertainty: the Case of Korea," Finance and Economics Discussion Series 2017-066. Washington: Board of Governors of the Federal Reserve System, https://doi.org/10.17016/FEDS.2017.066.

Measuring International Uncertainty: the Case of Korea

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This version: April 20, 2017

Abstract

We leverage a data rich environment to construct and study a measure of macroeconomic uncertainty for the Korean economy. We provide several stylized facts about uncertainty in Korea from 1991M10–2016M5. We compare and contrast this measure of uncertainty with two other popular uncertainty proxies, financial and policy uncertainty proxies, as well as the U.S. measure constructed by Jurado et al. (2015).

Key words: Uncertainty, Stochastic volatility, Business cycle, Korean economy, Data rich environment.

JEL codes: C11, C32, E32

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Measuring International Uncertainty: the Case of Korea

1 Introduction

Macroeconomic uncertainty and its relationship with the business cycle has received much attention in the U.S. and internationally. Measuring uncertainty, however, has proven challenging because it is not directly observable. International studies largely proxy for uncertainty using the VIX or economic policy uncertainty index (e.g., Carriere-Swallow and Cespedes, 2013; Choi and Shim, 2016; Baker et al., 2017).

Recently, Jurado et al. (2015) have provided a leading measure of "objective" uncertainty for the U.S. economy. This index has two attractive features: it is measured from macroeconomic data volatility in a reduced-form way and it covers a broad range of indicators spanning the entire macroeconomy. Internationally, this strategy for measuring uncertainty has remained unused because of data availability costs. This paper works to resolve this gap by using 112 data series to provide a broad-based measure of uncertainty for Korea. We hope that this paper encourages more work on uncertainty fluctuations in small open economies such as the Korean economy.[1]

2 Construction of the uncertainty measure

2.1 Methodology

Following Jurado et al. (2015), we define the uncertainty of an individual series as the conditional volatility of the unforecastable component of the future values of that series. The h-period ahead uncertainty in the variable $y_{jt} \in Y_t = (y_{1t}, ..., y_{N_y t})'$ is defined as

$$U_{jt}^{y}(h) \equiv \sqrt{E\left[\left(y_{jt+h} - E\left[y_{jt+h}\middle|I_t\right]\right)^2\middle|I_t\right]} \tag{1}$$

where the expectation is taken with respect to the information set I_t available to agents at time t. If the expectation of the squared error in forecasting y_{jt+h} rises, uncertainty in the

[1] We plan to make our estimated uncertainty indices available from our personal and journal websites.

variable increases. We compute the individual uncertainties by modeling the individual series as factor augmented AR(p) models where both common factor and idiosyncratic shocks have stochastic volatility. The description of the model is in the appendix.

A measure of macroeconomic uncertainty aggregates the individual uncertainties of each series at every date:

$$U_t^y(h) \equiv \sum_{j=1}^{N_y} w_j U_{jt}^y(h) \tag{2}$$

where w_j is a weight assigned to the uncertainty in the jth variable. Our baseline uncertainty measure is based on $w_j = 1/N_y$ and $h = 1$. This index measures an average difficulty of predicting a time series in the economy.[2]

2.2 Data

We use 112 monthly time series that represent the Korean economy from 1991M10-2016M5. We categorize these 112 individual series into 8 groups: (1) Output; (2) Labor market; (3) Housing market; (4) Consumption, orders, and inventories; (5) Money and loans; (6) Bonds and stocks; (7) Prices; (8) Imports and exports.

We also compare our uncertainty index with two other popular uncertainty proxies. The first is the VKOSPI index, which is the Korean version of the VIX (option implied volatility).[3] The second is the economic policy uncertainty (EPU) index (Baker et al., 2017), which is a news-based uncertainty measure meant to capture movements in policy-related economic uncertainty.

3 Korean Uncertainty Index

3.1 Aggregate uncertainty measure

In Figure 1, we present our uncertainty measure for Korea overlaid with other uncertainty proxies. The shaded areas are Korea's recessionary periods defined by the Korea National Statistical Office. We provide three stylized facts about uncertainty fluctuations.

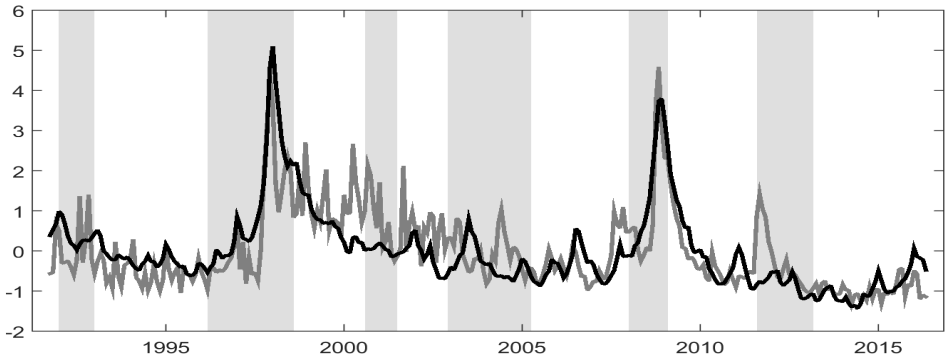
First, our uncertainty measure typically starts going up at the beginning of recessionary periods and has local peaks in the middle of recessionary periods. The exception is the

[2] We also compute the aggregate uncertainty index with w_j obtained from the first principal component. The main features are not different from the simple average.

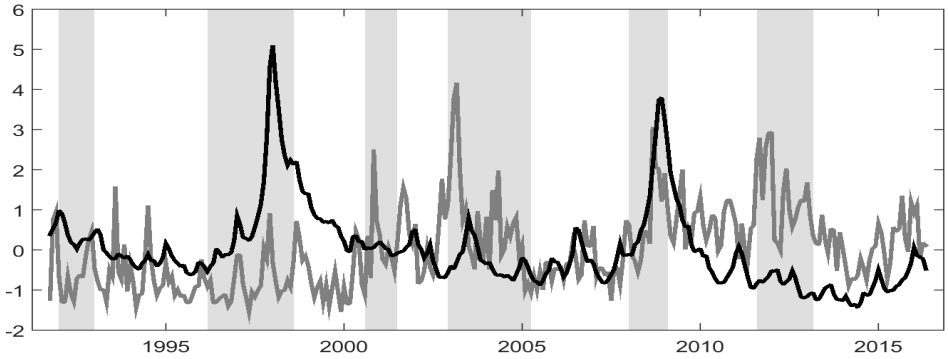
[3] We use the term VIX and VKOSPI interchangeably.

Figure 1 Korean Economic Uncertainty Index (UI)

(a) Uncertainty Index (black) and VKOSPI/VIX (grey)



(b) Uncertainty Index (black) and EPU (grey)



Note: Uncertainty index overlaid with VIX index (upper panel) and EPU index (lower panel) for 1991M10-2016M5. Pairwise correlations of these series are corr(UI, VIX) = 0.74, corr(UI, EPU) = -0.03, corr(VIX, EPU) = 0.17.

2000M8–2001M7 recession when the Korean economy suffered several damaging domestic (Daewoo Motors' Bankruptcy) and foreign (9/11 attacks) economic events. Such shocks worsened Korea's economic performance, but did not affect overall uncertainty.

Second, the uncertainty index is persistent, positively-skewed, and fat-tailed. Table 1 presents descriptive statistics of our uncertainty measure. We also compute the same statistics for the other uncertainty proxies. They share similar properties although our measure exhibits higher persistence, skewness, and kurtosis.

Third, our uncertainty index is countercyclical. Table 1 shows that the index's contemporaneous correlation with industrial production growth is -0.28. The rest shows cross-correlations between our uncertainty measure and IP growth (correlation between the uncertainty index at t and IP growth at $t+k$). They are negatively correlated within 6 month leads and lags. However, the correlation between uncertainty and IP growth becomes positive as k becomes large and is maximized at $k = 18$, which matches the average duration of

Table 1 Korean Economic Uncertainty Index (UI)

	UI	VIX	EPU	Corr.	UI	VIX	EPU	Corr.	UI	VIX	EPU
AR(1)	0.97	0.82	0.72	with IP(k)				with IP(k)			
Half Life	21.09	3.51	2.07	$k=-1$	-0.24	-0.06	-0.21	$k=+1$	-0.29	-0.14	-0.26
Skewness	2.08	1.61	1.03	$k=-3$	-0.16	0.02	-0.15	$k=+3$	-0.25	-0.13	-0.28
Kurtosis	8.83	6.26	4.34	$k=-6$	-0.07	0.08	-0.12	$k=+6$	-0.08	-0.01	-0.20
IP-corr(0)	-0.28	-0.11	-0.24	$k=-12$	0.05	0.13	0.00	$k=+12$	0.43	0.30	-0.01

Table 2 Individual Uncertainties and Other Uncertainty Proxies

with VIX						
	Full sample		Recession		Expansion	
Top 1	KOSPI	0.73	Ex rate: UK	0.73	KOSPI	0.81
Top 2	Ex rate: UK	0.64	Ex rate: avg (nominal)	0.72	M2	0.62
Top 3	Ex rate: US	0.62	Ex rate: US	0.72	TB3y-MSB1y spread	0.57

with EPU						
	Full sample		Recession		Expansion	
Top 1	BoP: CA	0.50	BoP: CA	0.54	BoP: CA	0.47
Top 2	Baltic Dry Index	0.47	Baltic Dry Index	0.48	Exports of goods	0.42
Top 3	PIP: Total	0.45	PIP: Total	0.47	Baltic Dry Index	0.42

Note: Numbers in the table are correlation between uncertainty proxies and corresponding individual uncertainties. A detailed description of the individual series is in the online appendix.

recessions (18.4 months).

3.2 Comparisons with other uncertainty measures

VIX. Panel (a) in Figure 1 shows the VIX index. It generally moves together with our uncertainty measure with a correlation of 0.74. Although both measures move closely, there are differences.[4]

One example is the 2002M12–2005M4 recession. At the beginning of this recession, both uncertainty measures increased. Our uncertainty measure had its highest peak on 2003M7, mostly due to heightened uncertainties of the variables in Group 1 (Output) and Group 4 (Consumption, orders, inventories) driven by the Korean credit card lending boom (1999–2002) and bust (2003).[5] Unlike our uncertainty measure, the VIX had its highest peak

[4]Moreover, as we show in a VAR exercise in the online appendix that includes both our uncertainty index and the VIX, shocks to our uncertainty index have different effects on the macroeconomy relative to shocks to the VIX.

[5]This recession is also known as the credit card crisis. See for example, Kang and Ma (2007).

around 2004M6 from news about policy rate increases by the Chinese government and the Federal Reserve. During this period, variables in Group 4 (Consumption, orders, inventories) and Group 9 (Imports and exports) contributed the most to our uncertainty measure, which distinguished the origin of this uncertainty from that of the 2003M7 peak. However, this heightened uncertainty in the international market did not translate into uncertainty about the overall Korean economy as our overall measure did not move much during this period.

Table 2 reveals this disconnect between the two uncertainty measures. It reports the three individual uncertainties that are most associated with the volatility proxies. The VIX index is most related to uncertainty about financial variables such as the KOSPI index, exchange rates, and interest rate spreads.

EPU. The second panel in Figure 1 shows the time series plot of the EPU overlaid with our uncertainty measure. Our uncertainty measure and the EPU show quite different dynamics. For example, based on our measure, economic uncertainty was highest during the Asian financial crisis, while the EPU put low weight to the crisis. Other examples are periods with international affairs such as the 9/11 attacks, Gulf War II, the Eurozone debt crisis that may have increased uncertainty outside the Korean economy but not inside.

The correlation between our uncertainty measure and the EPU is essentially zero (-0.03). One explanation for the low correlation is that some of the economic policy related uncertainty that the Korean news articles mentioned did not manifest as increases in the overall uncertainty of the Korean economy. Table 2 shows that the EPU index is correlated with uncertainties related to trade activities such as the current account, Baltic Dry index, import price index, and the exports of goods. This finding suggests that the index weighs heavily international affairs relative to domestic affairs.

3.3 Comparison to U.S. index

The Korean and U.S. uncertainty measures share some common statistical properties. As we can see from Table 3a, economic uncertainty measures for both countries are persistent, positively skewed, fat-tailed, and countercyclical.

In Table 3b, we report relationships among the various uncertainty measures from Korea and the U.S. We find that these uncertainty measures are correlated with each other with the exception of the Korean uncertainty index and the EPU index pair. Moreover, uncertainty in the Korean and U.S. financial markets are more related than are the broad-based uncertainty

Table 3 Korean and U.S. Uncertainty Measures

(a) Descriptive statistics

	Korea			U.S.		
	UI	VIX	EPU	UI	VIX	EPU
AR(1)	0.96	0.78	0.73	0.99	0.89	0.73
Half Life	18.73	2.85	2.19	50.81	6.01	2.25
Skewness	2.23	1.59	1.19	2.33	1.79	1.48
Kurtosis	8.92	6.06	4.62	9.69	8.19	5.72
IP-corr(0)	-0.49	-0.29	-0.22	-0.79	-0.49	-0.34

(b) Correlation among uncertainty measures

	UI-K	VIX-K	EPU-K	UI–US	VIX-US
UI-K	1	.	.	.	.
VIX-K	0.70	1	.	.	.
EPU-K	0.03	0.25	1	.	.
UI-US	0.33	0.38	0.45	1	.
VIX-US	0.50	0.69	0.50	0.63	1
EPU-US	0.12	0.30	0.68	0.39	0.61

Note: Our sample for this table covers 1991M10–2011M12. K: Korea, US: United States.

indices. This is sensible given that financial trading has less barriers than trading in other markets.

Furthermore, the Korean EPU index is more associated with U.S. uncertainty measures than Korean ones. This suggests that Korean newspapers overweight news about foreign policy-related uncertainty which may not pass through to the domestic market. This is consistent with the previous subsection: the Korean EPU index is related to international trade activities variables, which may not be relevant for uncertainty about the Korean economy. The Korean EPU index is also less correlated with the Korean VIX and uncertainty index relative to the U.S. EPU index's correlation with its U.S. counterparts.

4 Conclusion

We construct an uncertainty measure based on 112 economic time series for Korea. We provide a set of stylized facts about Korean economic uncertainty. In addition, we find that other uncertainty proxies are associated with specific sectors and do not represent uncertainty of the whole economy. One needs to be cautious about the use of news-based measures because journalists' view about uncertainty can be quite different across countries. For example, the EPU index for the Korean economy is more associated foreign uncertainty.

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Online appendix (not for publication)

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This version: April 20, 2017

This appendix has three sections:

1. Section 1 describes data used in this paper.
2. Section 2 provides the detailed description of the computation of the uncertainty index.
3. Section 3 provides further comparisons of the uncertainty index and other proxies based on the VAR estimation.
4. Section 4 presents additional VAR results with different model specifications (different lag length, ordering of variables, and other combinations of variables).

1 Variables used in analysis

In this section we present a list of variables used in the construction of our uncertainty measure. In each table, there are 5 columns:

- ID: Numeric number that identifies each series.
- Group: Numeric number that identifies each group.
- Trans: Numeric number that indicates the type of data transformation that is applied to each individual series (Transformation code 3 and 5 are not used in this application).
  - Trans = 1: Transformation is not applied.
  - Trans = 2: $X_{i,t} = log(X^{raw}_{i,t}) - log(X^{raw}_{i,t-1})$.
  - Trans = 4: $X_{i,t} = log(X^{raw}_{i,t})$.
  - Trans = 6: $X_{i,t} = X^{raw}_{i,t} - 100$.
- Name: Name of each variable.

- Description: Description of each variable.

We apply X-12 to remove the seasonal component from each individual series and apply appropriate transformations to make all individual series stationary.

In addition to these variables, we also use VKOSPI/VIX, EPU, and U.S. uncertainty measures.

1. The VKOSPI index (VIX), which is the Korean version of the VIX (the option implied volatility measure based on S&P500 index options). This measure is an implied volatility based on KOSPI 200 index options and it serves as a proxy for stock market uncertainty in Korea. More general discussion about VKOSPI can be found in Han et al. (2015). The VKOSPI index is only available from 2003. We follow Choi and Shim (2016) and extend the VKOSPI index series back to 1991 using the realized volatility of the daily KOSPI200 index..
2. The economic policy uncertainty (EPU) index constructed by Baker et al. (2017). This measure and its description are available from their webpage: http://www.policyuncertainty.com/
3. U.S. uncertainty measure of Jurado et al. (2015) is taken from Serena Ng's webpage: http://www.columbia.edu/~sn2294/pub.html

Table 1 Variables in Group 1: Output

ID	Group	Trans	Name	Description
1	1	2	IP: Total	Industry, Industrial Production Index by Industry, All Groups, Production Index (2010), SA
2	1	2	IP: Manufacturing	Industrial Production Index by Industry, Manufacturing (2010), SA
3	1	2	IP: Chemical	Industry, Industrial Production Index by Industry, Manufacture of Chemicals and Chemical Products except Pharmaceuticals, Production Index (2010), SA
4	1	2	IP: Equipment	Industrial Production Index by Industry, Electrical Equipment (2010), SA
5	1	2	IP: Vehicles	Industrial Production Index by Industry, Motor Vehicles, Trailers and Semitrailers (2010), SA
6	1	2	IP: Capital goods	Industry, Industrial Production Index by Market Group, Whole Country, Capital Goods, Production Index (2010), SA
7	1	2	IP: Intermediate goods	Industry, Industrial Production Index by Market Group, Whole Country, Intermediate Goods, Production Index (2010), SA
8	1	2	IP: Consumers goods	Industrial Production Index by Market Group, Whole Country, Consumers' Goods, Production Index (2010), SA
9	1	2	SI: Total	Industry, Industrial Production Index by Industry, All Groups, Shipment Index (2010), SA - Korea, Republic of
10	1	2	OI: Manufacturing	MANUFACTURING OPERATION RATIO INDEX (2010), SA - SOUTH KOREA
11	1	2	OI: Chemicals	Chemicals OPERATION RATIO INDEX (2010), SA - SOUTH KOREA
12	1	2	OI: Equipment	Electrical Equipment OPERATION RATIO INDEX (2010), SA - SOUTH KOREA
13	1	2	OI: Vehicles	Motor Vehicles, Trailers and Semitrailers OPERATION RATIO INDEX (2010), SA - SOUTH KOREA
14	1	6	Business conditions (total, actual)	Surveys and Cyclical Indicators, Business Survey Index, All Industries, Actual, Composite Business Conditions Index, Actual, NSA
15	1	6	Business conditions (manufacturing, actual)	Surveys and Cyclical Indicators, Business Survey Index, Manufacturing, Actual, Composite Business Conditions Index, Actual, NSA
16	1	6	Business conditions (total, forecast)	Surveys and Cyclical Indicators, Business Survey Index, All Industries, Forecast, Composite Business Conditions Index, NSA - Kor
17	1	6	Business conditions (manufacturing, forecast)	Surveys and Cyclical Indicators, Business Survey Index, Manufacturing, Forecast, Composite Business Conditions Index, NSA - Kore

Table 2 Variables in Group 2: Labor Markets

ID	Group	Trans	Name	Description
18	2	2	EMP: Employed	Labor Market, Population, Total, Employed Persons, SA
19	2	2	EMP: Unemployed	Labor Market, Population, Total, Unemployed Persons, SA
20	2	1	EMP: Unemployment rate	Labor Market, Population, Total, Unemployment Rate, SA
21	2	2	EMP: Emplyees, Manufacturing	Employees: Manufacturing
22	2	2	EMP: regular workers	Labor Market, Employed, Total, Wage & salary workers, Regular employees, NSA
23	2	2	EMP: temporary workers	Labor Market, Employed, Total, Wage & salary workers, Temporary employees, NSA
24	2	1	EMP: participation rate	Labour Market, Participation Rate, Total, NSA - Korea, Republic of
25	2	1	Hours worked	Labour Market, Employed Persons by Hours Worked, Average Weekly Working Hours, NSA - Korea, Republic of
26	2	6	Business conditions (emloyment, actual)	Surveys and Cyclical Indicators, Business Survey Index, All Industries, Actual, Employment Index, Actual, NSA - Korea, Republic
27	2	6	Business conditions (employment, forecast)	Surveys and Cyclical Indicators, Business Survey Index, All Industries, Forecast, Employment Index, NSA - Korea, Republic of

Table 3 Variables in Group 3: Housing Markets

ID	Group	Trans	Name	Description
28	3	1	Permits: Dwellings (level)	KOR Permits issued for dwellings sa / Monthly Level SA - KOREA
29	3	2	Housing starts	Korea, Republic of (South Korea) - Housing starts - Unit - Unit - NSA - Monthly
30	3	1	Permits: Dwellings (YoY growth)	KOR Permits issued for dwellings sa / Growth rate same period previous year SA - KOREA
31	3	2	Housing price index	Housing purchase price composite indices (seasonally adjusted), (2015.12=100)
32	3	2	Housing jeonse price index	Housing jeonse price composite indices (seasonally adjusted) (*Jeonse : Key money deposit lease) (2015.12=100)
33	3	2	Construction contracts	Construction contracts
34	3	2	Construction contracts: Public	Construction contracts: Public
35	3	2	Construction contracts: Private	Construction contracts: Private
36	3	2	Permits: Total	Permits: Total

Table 4 Variables in Group 4: Consumption, Order, Inventory

ID	Group	Trans	Name	Description
37	4	2	II: Total	Industry, Industrial Production Index by Industry, All Groups, Inventory Index (2010), SA
38	4	2	II: Manufacturing	Industry, Industrial Production Index by Industry, Manufacturing, Production Index (2010), SA
39	4	2	II: Capital goods	Industry, Industrial Production Index by Market Group, Whole Country, Capital Goods, Inventory Index (2010), SA
40	4	2	II: Intermediate goods	Industry, Industrial Production Index by Market Group, Whole Country, Intermediate Goods, Inventory Index (2010), SA
41	4	2	II: Consumers goods	Industry, Industrial Production Index by Market Group, Whole Country, Consumers' Goods, Inventory Index (2010), SA
42	4	2	Automobile registration	Wholesale Trade and Retail Sales, Automobile Registration, Total, NSA - Korea, Republic of
43	4	6	Business conditions (demand, actual)	Surveys and Cyclical Indicators, Business Survey Index, All Industries, Actual, Domestic Demand Index, Actual, NSA - Korea, Repu
44	4	6	Business conditions (demand, forecast)	Surveys and Cyclical Indicators, Business Survey Index, All Industries, Forecast, Domestic Demand Index, NSA - Korea, Republic o
45	4	2	Sales of goods	KOR Sales of total manufactured goods (Volume) sa / Index publication base SA - KOREA
46	4	2	Sales of consumer goods	KOR Sales of total manufactured consumer goods (Volume) sa / Index publication base SA - KOREA
47	4	2	Sales of intermediate goods	KOR Sales of manufactured intermediate goods (Volume) sa / Index publication base SA - KOREA
48	4	2	Sales of investment goods	KOR Sales of manufactured investment goods (Volume) sa / Index publication base SA - KOREA
49	4	2	Retail trade volume	KOR Total retail trade (Volume) / Index publication base - KOREA
50	4	2	SI: Manufacturing	Industry, Industrial Production Index by Industry, Manufacturing, Shipment Index (2010), SA - Korea, Republic of
51	4	2	SI: Chemicals	Industry, Industrial Production Index by Industry, Manufacture of Chemicals and Chemical Products except Pharmaceuticals
52	4	2	SI: Equipment	Industry, Industrial Production Index by Industry, Manufacture of Electrical Equipment, Shipment Index (2010), SA
53	4	2	SI: Vehicles	Industry, Industrial Production Index by Industry, Motor Vehicles, Trailers and Semitrailers , Shipment Index (2010), SA
54	4	2	SI: Capital goods	Industry, Industrial Production Index by Market Group, Whole Country, Capital Goods, Shipment Index (2010), SA
55	4	2	SI: Intermediate goods	Industry, Industrial Production Index by Market Group, Whole Country, Intermediate Goods, Shipment Index (2010), SA
56	4	2	SI: Consumers goods	Industrial Production Index by Market Group, Whole Country, Consumers' Goods, Shipment Index (2010), SA
57	4	2	SI: Capital goods (domestic)	Industry, Industrial Production Index by Market Group, Whole Country, Capital Goods (domestic), Shipment Index (2010), SA
58	4	2	SI: Intermediate goods (domestic)	Industry, Industrial Production Index by Market Group, Whole Country, Intermediate Goods (domestic), Shipment Index (2010), SA
59	4	2	SI: Consumers goods (domestic)	Industrial Production Index by Market Group, Whole Country, Consumers' Goods (domestic), Shipment Index (2010), SA

Table 5 Variables in Group 5: Money and Loan

ID	Group	Trans	Name	Description
60	5	2	M1	Money and Banking, Money Supply, Seasonally Ajusted M1 (End of), SA - Korea, Republic of
61	5	2	M2	Supply, Seasonally Ajusted M2 (End of), SA - Korea, Republic of
62	5	2	LF	Supply, Seasonally Adjusted Lf (End Of), SA - Korea, Republic of
63	5	2	Total Deposits	Money and Banking, Money Supply, Total Deposits of CBs & SBs. (End Of), NSA - Korea, Republic of
64	5	2	Total Loans	Money and Banking, Money Supply, Loans of CBs & SBs(End Of), NSA - Korea, Republic of
65	5	1	Turnover ratio	Money and Banking, Money Supply, Turnover Ratio of Demand Deposits, CBs & SBs, NSA - Korea, Republic of
66	5	2	International reserves	International Liquidity, International Reserves, Korea, Republic Of

Table 6 Variables in Group 6: Bond and Stock

ID	Group	Trans	Name	Description
67	6	1	Call rate	Money and Banking, Market Interest Rates, Uncollateralized Call Rates (All Transactions), NSA - Korea, Republic of
68	6	1	Housing bonds (5y)	KOR Yield 5-year housing bonds / Quantum (non-additive or stock figures) - KOREA
69	6	1	MSB (1y)	Money and Banking, Market Interest Rates, Yields of Monetary Stab. Bonds(364-day), NSA - Korea, Republic of
70	6	1	Fin. debentures bonds (1y)	Money and Banking, Market Interest Rates, Yields of Financial Debentures(1-year), NSA - Korea, Republic of
71	6	1	Fin. debentures bonds (3y)	Money and Banking, Market Interest Rates, Yields of Financial Debentures(3-Year), NSA - Korea, Republic of
72	6	1	Corp. bonds (AA-, 3y)	Money and Banking, Market Interest Rates, Yields of Corporate Bonds : O.T.C (3-year, AA-), NSA - Korea, Republic of
73	6	1	CDs (91 days)	KOR Yield 91-day CDs / Quantum (non-additive or stock figures) - KOREA
74	6	1	Treasury bonds (3y)	Money and Banking, Market Interest Rates, Yields of Treasury Bonds(3-year), NSA - Korea, Republic of
75	6	1	Treasury bonds (5y)	Money and Banking, Market Interest Rates, Yields of Treasury Bonds(5-year), NSA - Korea, Republic of
76	6	1	FD3y-MSB1y spread	FD3y-MSB1y spread
77	6	1	CB3y-MSB1y spread	CB3y-MSB1y spread
78	6	1	TB3y-MSB1y spread	TB3y-MSB1y spread
79	6	1	TB5y-MSB1y spread	TB5y-MSB1y spread
80	6	1	CB3y-TB3y	CB3y-TB3y
81	6	2	KOSPI	Korea Composite Stock Price Index

Table 7 Variables in Group 7: Price

ID	Group	Trans	Name	Description
82	7	2	CPI: All	Prices, Consumer Price Index, CPI: All Items (2010), NSA - Korea, Republic of
83	7	2	CPI: except Agri and Oils	Prices, Consumer Price Index, CPI: All items, excluding Agricultural Products and Oils (2010), NSA - Korea, Republic of
84	7	2	CPI: except Food and Energy	Prices, Consumer Price Index, CPI: All Items, excluding Food and Energy (2010), NSA - Korea, Republic of
85	7	2	PPI: Total	Prices, Producer Price Index PPI: Total (2010=100) NSA - Korea, Republic of
86	7	2	PIP: Total	Prices, Import Price Index by Special Groups, All Commodities (Dollar Basis) (2010), NSA - Korea, Republic of
87	7	2	Crude Oil Price	Oil; Dubai, medium, Fateh 32 API, fob Dubai Crude Oil (petroleum), Dubai Fateh Fateh 32 API, US$ per barrel
88	7	2	Metals Price	Metals Price Index, 2005 = 100, includes Copper, Aluminum, Iron Ore, Tin, Nickel, Zinc, Lead, and Uranium Price Indices
89	7	2	Agricultural Price	Agricultural Raw Materials Index, 2005 = 100, includes Timber, Cotton, Wool, Rubber, and Hides Price Indices

Table 8 Variables in Group 8: Export, Import, and Trade Condition

ID	Group	Trans	Name	Description
90	8	2	Export vol	EXPORT VOLUME INDEX (2010) - TOTAL, NSA - SOUTH KOREA
91	8	2	Import vol	IMPORT VOLUME INDEX (2010) - TOTAL, NSA - SOUTH KOREA
92	8	2	Exports of goods	EXPORTS OF GOODS - MILLIONS OF US DOLLARS, NSA - SOUTH KOREA, then change to in 1000 dollars
93	8	2	Imports of goods	IMPORTS OF GOODS - MILLIONS OF US DOLLARS, NSA - SOUTH KOREA, then change to in 1000 dollars
94	8	1	BoP: CA	Balance of Payments, Current Account, SA - Korea, Republic of
95	8	6	CLI: OECD	OECD Composite Leading Indicators, amplitude adjusted
96	8	2	WTM index	CPB World Trade Monitor (WTM), index 2005=100
97	8	2	CLI: France	OECD Composite Leading Indicators, France
98	8	2	CLI: Germany	OECD Composite Leading Indicators, Germany
99	8	2	CLI: Japan	OECD Composite Leading Indicators, Japan
100	8	2	CLI: Japan	OECD Composite Leading Indicators, United Kingdom
101	8	2	CLI: US	OECD Composite Leading Indicators, US
102	8	2	CLI: G7	OECD Composite Leading Indicators, G7
103	8	2	CLI: Europe	OECD Composite Leading Indicators, Europe
104	8	2	CLI: Total	OECD Composite Leading Indicators, OECD all
105	8	2	Baltic Dry Index	Baltic Dry Index
106	8	2	Ex rate: US	Foreign Excahnge Rate: US
107	8	2	Ex rate: Yen	Foreign Exchange Rate: Japan
108	8	2	Ex rate: UK	Foreign Exchange Rate: United Kingdom
109	8	2	Ex rate: avg (real)	Real Effective Exchange Rate
110	8	2	Ex rate: avg (nominal)	Nominal Effective Exchange Rate
111	8	6	Business conditions (export, actual)	Surveys and Cyclical Indicators, Business Survey Index, All Industries, Actual, Exports Index, Actual, NSA - Korea, Republic of
112	8	6	Business conditions (export, forecast)	Surveys and Cyclical Indicators, Business Survey Index, All Industries, Forecast, Exports Index, NSA - Korea, Republic of

2 Uncertainty index computation

The main step in computing the individual uncertainties is to approximate the purely unforecastable component of the future values of individual series, $y_{jt+h} - E\left[y_{jt+h}\middle|I_t\right]$, and its variance, $E\left[\left(y_{jt+h} - E\left[y_{jt+h}\middle|I_t\right]\right)^2\middle|I_t\right]$. To do so, we compute the conditional mean of y_{jt+h} as the h-step ahead point prediction made at time t based on the following model:

$$\begin{aligned} y_{j,t} &= \sum_{l=1}^{p_1} \phi_{j,l} y_{j,t-l} + \sum_{l=1}^{p_2} \Gamma'_{j,l} Z_{t-l} + v_{j,t} \\ Z_t &= \sum_{l=1}^{p_3} \Phi_l Z_{t-1} + v_t^Z \end{aligned} \tag{1}$$

where $Z_t = [(F_t)', (F_{1,t}^2)', (G_t)']'$. F_t is a vector of the first r_f principal components of Y_t, $(F_{1,t}^2)$ is the squared first principal component of Y_t, and G_t is a vector of the first r_g principal components of Y_t^2. Based on this model, we can approximate each individual uncertainty by assuming distributional characteristics of the shocks in the system above. To take into account the time-varying forecast error variance, we assume that both innovations v_{jt} and v_t^Z follow the stochastic volatility model:

$$\begin{aligned} v_{j,t} &\sim N(0,\ \exp(h_{j,t})) \quad \text{where} \quad h_{j,t} = c_j^h + \varphi_j^h h_{j,t-1} + \sigma_j^h \eta_{j,t}, \quad \eta_{j,t} \sim_{i.i.d.} N(0,1) \\ v_{k,t}^Z &\sim N(0,\ \exp(w_{k,t})) \quad \text{where} \quad w_{k,t} = c_k^w + \varphi_k^w w_{k,t-1} + \sigma_k^w \zeta_{k,t}, \quad \zeta_{k,t} \sim_{i.i.d.} N(0,1) \end{aligned} \tag{2}$$

for $j = 1, ..., N_y$ and $k = 1, ..., (r_f + r_g + 1)$. In our empirical application, we select the number of factor predictors based on the Bayesian information criteria and follow Jurado et al. (2015) to select other tuning parameters ($r_f = 9$, $r_g = 1$, $p_1 = 4$, $p_2 = 2$, $p_3 = 4$). As in Jurado et al. (2015), individual uncertainties are computed in two steps. In the first step we obtain forecast errors by estimating the model in Equation 1 via OLS estimation. Then, we run an MCMC algorithm (Kastner and Fruhwirth-Schnatter, 2014) to generate posterior draws for $(h_{j,1:T}, c_j^h, \varphi_j^h, \sigma_j^h, w_{k,1:T}, c_k^w, \varphi_k^w, \sigma_k^w)$ in Equation 2.

To see how the forecast error variances fluctuate over time, consider a case with $p_1 = p_2 = p_3 = 1$. The one-step-ahead forecast error is $v_{j,t}$ and its variance is

$$U_{j,t}^y(1) = E\left[\left(y_{j,t+1} - E\left[y_{j,t+1}\middle|I_t\right]\right)^2\right] = \exp(h_{j,t+1}).$$

When $h > 1$, predictor uncertainties also play a role in measuring uncertainty. For example,

if $h = 2$, then,

$$U^{y}_{j,t}(2) = E\left[\left(y_{j,t+2} - E\left[y_{j,t+2}\middle|I_t\right]\right)^2\right] = \phi_j^2 \exp(h_{j,t+1}) + \Gamma'_j \Sigma^{Z}_{t+1|t} \Gamma_j + \exp(h_{j,t+2})$$

where $\Sigma^{Z}_{t+1|t}$ is the forecast error variance-covariance matrix for the one-step-ahead prediction made for Z_{t+1} at time t. As the above equation reveals, the two-step-ahead prediction error variance depends also on any uncertainty variation from predicting Z_{t+1}. The same logic applies to the case with $h > 2$.

3 Real effects of uncertainty shocks

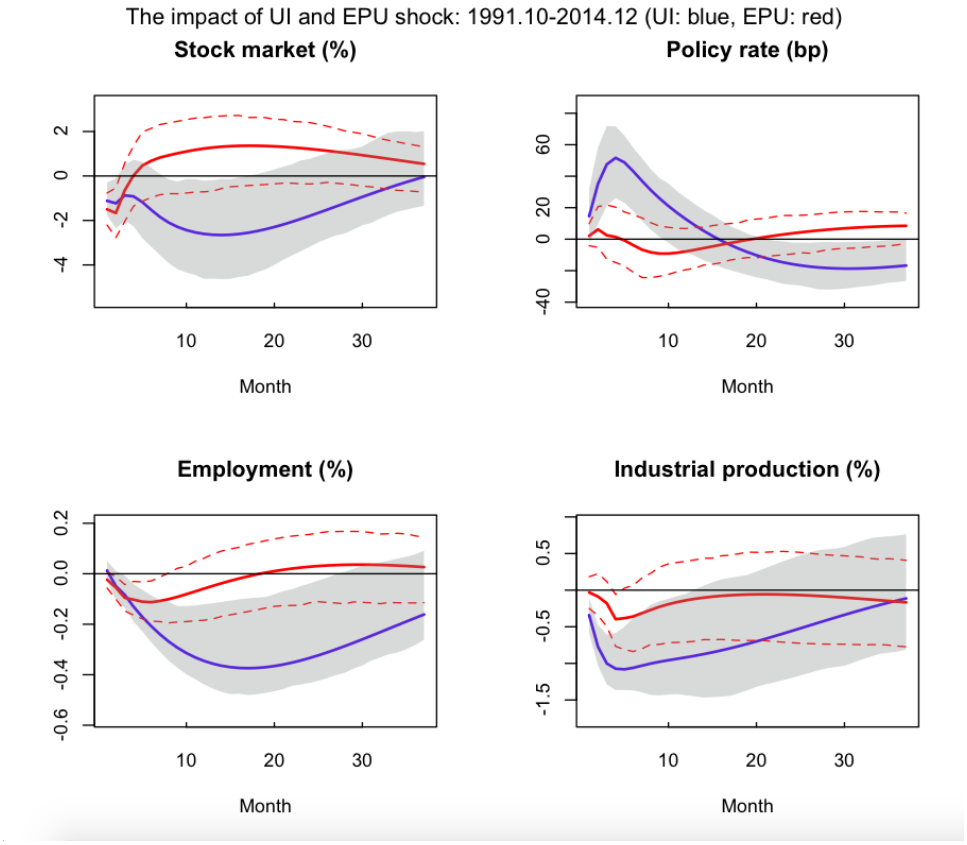
To investigate the dynamic relationships between our uncertainty measure and aggregate economic activity, we fit VAR models to monthly Korean data from 1991M10 to 2014M12. Our main focus is to study the effects of uncertainty shocks on economic activity. To identify the uncertainty shocks, we use a Cholesky decomposition with our uncertainty measure ordered first (Baker et al., 2017; Choi and Shim, 2016). The main VAR specification includes three lags of the log of the KOSPI index, the policy rate (overnight call rate), log employment, and log industrial production. As a comparison, we also identify the uncertainty shocks using both the VKOSPI index or the EPU index.

Figure 1 presents the impulse response functions of the identified uncertainty shocks using our economic uncertainty index (UI, blue) and using the EPU index (EPU, red). These two shocks are identified based on separate estimated VAR models. Bands around the thick lines are 90% confidence sets. There are significantly negative and prolonged effects of uncertainty shocks to the KOSPI index, employment, and industrial production based on our economic uncertainty index. On impact, the policy rate increases for 6 months and remains positive for one year. These positive responses are due to the so-called the "flight to safety" motive where the central bank increases the policy rate to prevent capital outflows (Gourio et al., 2014; Choi, 2016; Rey, 2016).

On the other hand, uncertainty shocks based on the EPU index have very little (and insignificant) impact on all other variables. The signs of these impacts on employment and industrial production are negative, but their magnitudes are small and insignificant. The impact on the policy rate is almost zero for all horizons. There is a negative effect on the stock price index on impact, but the response becomes positive after 8 months. Figure 2 shows impulse response functions of uncertainty shocks based on the VKOSPI index (Blue) and the EPU index (Red). The effects of uncertainty shocks based on the VKOSPI are qualitatively and quantitatively similar to those from our uncertainty measure.

As we argued in the main text, the VKOSPI and the EPU indices capture uncertainty about specific aspects of the Korean economy. Therefore, they may not serve as a comprehensive uncertainty measure. In addition, uncertainty originated from the financial market may have different real effects than those originated from other sources (Ludvigson et al., 2015; Shin and Zhong, 2016; Carriero et al., 2016). To disentangle these effects, we re-estimate our VAR model by including both the VKOSPI and our economic uncertainty measure. To make sure that we separate the uncertainty shocks originating from the financial market from uncertainty variations due to other sources, we order the VKOSPI index first and our

Figure 1 Impulse responses of uncertainty shocks (separate estimation)

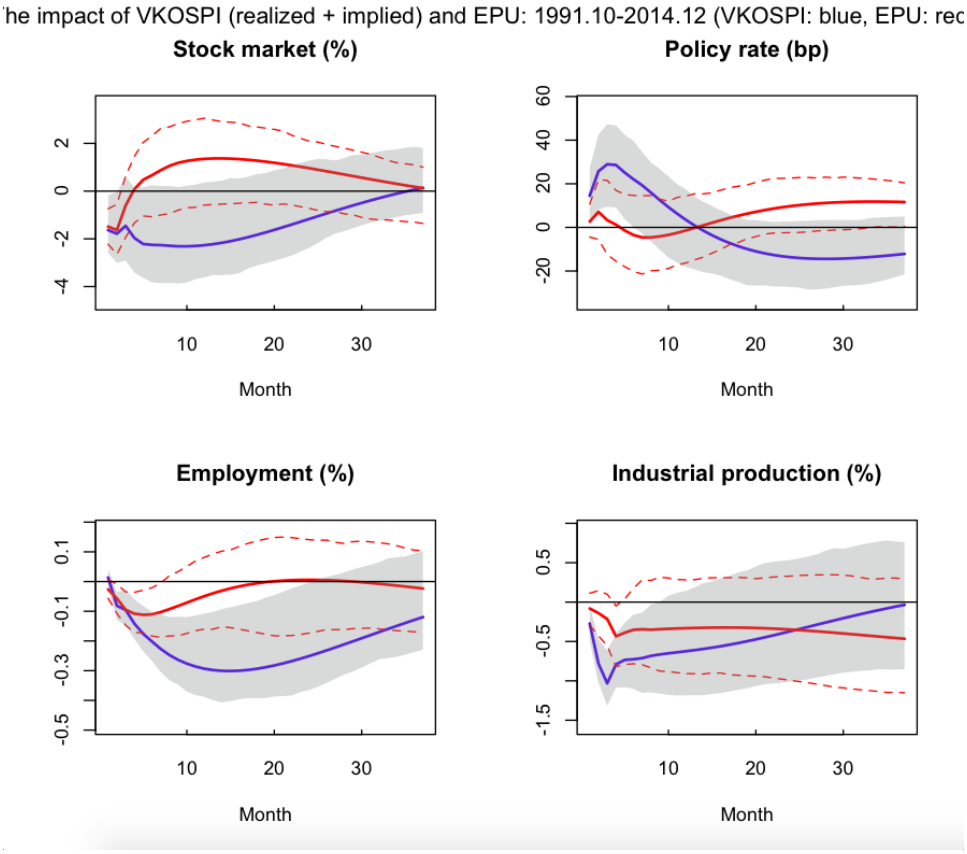


uncertainty measure second. In this way, the second shock contains exogenous variation that does not move financial uncertainty contemporaneously.[1]

Figure 3 presents impulse responses of the two different uncertainty shocks. The red lines are impulse response functions of the uncertainty shocks originating from the financial market (financial uncertainty shocks) and the blue lines are impulse response functions of the uncertainty shocks that move the overall uncertainty index without affecting the VKOSPI contemporaneously (real activity uncertainty shocks). As we can see from the upper left panel, the impact of financial uncertainty shocks to the KOSPI index is significantly negative for at least 7 months and are around four times larger than the impact of the real activity uncertainty shocks contemporaneously. Unlike the results based on the separate identification of different uncertainty shocks, it turns out that the "flight to safety" story only holds for the real activity uncertainty shocks. The financial uncertainty shocks actually decrease the policy rate on impact. The real activity uncertainty shocks have a much larger and more

[1]This ordering assumption is quite important because our uncertainty measure contains uncertainty from the KOSPI index. However, changing the order of variables does not alter our main results. See the appendix for robustness checks.

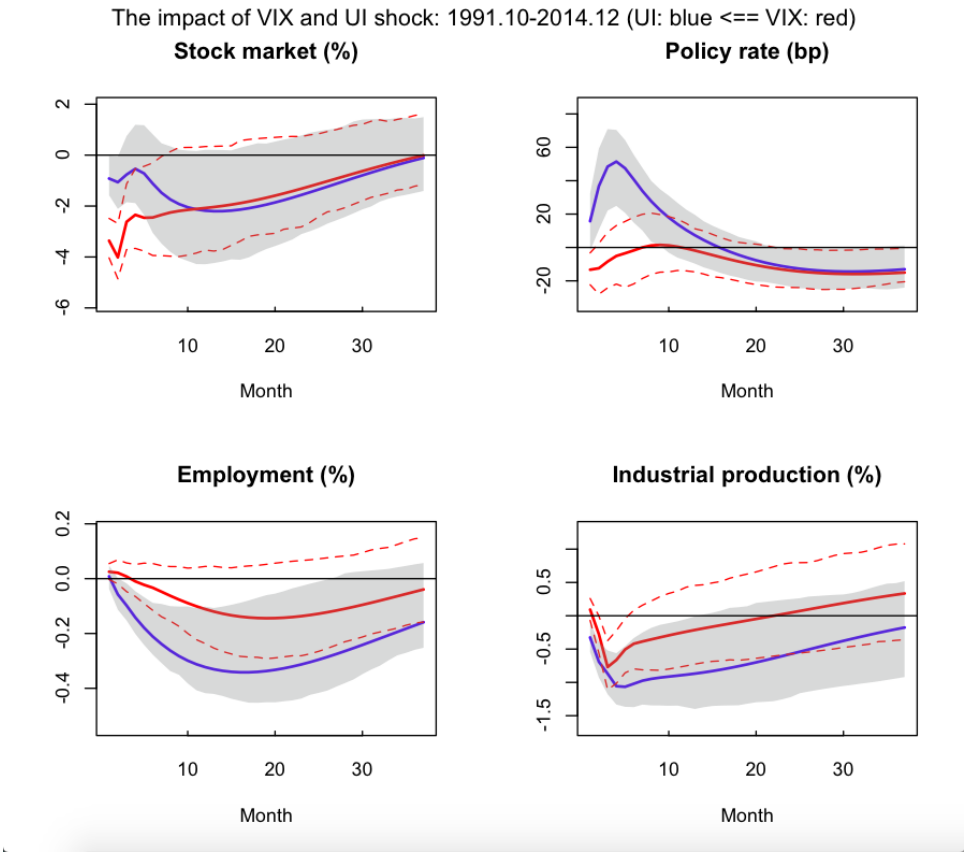
Figure 2 Impulse responses of uncertainty shocks (separate estimation)



persistent effect on real variables when compared to the financial uncertainty shocks.

Caveat. Even though our results are quite robust as shown in the next section, we want to comment that these results have some limitations. First, unlike the U.S., Korea is a small open economy. Therefore, its international economic activities play an important and significant role. Second, when we include two uncertainties at the same time in our VAR model, we need to be careful about the interpretation of the two uncertainty shocks. Our ordering of variables (or exclusion restriction) decomposes unexpected movements in uncertainty measures into two pieces. One moves VIX and UI contemporaneously and another moves only UI within a month. Our categorization of the two uncertainty shocks (financial versus real activity uncertainty shocks) comes from the additional assumption that any uncertainty shock that moves both the VIX and UI contemporaneously (within a month) originated from the financial market. However, there may be an uncertainty shock that originated from another source that has an impact on the financial market in a month. For these reasons, we view our VAR exercise as a convenient way to present and compare the dynamic relationships between the uncertainty measures and other key macroeconomic variables.

Figure 3 Impulse responses of uncertainty shocks (both measures are included in VAR)



4 Robustness checks for VAR analysis

In this section, we present other VAR results where

1. we include two lags as opposed to three lags and include a time trend (Figure 4 and Figure 5).
2. we show that the ordering does not matter for conclusion made from results in Figure 3. Our economic uncertainty measure is ordered first and the VKOSPI index is ordered second (Figure 7).
3. we include both the EPU and the our economic uncertainty measure in the VAR model. Impacts of our uncertainty shocks do not change much from our baseline estimation results (Figure 6).

Figure 4 Impulse responses of uncertainty shocks (separate esimation with 2 lags and time trend)

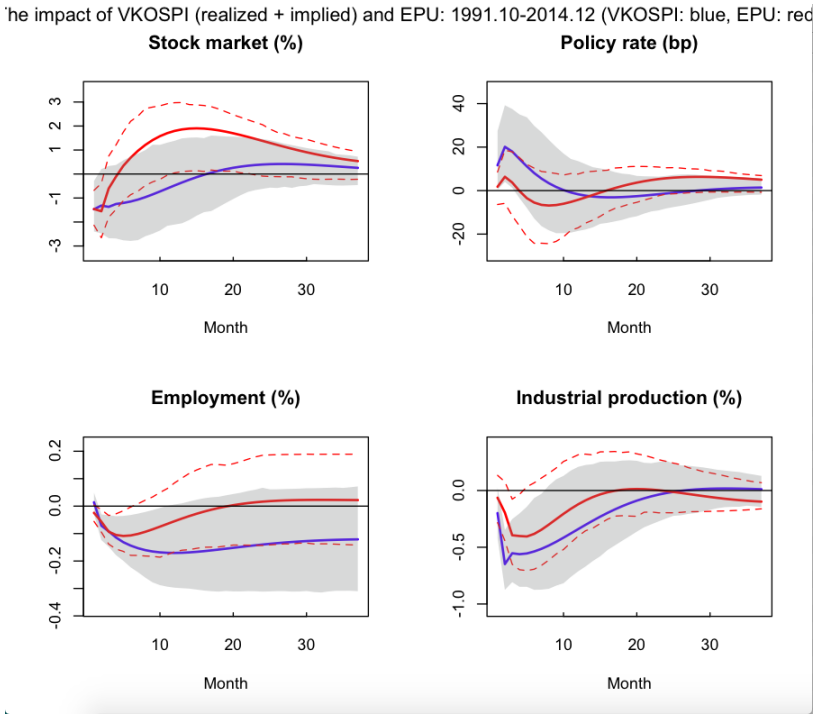


Figure 5 Impulse responses of uncertainty shocks (separate esimation with 2 lags and time trend)

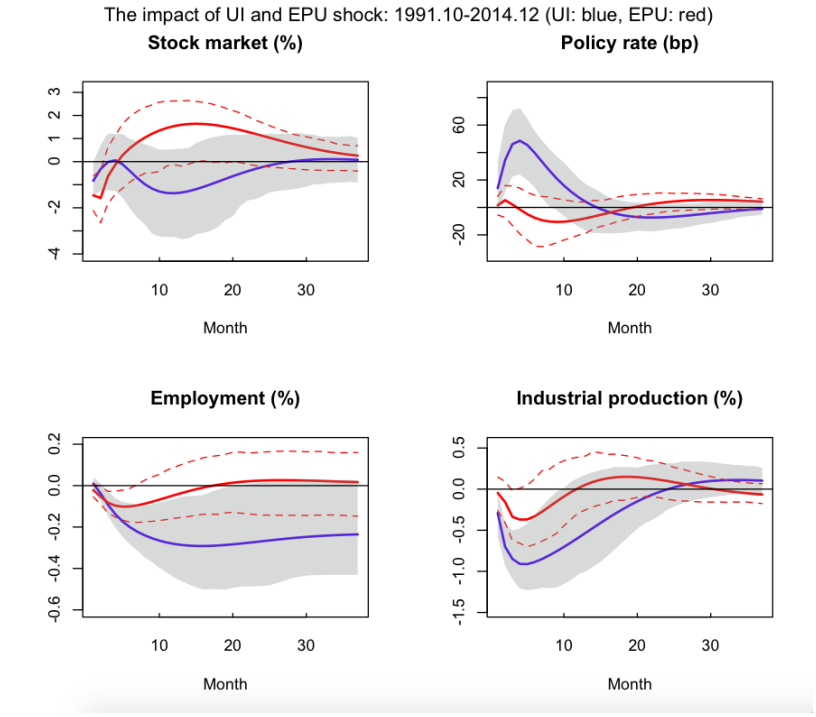


Figure 6 Impulse responses of uncertainty shocks (both measures are included in VAR)

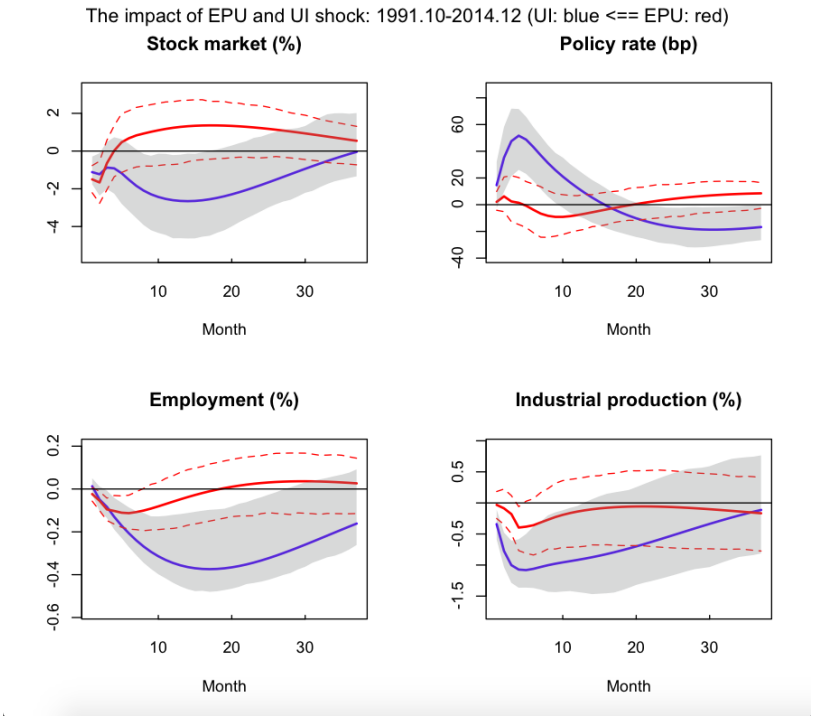
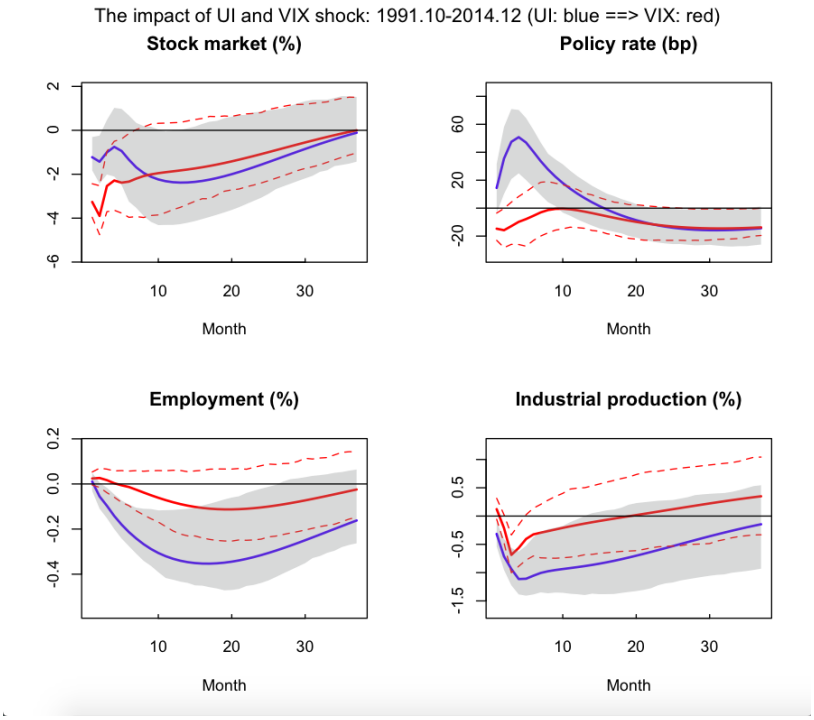


Figure 7 Impulse responses of uncertainty shocks (both measures are included in VAR)



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