Online appendix (not for publication)

Measuring International Uncertainty: the Case of Korea

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This appendix has five sections:

1. Section 1 describes the 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 VAR models.
4. Section 4 presents additional VAR results with different model specifications (ordering of variables and other combinations of variables).
5. Section 5 attempts to provide some practical guidance for those who want to construct an uncertainty index for other countries, especially where collecting a large number of macroeconomic series is costly. We construct the uncertainty index using a subset of variables and compare its dynamic properties with the original uncertainty index.

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. We use the VKOSPI/VIX and the option-implied volatility (OIV) interchangeably.
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

Table 8 Variables in Group 8: International Trade (Import and Export)

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
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

Table 9 Variables in Group 9: External Variables

ID	Group	Trans	Name	Description
86	9	2	PIP: Total	Prices, Import Price Index by Special Groups, All Commodities (Dollar Basis) (2010), NSA - Korea, Republic of
87	9	2	Crude Oil Price	Oil; Dubai, medium, Fateh 32 API, fob Dubai Crude Oil (petroleum), Dubai Fateh Fateh 32 API, US$ per barrel
88	9	2	Metals Price	Metals Price Index, 2005 = 100, includes Copper, Aluminum, Iron Ore, Tin, Nickel, Zinc, Lead, and Uranium Price Indices
89	9	2	Agricultural Price	Agricultural Raw Materials Index, 2005 = 100, includes Timber, Cotton, Wool, Rubber, and Hides Price Indices
95	9	6	CLI: OECD	OECD Composite Leading Indicators, amplitude adjusted
96	9	2	WTM index	CPB World Trade Monitor (WTM), index 2005=100
97	9	2	CLI: France	OECD Composite Leading Indicators, France
98	9	2	CLI: Germany	OECD Composite Leading Indicators, Germany
99	9	2	CLI: Japan	OECD Composite Leading Indicators, Japan
100	9	2	CLI: UK	OECD Composite Leading Indicators, United Kingdom
101	9	2	CLI: US	OECD Composite Leading Indicators, US
102	9	2	CLI: G7	OECD Composite Leading Indicators, G7
103	9	2	CLI: Europe	OECD Composite Leading Indicators, Europe
104	9	2	CLI: Total	OECD Composite Leading Indicators, OECD all
105	9	2	Baltic Dry Index	Baltic Dry Index

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 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 $h > 2$.

Two uncertainty indices. External variables (group 9) are variables that are known to be useful in predicting the Korean economy but are not endogenously determined within the Korean economy. Hence, we include theses variables in the information set I_t (equation 1 in the main text), but we exclude them from the Korean uncertainty index (equation 2 in the main text).

We also define a foreign uncertainty index (UI-F) by taking the average of forecast error variances of external variables. This index serves as a proxy for uncertainty originating outside Korea.

3 Real effects of uncertainty shocks

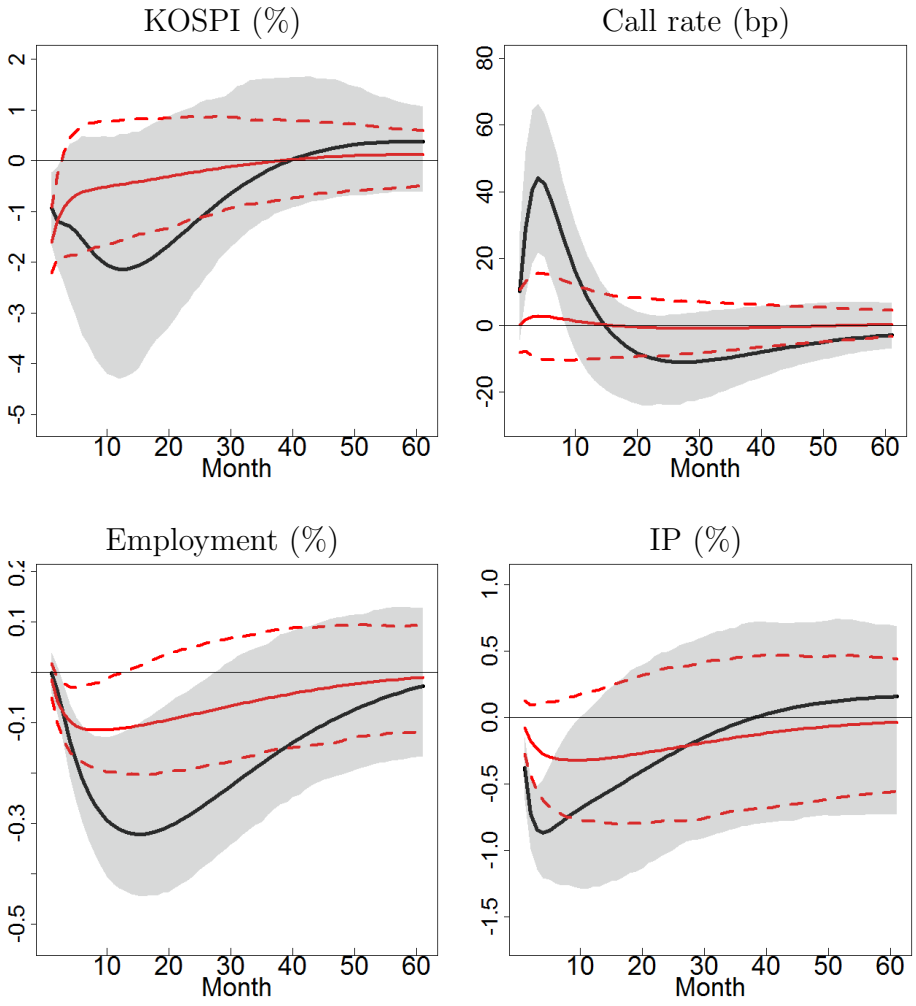
To investigate the dynamic relationships between our uncertainty measure and aggregate economic activity, we fit VAR models to monthly Korean data from 1991M10 to 2016M5. Our main focus is to study the effects of uncertainty shocks on economic activity. To identify the uncertainty shocks, we use a Cholesky decomposition with our uncertainty measure ordered first (Baker et al., 2017; Choi and Shim, 2016). The main VAR specification includes the log of the KOSPI index, the policy rate (overnight call rate), log employment, and log industrial production. The number of lags is selected by the Bayesian information criteria. As a comparison, we also identify the uncertainty shocks using both the option-implied volatility (OIV) or the economic policy uncertainty (EPU) index.

Figure 1 presents the impulse response functions of the identified uncertainty shocks using our economic uncertainty index (UI, black) 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; Choi and Shim, 2016; Rey, 2016).

On the other hand, uncertainty shocks based on the EPU index have very little (and insignificant) impact on all other variables except on the KOSPI index. 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. Figure 2 shows impulse response functions of uncertainty shocks based on the option-implied index (Blue) and the EPU index (Red). The effects of uncertainty shocks based on the option-implied index are qualitatively and quantitatively similar to those from our uncertainty measure.

As we argued in the main text, the option-implied 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 option-implied and our economic uncertainty measure. To make sure that we separate the uncertainty shocks originating from the financial

Figure 1 Impulse responses of uncertainty shocks (separate estimation), UI (black) and EPU (red).

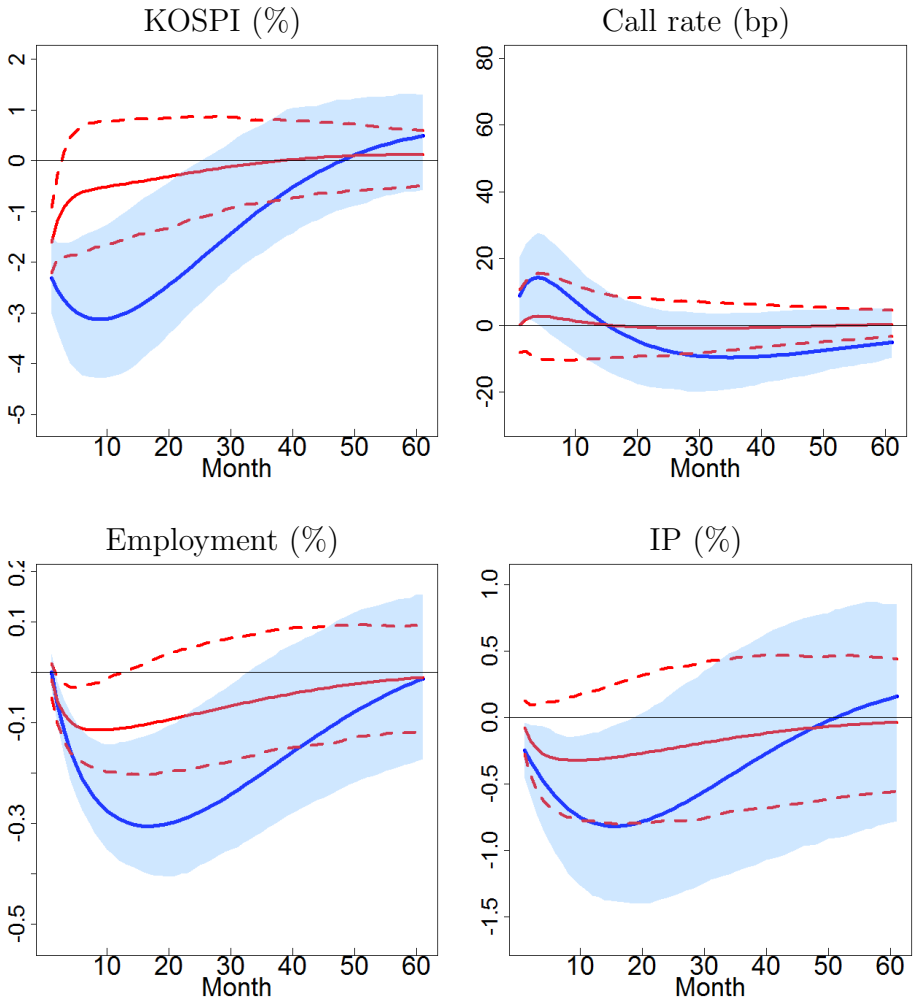


market from uncertainty variations due to other sources, we order the option-implied index first and our uncertainty measure second. In this way, the second shock contains exogenous variation that does not move financial uncertainty contemporaneously.[1]

Figure 3 presents impulse responses of the two different uncertainty shocks. The blue lines are impulse response functions of the uncertainty shocks originating from the financial market (financial uncertainty shocks) and the black lines are impulse response functions of the uncertainty shocks that move the overall uncertainty index without affecting the option-implied volatility contemporaneously (real activity uncertainty shocks). As we can see from the upper left panel, the impact of financial uncertainty shocks to the KOSPI index

[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.

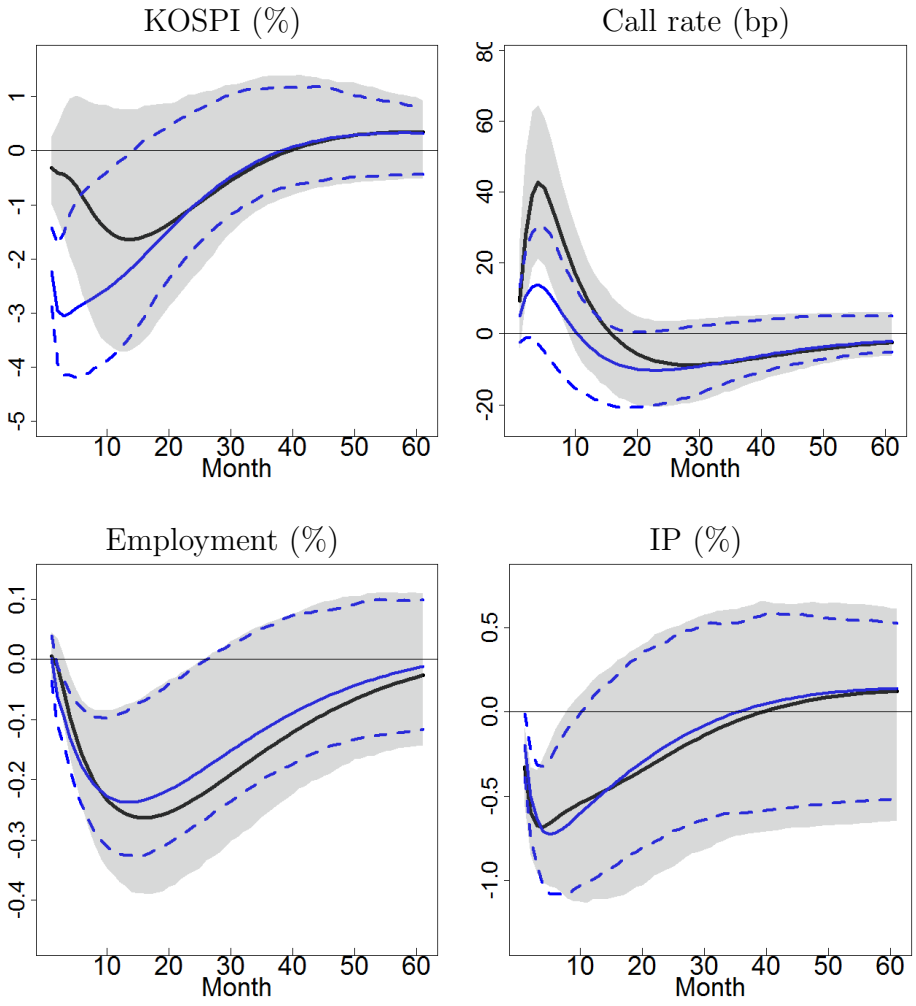
Figure 2 Impulse responses of uncertainty shocks (separate estimation), OIV (blue) and EPU (red)



is significantly negative for at least 12 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. Both the real activity uncertainty shocks and the financial uncertainty shocks have roughly the same effect on real variables.

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 order-

Figure 3 Impulse responses of uncertainty shocks (both measures are included in VAR), UI (black) and OIV (blue)



ing of variables (or exclusion restriction) decomposes unexpected movements in uncertainty measures into two pieces. One moves OIV 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 OIV and UI contemporaneously (within a month) originated from the financial market.[2] 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.

[2]See Shin and Zhong (2016) for an example of a strategy using sign restrictions to separately identify financial and real uncertainty shocks.

4 Robustness checks for VAR analysis

In this section, we present other VAR results where

1. we show that the ordering does not matter for the conclusion made from results in Figure 1 and Figure 2. We order the uncertainty proxy after the stock market variable (Figure 4 and Figure 5).
2. we show that the ordering does not matter for the conclusion made from results in Figure 3. Our economic uncertainty measure is ordered first and the option-implied volatility (OIV) is ordered second (Figure 6).
3. we include both the EPU and our economic uncertainty measure in the VAR model. Impacts of our uncertainty shocks do not change much from our baseline estimation results (Figure 7).

Figure 4 Impulse responses of uncertainty shocks (separate estimation, KOSPI ordered first), UI (black) and EPU (red)

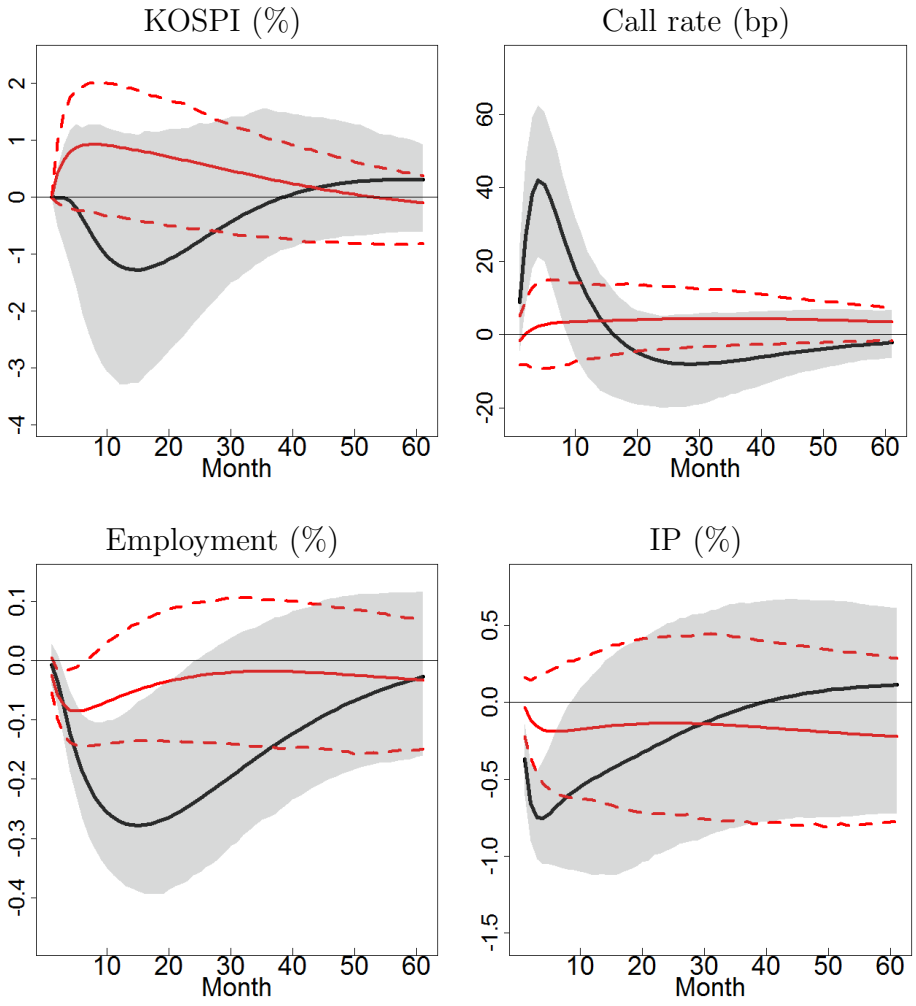


Figure 5 Impulse responses of uncertainty shocks (separate estimation, KOSPI ordered first), OIV (blue) and EPU (red)

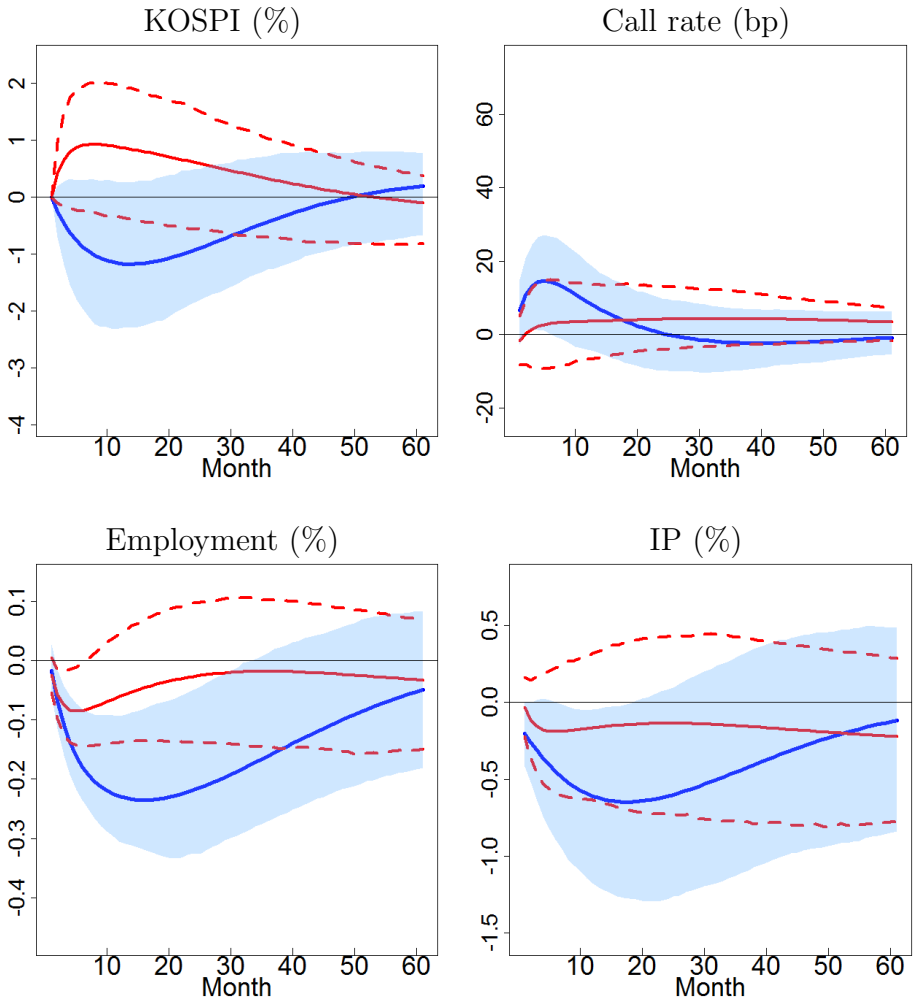


Figure 6 Impulse responses of uncertainty shocks (both measures are included in VAR, UI ordered first), UI (black) and OIV (Blue)

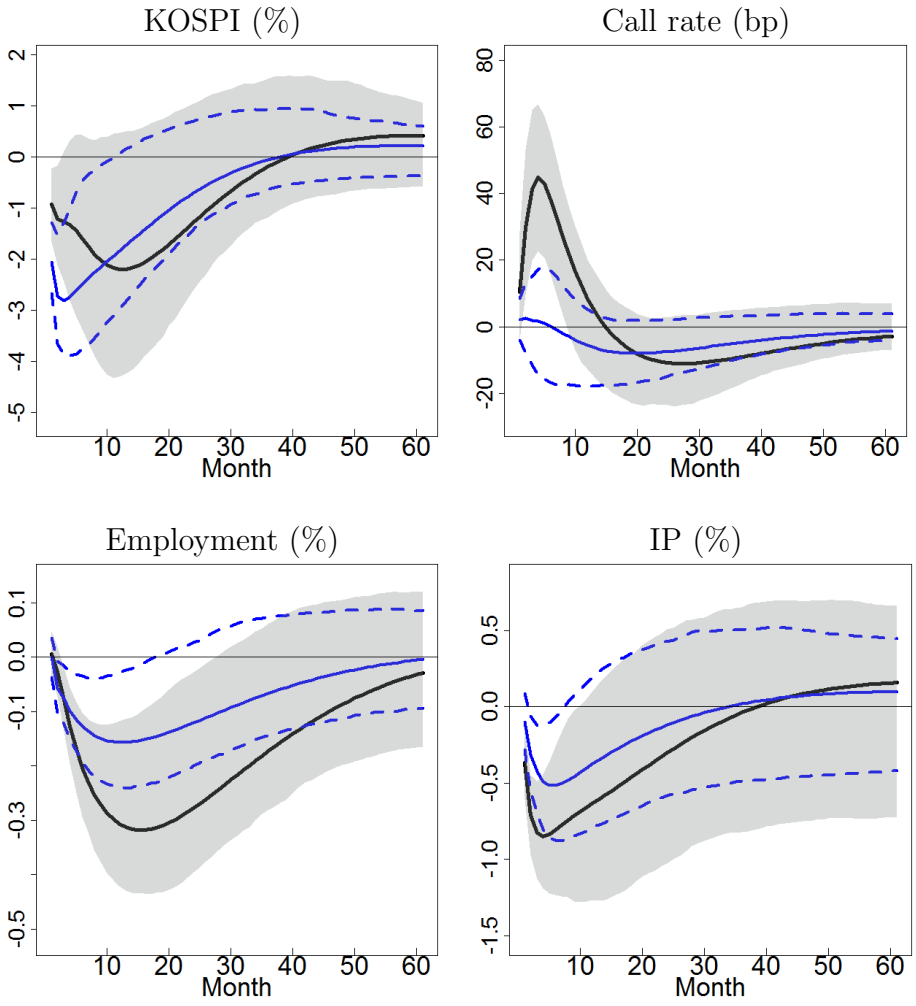
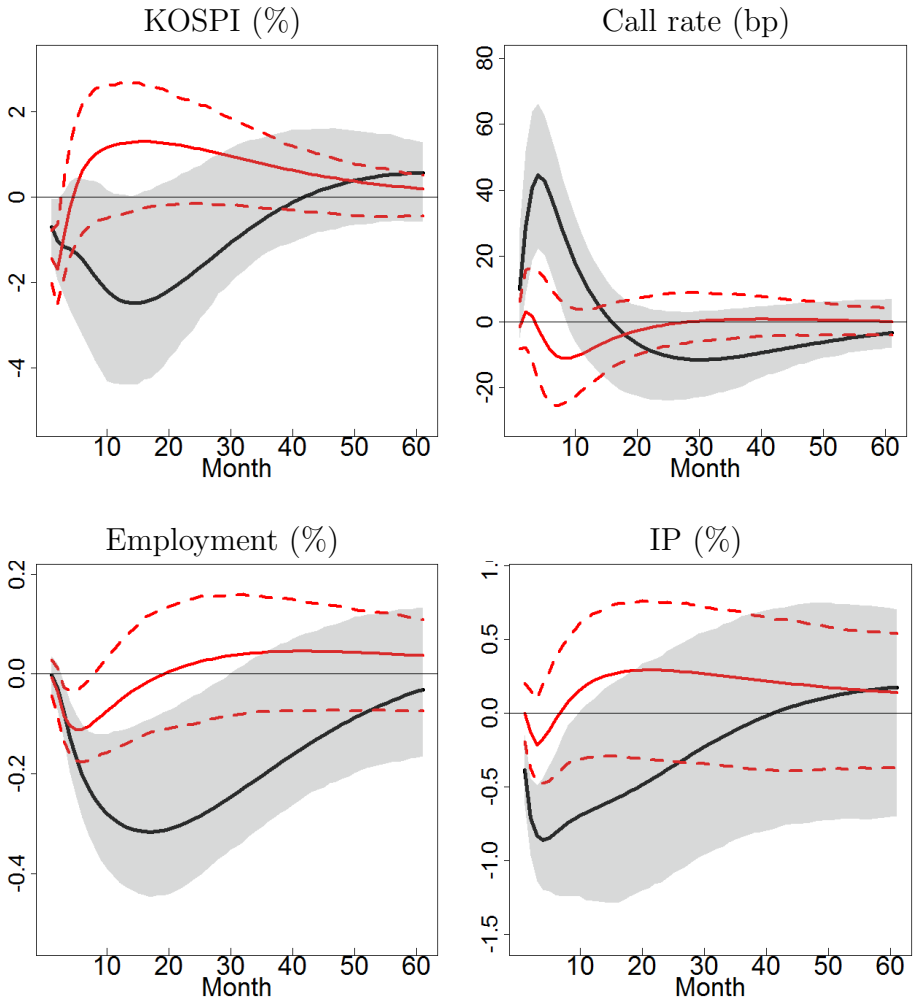


Figure 7 Impulse responses of uncertainty shocks (both measures are included in VAR, EPU ordered first), UI (black) and EPU (red)



5 Uncertainty index using a subset of individual uncertainties

In this section, we construct the uncertainty index with a subset of our data set and present its dynamic properties. This exercise attempts to provide some practical guidance for those who want to construct the uncertainty index for other countries, especially where collecting a large number of macroeconomic series is costly.

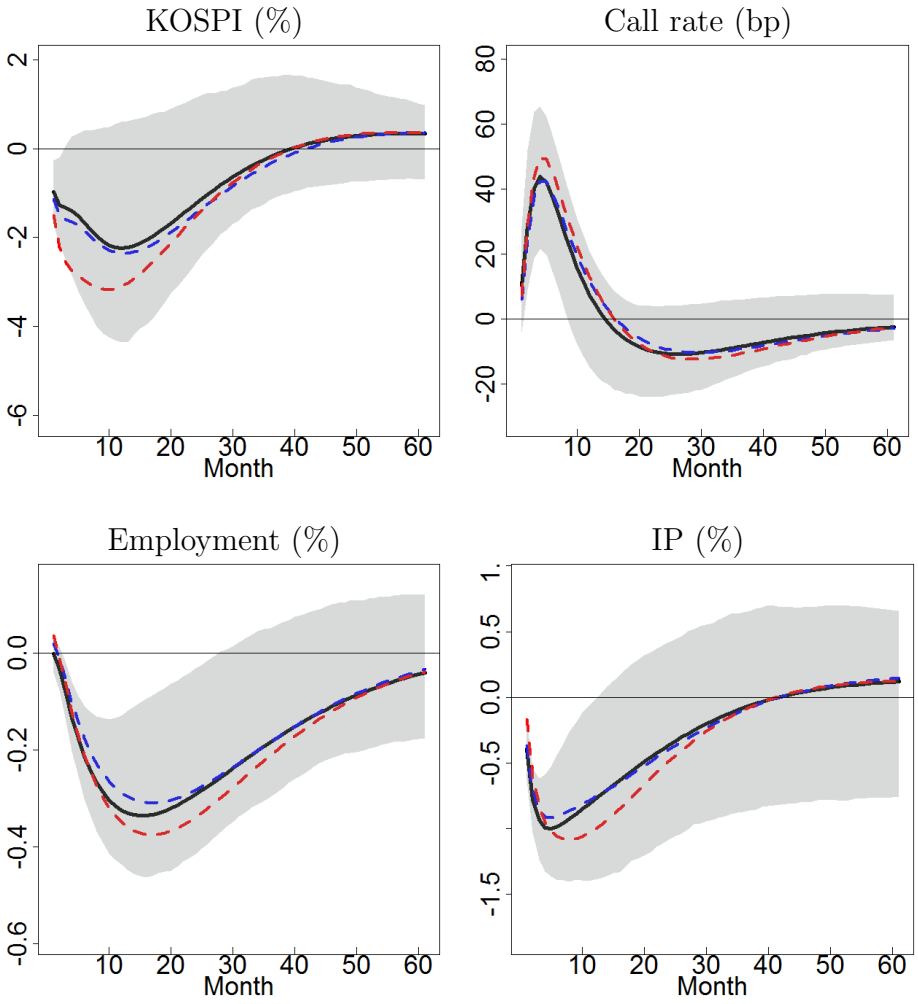
To do so, we first sort the individual series by the strength of the association between our uncertainty index and those series. For each of the 112 series, we compute the R^2 from a regression of $U^y_{j,t}$ (individual uncertainty) on U^y_t (uncertainty index based on all 112 series). We sort 112 series by R^2 and present them in table 10.

Second, we construct the uncertainty index using only series whose uncertainty are highly associated with our original uncertainty index. We consider two cases. We select variables that have R^2 higher than 0.4 (29 variables from group 1, 4, 6, and 8) in the first case and 0.2 (60 variables from group 1, 3, 4, 5, 6, 7, 8, 9) in the second case. For each case, we compute the uncertainty index based only on selected variables. Note that this requires us to re-estimate individual uncertainties conditioned only on selected variables. The correlation between the original uncertainty index and the uncertainty index with a subset of variables is 0.96 for the case 1 and 0.97 for the case 2. In figure 8, we present impulse responses of different uncertainty measures to other macro variables (black line: original uncertainty index; red line: variables with R^2 higher than 0.4; blue line: variables with R^2 higher than 0.2). When we include 60 variables (case 2), the impulse responses are visually similar to those based on the original uncertainty index. However, we note that when we include only the top 29 variables (case 1), the uncertainty shocks have a stronger impact on the stock market. This is because these 29 variables are mostly related to financial variables (bond, stock, and exchange rate variables) and the constructed uncertainty index does not have to represent the overall uncertainty of the economy.

Table 10 R^2 by individual uncertainty series

Ranking	ID	Group	R2	Name	Ranking	ID	Group	R2	Name
1	108	8	0.60	'Ex rate: UK'	57	95	9	0.23	'CLI: OECD'
2	78	6	0.60	'TB3y-MSB1y spread'	58	90	8	0.23	'Export vol'
3	71	6	0.60	'Fin. debentures bonds (3y)'	59	53	4	0.22	'SI: Vehicles'
4	52	4	0.60	'SI: Equipment'	60	98	9	0.21	'CLI: Germany'
5	76	6	0.58	'FD3y-MSB1y spread'	61	65	5	0.20	'Turnover ratio'
6	70	6	0.55	'Fin. debentures bonds (1y)'	62	3	1	0.20	'IP: Chemical'
7	110	8	0.54	'Ex rate: avg (nominal)'	63	63	5	0.19	'Total Deposits'
8	109	8	0.54	'Ex rate: avg (real)'	64	104	9	0.19	'CLI: Total'
9	106	8	0.54	'Ex rate: US'	65	49	4	0.17	'Retail trade volume'
10	81	6	0.52	'KOSPI'	66	103	9	0.16	'CLI: Europe'
11	9	1	0.52	'SI: Total'	67	102	9	0.16	'CLI: G7'
12	45	4	0.52	'Sales of goods'	68	83	7	0.15	'CPI: except Agri and Oils'
13	74	6	0.52	'Treasury bonds (3y)'	69	42	4	0.15	'Automobile registration'
14	50	4	0.51	'SI: Manufacturing'	70	26	2	0.15	'Business conditions (emloyment, actual)'
15	91	8	0.49	'Import vol'	71	29	3	0.15	'Housing starts'
16	107	8	0.49	'Ex rate: Yen'	72	101	9	0.15	'CLI: US'
17	7	1	0.48	'IP: Intermediate goods'	73	27	2	0.15	'Business conditions (employment, forecast)'
18	10	1	0.46	'OI: Manufacturing'	74	112	8	0.15	'Business conditions (export, forecast)'
19	8	1	0.46	'IP: Consumers goods'	75	60	5	0.14	'M1'
20	79	6	0.45	'TB5y-MSB1y spread'	76	23	2	0.13	'EMP: temporary workers'
21	72	6	0.43	'Corp. bonds (AA-, 3y)'	77	31	3	0.11	'Housing price index'
22	2	1	0.43	'IP: Manufacturing'	78	100	9	0.10	'CLI: UK'
23	80	6	0.42	'CB3y-TB3y'	79	35	3	0.10	'Construction contracts: Private'
24	66	5	0.42	'International reserves'	80	20	2	0.10	'EMP: Unemployment rate'
25	75	6	0.42	'Treasury bonds (5y)'	81	37	4	0.10	'II: Total'
26	68	6	0.42	'Housing bonds (5y)'	82	87	9	0.10	'Crude Oil Price'
27	77	6	0.41	'CB3y-MSB1y spread'	83	24	2	0.09	'EMP: participation rate'
28	47	4	0.41	'Sales of intermediate goods'	84	38	4	0.08	'II: Manufacturing'
29	55	4	0.41	'SI: Intermediate goods'	85	62	5	0.08	'LF'
30	85	7	0.40	'PPI: Total'	86	84	7	0.08	'CPI: except Food and Energy'
31	111	8	0.40	'Business conditions (export, actual)'	87	18	2	0.08	'EMP: Employed'
32	59	4	0.39	'SI: Consumers goods (domestic)'	88	44	4	0.08	'Business conditions (demand, forecast)'
33	58	4	0.38	'SI: Intermediate goods (domestic)'	89	99	9	0.07	'CLI: Japan'
34	82	7	0.38	'CPI: All'	90	19	2	0.06	'EMP: Unemployed'
35	1	1	0.37	'IP: Total'	91	39	4	0.06	'II: Capital goods'
36	73	6	0.37	'CDs (91 days)'	92	54	4	0.05	'SI: Capital goods'
37	5	1	0.37	'IP: Vehicles'	93	48	4	0.05	'Sales of investment goods'
38	61	5	0.36	'M2'	94	14	1	0.05	'Business conditions (total, actual)'
39	6	1	0.34	'IP: Capital goods'	95	41	4	0.05	'II: Consumers goods'
40	46	4	0.34	'Sales of consumer goods'	96	36	3	0.05	'Permits: Total'
41	56	4	0.34	'SI: Consumers goods'	97	15	1	0.05	'Business conditions (manufacturing, actual)'
42	51	4	0.33	'SI: Chemicals'	98	86	9	0.04	'PIP: Total'
43	32	3	0.33	'Housing jeonse price index'	99	22	2	0.04	'EMP: regular workers'
44	4	1	0.30	'IP: Equipment'	100	97	9	0.04	'CLI: France'
45	13	1	0.29	'OI: Vehicles'	101	34	3	0.02	'Construction contracts: Public'
46	12	1	0.28	'OI: Equipment'	102	16	1	0.02	'Business conditions (total, forecast)'
47	92	8	0.28	'Exports of goods'	103	105	9	0.01	'Baltic Dry Index'
48	89	9	0.28	'Agricultural Price'	104	21	2	0.01	'EMP: Emplyees, Manufacturing'
49	67	6	0.28	'Call rate'	105	17	1	0.01	'Business conditions (manufacturing, forecast)'
50	43	4	0.28	'Business conditions (demand, actual)'	106	88	9	0.01	'Metals Price'
51	93	8	0.27	'Imports of goods'	107	94	8	0.01	'BoP: CA'
52	11	1	0.26	'OI: Chemicals'	108	40	4	0.01	'II: Intermediate goods'
53	96	9	0.26	'WTM index'	109	25	2	0.00	'Hours worked'
54	64	5	0.26	'Total Loans'	110	30	3	0.00	'Permits: Dwellings (YoY growth)'
55	57	4	0.25	'SI: Capital goods (domestic)'	111	28	3	0.00	'Permits: Dwellings (level)'
56	69	6	0.24	'MSB (1y)'	112	33	3	0.00	'Construction contracts'

Figure 8 Impulse responses of uncertainty shocks (both measures are included in VAR)



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