REGIONAL SPILLOVER EFFECTS OF THE TOHOKU EARTHQUAKE (MARCH 2016)

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Work to understand how the 2011 earthquake shock was transmitted throughout Japan.

Focus is on how the relationship among regions can propagate the exogenous earthquake shock.

Focus on Industrial Production. Available monthly. Correlates with GDP.

TWO MAIN STRANDS OF REGIONAL INTERACTIONS

1. STRUCTURAL CALIBRATED MULTISECTORAL MODELS (DUPOR, 1999; CALIENDO, ET. AL. 2015).

2. TIME SERIES METHODS WITH BROAD STRUCTURAL RESTRICTIONS (REICHLIN AND FORNI, 2000; SHEA, 1998).

THIS PAPER IS IN SECOND STRAND.

REGIONAL INTERACTIONS ARE COMPLEX

NOT JUST INPUT-OUTPUT

TECHNOLOGICAL SPILLOVERS

DEMAND EFFECTS. TOHOKU IP FALLS, CHUBU SALES TO TOHOKU FALLS, CHUBU IP FALLS.

FINDINGS

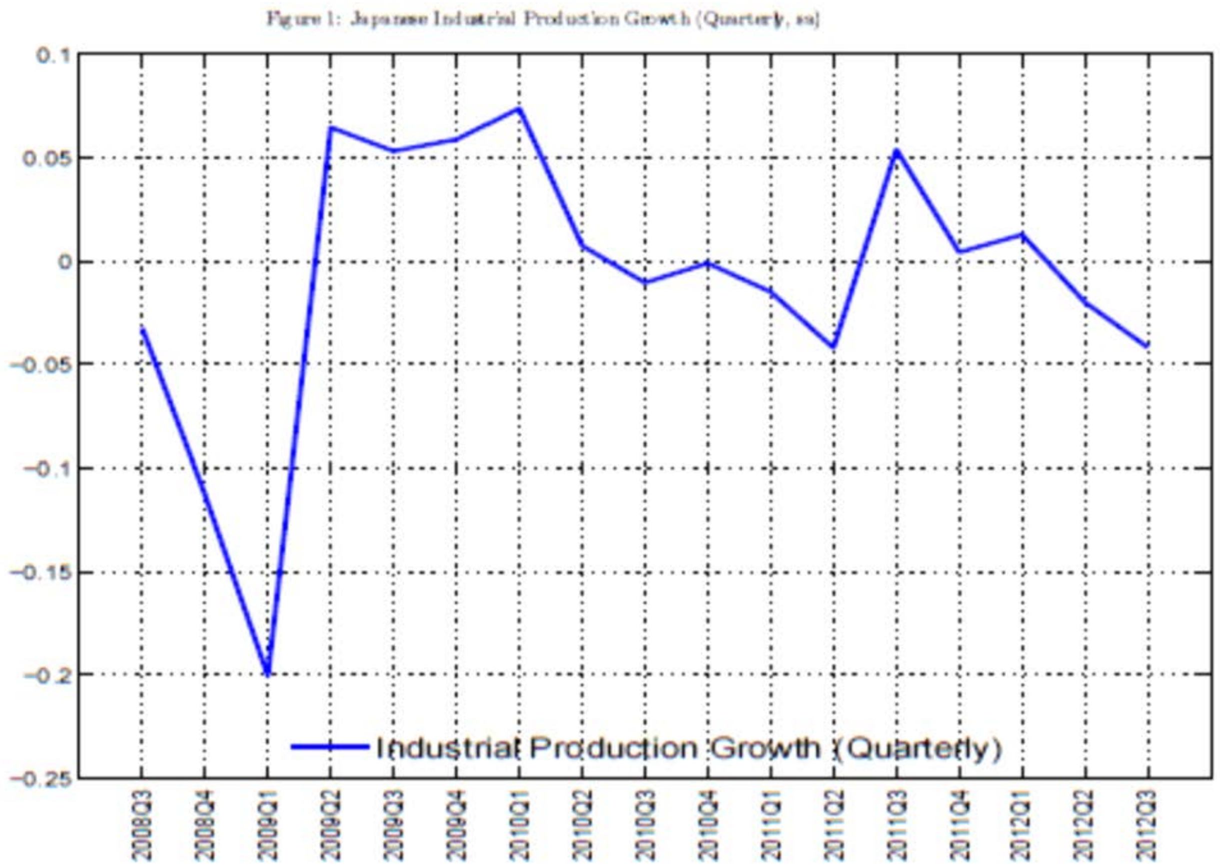
The maximal impact of the earthquake occurs in about 6 months.

The Tohoku shock was about 33 percent of Tohoku Industrial Production on impact.

Analysis Shows:

In 1 month, the impact on aggregate Japanese industrial production was 6 percent; in 6 months, 12 percent; and in 20 months, 9.6 percent.

JAPANESE INDUSTRIAL PRODUCTION



Shock to aggregate IP was much larger during the financial crisis of 2009 than the effect of the earthquake.

The effect of the earthquake was highly concentrated in Tohoku, which experienced a decline in industrial production that was larger than during the financial crisis.

MAIN REGIONS OF JAPAN

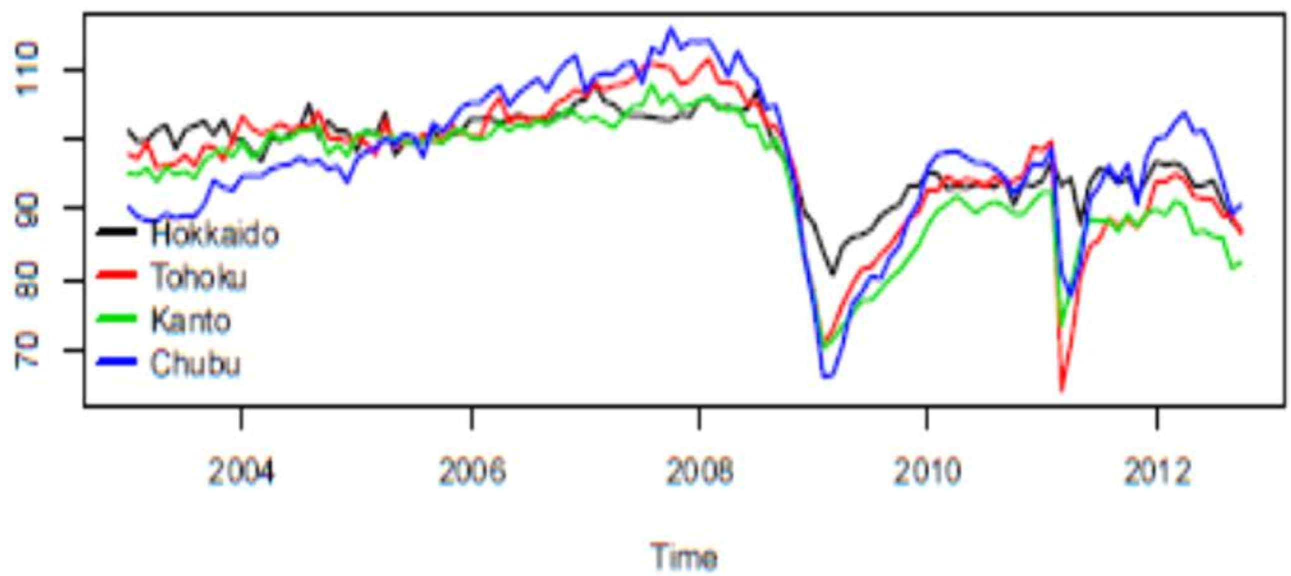
Figure 2: Japanese Regional Map

REGIONS DICTATED BY AVAILABILITY OF REGIONAL INPUT-OUTPUT TABLES

REGIONAL MONTHLY INDUSTRIAL PRODUCTION DATA FROM REGIONAL METI OFFICES.

LARGE DECLINES IN TOHOKU AND KANTO IP

Fig. 3(a): Total Industrial Production from 2003.1 to 2012.10



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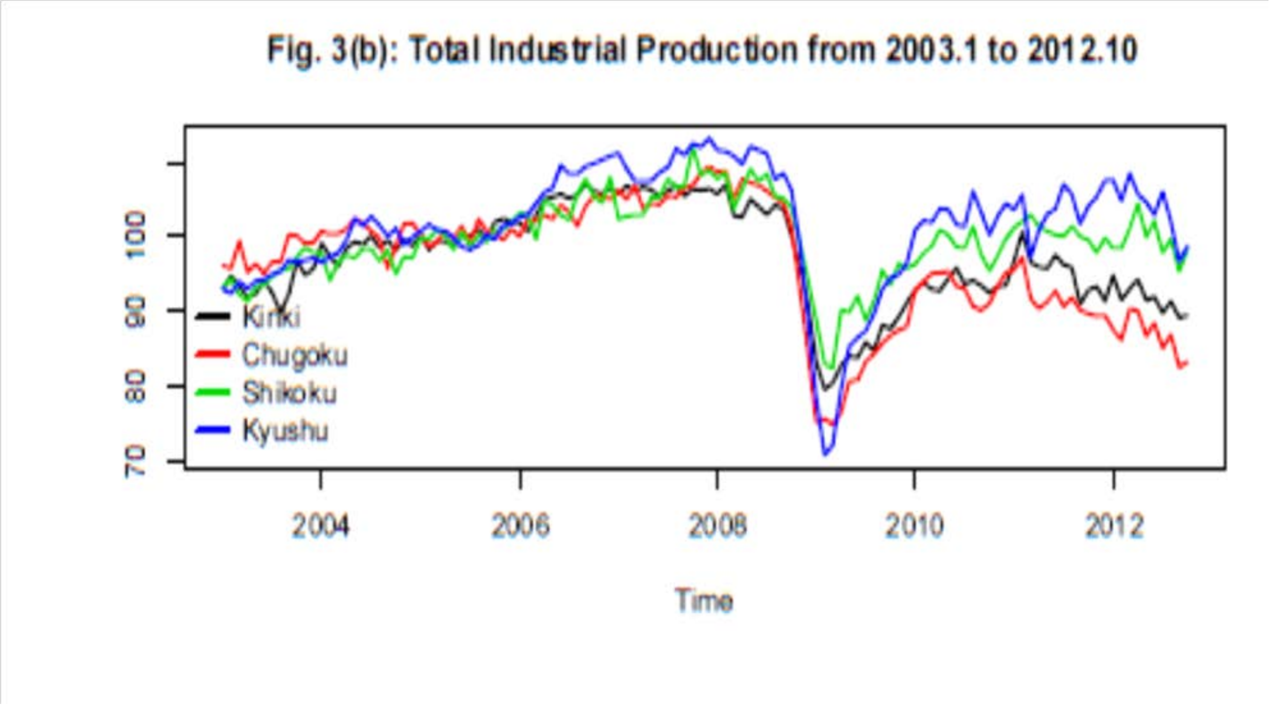
SOUTHERN REGIONS EXPERIENCED LITTLE EFFECT



IMPACT OF EARTHQUAKE ON REGIONAL AND AGGREGATE IP OVER TIME

Confounding factors on regional IP. After the earthquake, massive fiscal and rescue (both govt and charitable) spending in Tohoku and nearby regions, raising demand and IP. Appreciation of the yen caused by tight U.S. monetary policy also hurt Japanese IP. Cut in spending all over Japan due to empathy with the plight of people of people in Tohoku also lowered regional IP. (Cancellation of cherry blossom viewing festivals.)

Need to try to isolate Tohoku Earthquake impact by estimating model on long time series sample and examining impulse responses of Tohoku shock on each region, and then aggregating these regional responses. Earthquake is about 3 standard deviation shock to Tohoku IP.

METHODOLOGY: HOLLY, PESARAN AND YAMAGATA (2011)

Model of spatial and temporal diffusion

Two crucial preliminary steps.

1. Define a "**dominant**" region:
   - Its output growth has contemporaneous effects on the other regions.
   - The other regions have no contemporaneous effects on its output growth.

CONTINUED

2. For each region, define its “**neighbor**” :
   - Weighted average of the other regions’ output growth.
   - Weights are computed by some measure of proximity to the region
     (not necessarily geographical).

SPECIFICATION

Dominant region's Y = Error correction term with its "neighbors"

\+ Own lags + Lagged effects from its "neighbors"

Non-dominant region's Y = Error correction term with its "neighbors"

\+ Error correction term with the dominant region

\+ Own lags + Lagged effects from its "neighbors"

\+ Contemporaneous effects from the dominant region

SIMILARLY,

Spatio-Temporal VAR structure (Pesaran 2006).

$$
\begin{aligned}
\Delta p_{it} &= \phi_{is}\left(p_{i,t-1} - \bar{p}^{s}_{i,t-1}\right) + \phi_{i1}\left(p_{i,t-1} - p_{1,t-1}\right) + a_{i} \\
&+ \sum_{\ell=1}^{k_{ia}} a_{i\ell}\Delta p_{i,t-\ell} + \sum_{\ell=1}^{k_{ib}} b_{i\ell}\Delta \bar{p}^{s}_{i,t-\ell} + \sum_{\ell=1}^{k_{ic}} c_{i\ell}\Delta p_{1,t-\ell} + c_{i0}\Delta p_{1t} + \varepsilon_{it} \quad (1)
\end{aligned}
$$

Define Kanto (because of importance between 1980-2013) as the dominant region. Statistically, need to define the dominant region because it becomes the "common factor" that soaks up the contemporaneous unobserved dependencies (Pesaran, 2006).

Five measures of proximity, interrelatedness, economic distance.

- "Similarity" in industrial structure (correlated technology shocks). (Conley and Dupor, 2003)
- "Selling", Input-Output, Tohoku Supply Effects (Acemoglu, et. al. 2012)
- "Buying", Tohoku Demand Effects
- "Mutual buying".
- Contiguity, Two Regions share Common Border.

Note: no cross-equation restrictions across the regions. Makes estimation in large but finite samples plausible.

ECONOMIC DISTANCE MATRICES: S(I,J)

S(i,j), how region i is interrelated to the other matrices.

$$\bar{p}_{it}^{s} = \sum_{j=1}^{N} S_{ij} p_{jt}, \quad \text{with} \sum_{j=1}^{N} S_{ij} = 1$$

THREE MAIN S(I,J) MATRICES

$$D^b(i,j) = \left\{ \sum_k [B(k,i) - B(k,j)]^2 \right\}^{1/2}$$

“Similarity” matrix. Conley and Dupor (2003) holds that two regions are technologically if they buy goods from similar industries. Smaller the closer. A measure of technology spillovers.

(a) Similarity Matrix

	Tohoku	Hokkaido	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu
Tohoku	0.000	19.474	18.656	20.083	19.691	20.549	19.214	21.111
Hokkaido	19.474	0.000	19.898	19.982	19.942	20.734	19.435	21.410
Kanto	18.656	19.898	0.000	20.530	20.635	21.644	20.295	21.866
Chubu	20.083	19.982	20.530	0.000	18.954	20.382	19.200	21.104
Kinki	19.691	19.942	20.635	18.954	0.000	19.108	17.015	20.163
Chugoku	20.549	20.734	21.644	20.382	19.108	0.000	17.849	20.006
Shikoku	19.214	19.435	20.295	19.200	17.015	17.849	0.000	19.300
Kyushu	21.111	21.410	21.866	21.104	20.163	20.006	19.300	0.000

MUTUAL BUYING MATRIX

$$\mathcal{X}(i,j) = \frac{\sum_{m,n} \Gamma\left(i_{(m)}, j_{(n)}\right)}{\sum_{k,m,n} \Gamma\left(k_{(m)}, j_{(n)}\right)} + \frac{\sum_{m,n} \Gamma\left(i_{(m)}, j_{(n)}\right)}{\sum_{l,m,n} \Gamma\left(i_{(m)}, l_{(n)}\right)}$$

THE “BUYING” MATRIX IS JUST THE FIRST TERM OF THE “MUTUAL BUYING” MATRIX; AND THE “SELLING” MATRIX IS THE SECOND TERM.

(b) Mutual Buying Matrix

	Tohoku	Hokkaido	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu
Tohoku	1.204	0.045	0.293	0.063	0.055	0.025	0.016	0.029
Hokkaido	0.060	1.415	0.173	0.061	0.050	0.018	0.010	0.022
Kanto	0.264	0.146	1.590	0.244	0.162	0.118	0.127	0.138
Chubu	0.075	0.041	0.217	1.312	0.171	0.085	0.061	0.090
Kinki	0.063	0.038	0.171	0.176	1.353	0.120	0.133	0.090
Chugoku	0.030	0.020	0.129	0.102	0.135	1.332	0.099	0.117
Shikoku	0.024	0.010	0.154	0.081	0.118	0.080	1.149	0.062
Kyushu	0.025	0.014	0.115	0.065	0.081	0.085	0.046	1.404

CONTIGUITY MATRIX

Contiguity Matrix. Two Regions Share a Border. How two regions are related to each other.

(c) Contiguity Matrix

	Tohoku	Hokkaido	Kanto	Chubu	Kinki	Chugoku	Shikoku	Kyushu
Tohoku	0	1	1	1	0	0	0	0
Hokkaido	1	0	0	0	0	0	0	0
Kanto	1	0	0	1	0	0	0	0
Chubu	1	0	1	0	1	0	0	0
Kinki	0	0	0	1	0	1	1	0
Chugoku	0	0	0	0	1	0	1	1
Shikoku	0	0	0	0	1	1	0	1
Kyushu	0	0	0	0	0	1	1	0

ESTIMATION RESULTS

Estimation sample: Monthly IP data by Region, January 1998-October 2012

A positive "own lag" implies that the series continues to drift in the same direction as last period. A negative "own lag" implies that the series adjusts to last period's increase by a decrease in the current period. Significant own lag effects for most regions are found.

A positive “neighbor lag” effect implies that the series moves in the same direction as the weighted average of the industrial production of its neighbors in the last period. The estimated “neighbor lag” effects are mostly positive.

The magnitude of “Neighbor lag” tends to be highest for the “buying” and “mutual buying” economic distance measures.

“Kanto current” effect is the estimated contemporaneous effects of Kanto--all positive.

Table 4: Estimation results of region specific diffusion equation for Total Industrial Production

(a) Similarity Matrix

	OwnLag	NeighbL	Kanto Lag	Kanto Current	EC1	EC2	Wu-Haus	k_{ia}	k_{ib}	k_{ic}
Kanto	-0.3 (-2.624)	0.88 (6.149)	-	-	-	-	-	1	2	-
Tohoku	-0.262 (-3.253)	-0.026 (-0.168)	0.442 (3.22)	0.815 (11)	-	-0.22 (-3.653)	-0.815	1	1	1
Hokkaid	-0.478 (-6.518)	0.394 (4.042)	-	0.305 (3.666)	-	-	1.134	1	1	0
Chubu	-0.217 (-3.031)	0.471 (3.818)	-	1.012 (14.497)	-	-	0.263	1	1	0
Kinki	-0.541 (-4.785)	0.506 (5.437)	-	0.513 (7.752)	-	-0.108 (-2.343)	0.093	2	1	0
Chugoku	-0.119 (-1.394)	0.307 (2.86)	-	0.629 (7.424)	-	-0.37 (-4.561)	-0.632	1	1	0
Shikoku	-0.59 (-4.779)	0.519 (3.319)	-	0.526 (4.192)	-	-	2.099	2	1	0
Kyushu	-0.059 (-0.658)	0.1 (0.622)	0.366 (2.896)	0.785 (10.889)	-	-0.07 (-2.138)	1.039	1	1	1

(b) Mutual Buying Matrix

	OwnLag	NeighbL	Kanto Lag	Kanto Current	EC1	EC2	Wu-Haus	k_{ia}	k_{ib}	k_{ic}
Kanto	-0.309 (-2.566)	0.868 (6.022)	-	-	-	-	-	1	2	-
Tohoku	-0.254 (-3.024)	0.445 (4.132)	-	0.81 (11.391)	-	-0.254 (-3.609)	0.387	1	1	0
Hokkaid	-0.482 (-6.703)	0.401 (4.528)	-	0.328 (4.1)	-	-	0.527	1	1	0
Chubu	-0.262 (-3.432)	0.544 (4.153)	-	1.001 (14.383)	-	-	0.142	1	1	0
Kinki	-0.59 (-5.111)	0.529 (6.113)	-	0.522 (7.76)	-	-	-0.906	2	1	0
Chugoku	-0.174 (-2.048)	0.33 (3.102)	-	0.625 (7.15)	-	-0.251 (-3.569)	-0.912	1	1	0
Shikoku	-0.617 (-4.993)	0.563 (3.698)	-	0.519 (4.187)	-	-	1.64	2	1	0
Kyushu	-0.252 (-2.564)	0.607 (5.283)	-	0.78 (10.996)	-	-	0.872	2	1	0

(c) Contiguity Matrix

	OwnLag	NeighbL	Kanto Lag	Kanto Current	EC1	EC2	Wu-Haus	k_{ia}	k_{ib}	k_{ic}
Kanto	-0.159 (-1.306)	0.576 (4.82)	-	-	-	-	-	1	2	-
Tohoku	-0.216 (-2.628)	-0.152 (-1.038)	0.5 (3.444)	0.831 (11.898)	-	-0.286 (-4.098)	0.09	1	1	1
Hokkaid	-0.454 (-6.345)	-0.089 (-1.064)	0.444 (2.537)	0.373 (4.696)	-	-	-0.699	1	1	1
Chubu	-0.193 (-2.603)	0.369 (3.2)	-	1.042 (15.052)	-	-	-0.458	1	1	0
Kinki	-0.57 (-5.056)	0.114 (1.245)	0.363 (3.663)	0.574 (8.578)	-	-0.104 (-2.605)	-1.812	2	1	1
Chugoku	-0.185 (-2.303)	0.276 (2.916)	-	0.631 (6.888)	-0.148 (-2.882)	-	-1.649	1	1	0
Shikoku	-0.292 (-3.81)	-0.371 (-1.554)	0.534 (2.855)	0.677 (4.925)	-0.097 (-2.359)	-	-0.543	1	2	1
Kyushu	-0.252 (-2.681)	0.146 (2.142)	0.431 (2.838)	0.831 (11.597)	-	-	-1.027	2	1	1

Note: t-statistics in parentheses. Kanto's lagged effect are estimated to be 0 and thus omitted from the report. Lag orders are selected separately by Schwarz Bayesian criterion from a maximum lag order of 4.

SPATIO-TEMPORAL IMPULSE RESPONSE FUNCTIONS

We trace out how a decline in industrial production in one region can be propagated throughout Japan.

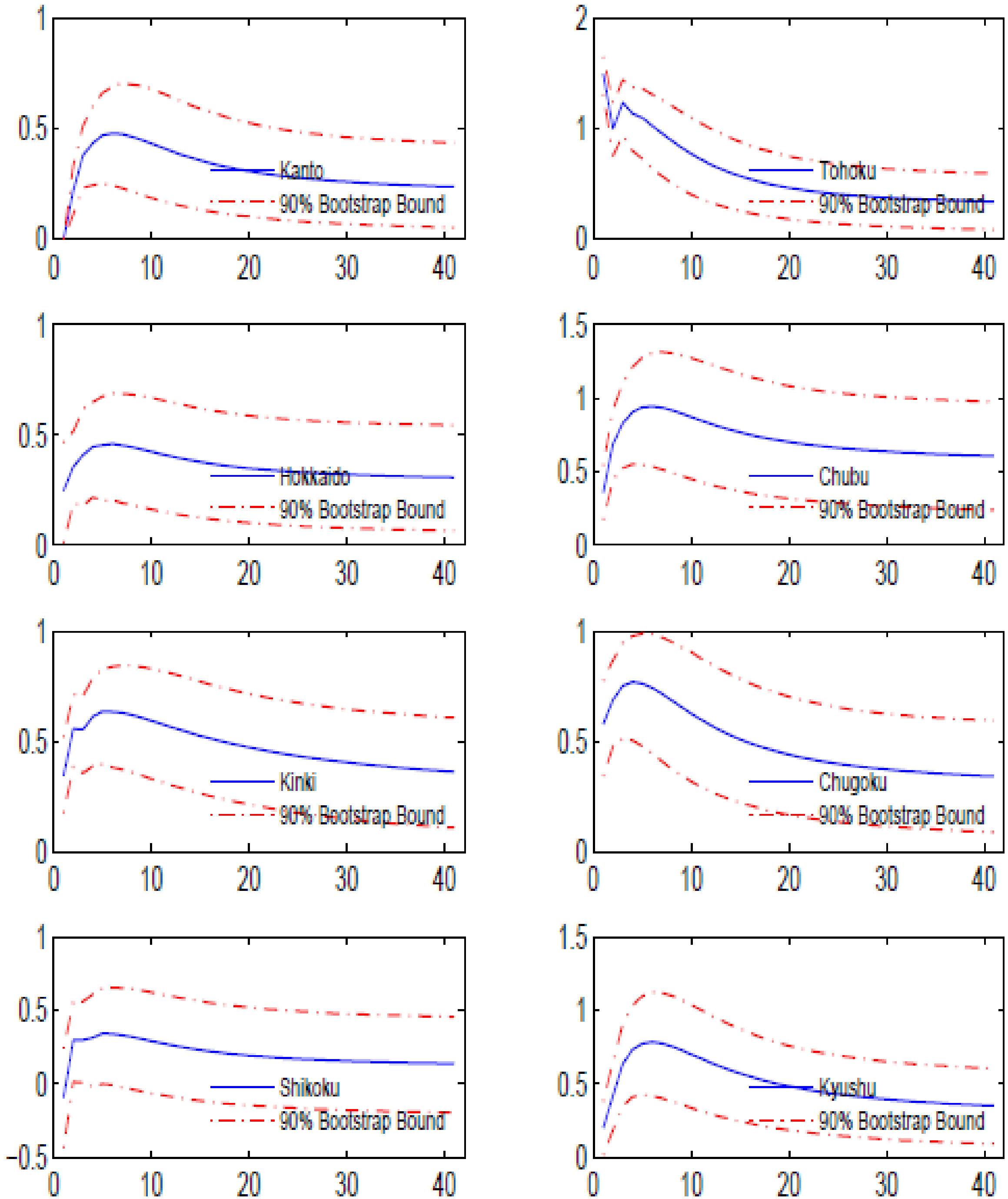
After the model is estimated, we shock Tohoku IP by 1 standard deviation.

We take Tohoku, and see how a shock to industrial production in Tohoku owing to the earthquake can be propagated throughout Japan.

IMPULSE RESPONSE FUNCTIONS

Impulse responses are very similar for all five measures of economic distance.

For all measures, the response of Chubu seems to be the largest. The response of Shikoku is the smallest.


Kanto
90% Bootstrap Bound
Tohoku
90% Bootstrap Bound
Hokkaido
90% Bootstrap Bound
Chubu
90% Bootstrap Bound
Kinki
90% Bootstrap Bound
Chugoku
90% Bootstrap Bound
Shikoku
90% Bootstrap Bound
Kyushu
90% Bootstrap Bound

PERSISTENCE PROFILE OF TOHOKU SUGGESTS THAT IT TAKES ABOUT 2 YEARS FOR TOHOKU TO ABSORB A UNIT SHOCK TO ITS MONTHLY IP LEVEL, ALTHOUGH IP LEVEL REMAINS LOWER THAN BEFORE.

THE PERSISTENCE PROFILES OF OTHER REGIONS OTHER THAN TOHOKU SHOW THAT A POSITIVE SHOCK CAN BE ADJUSTED WITHIN A YEAR'S TIME, ALTHOUGH IP LEVEL REMAINS LOWER THAN BEFORE.

Figure 7: Shock on IP based on Mutual Buying Matrix

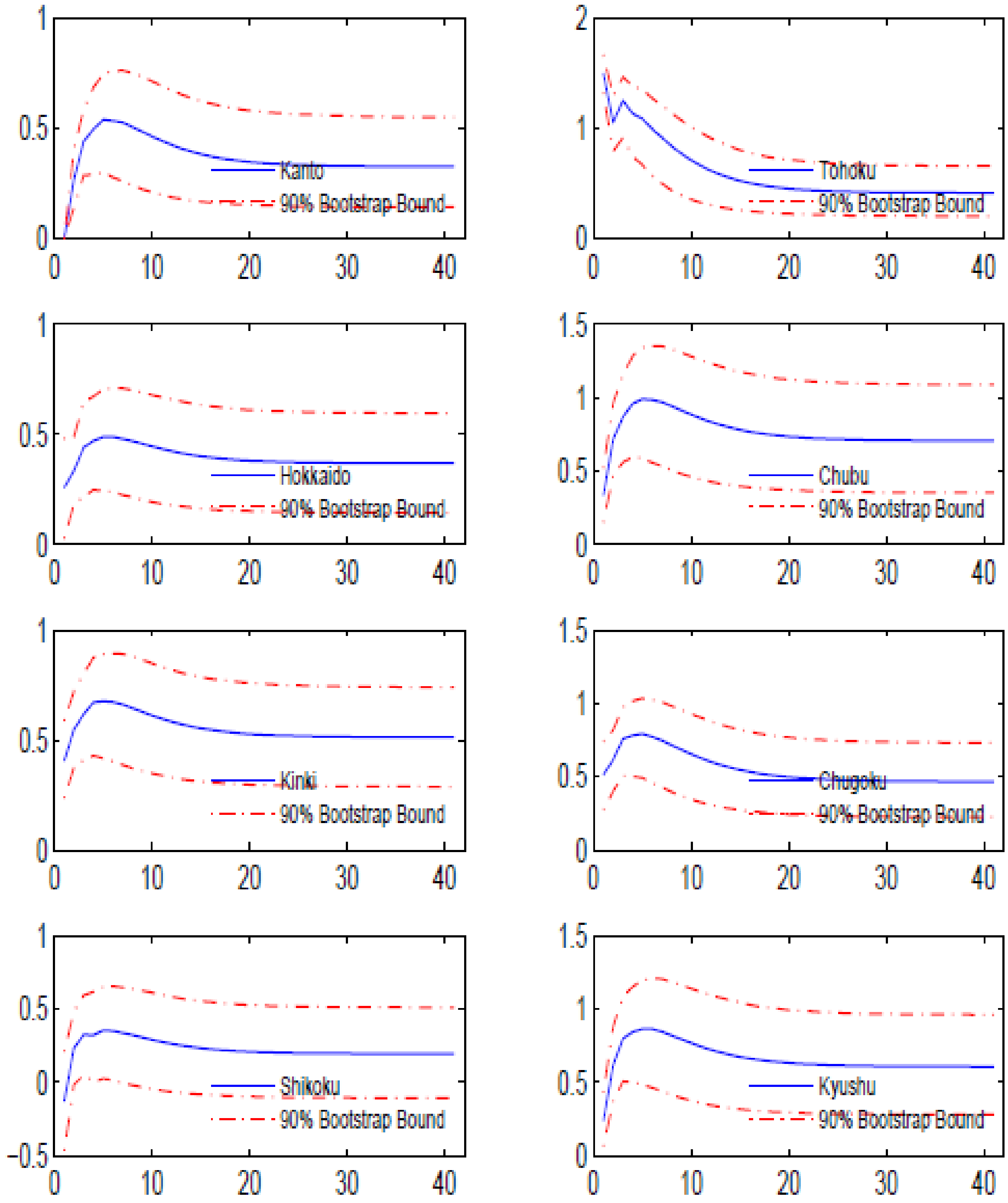
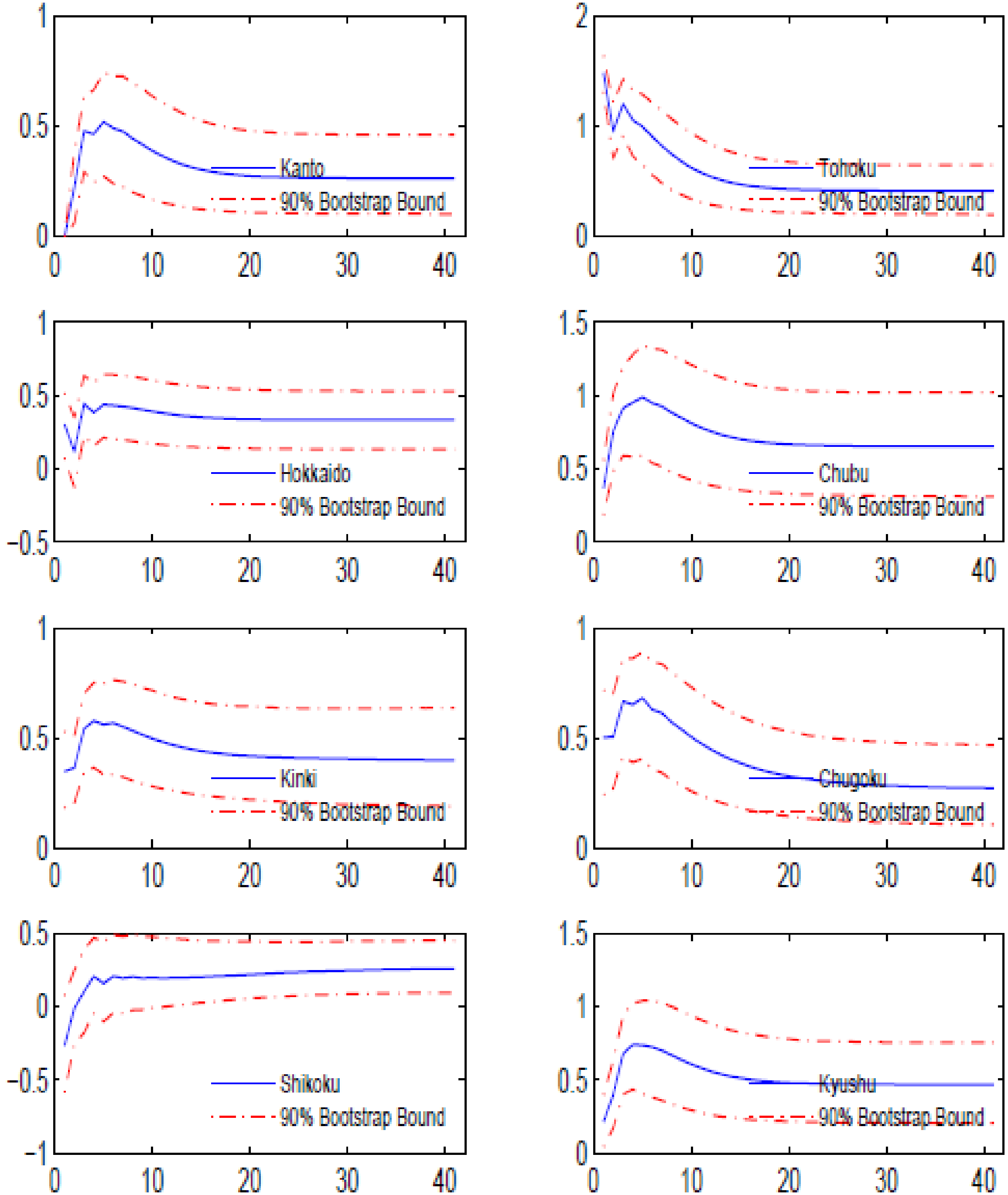


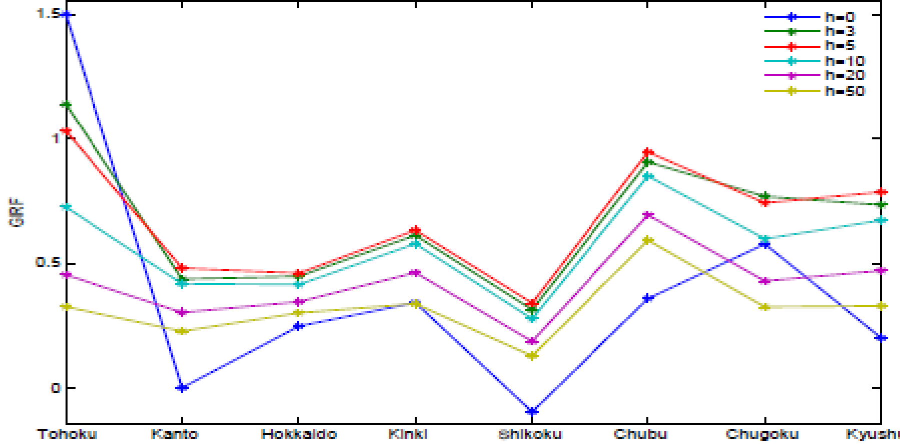
Figure 8: Shock on IP based on Contiguity Matrix



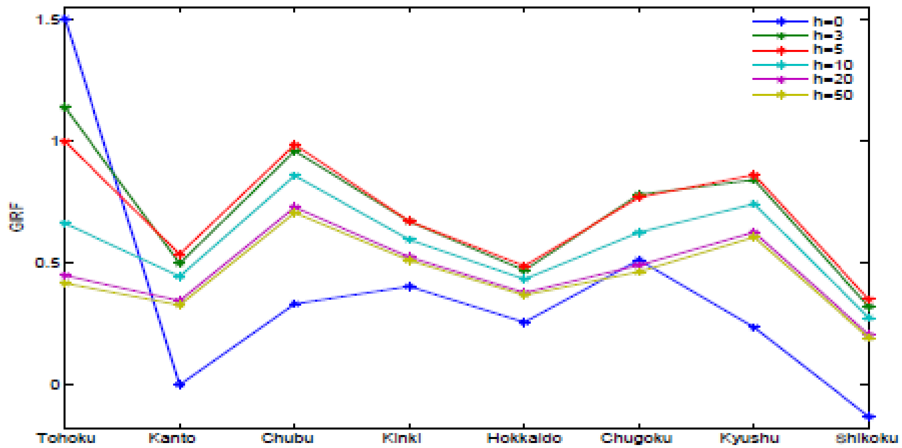
GIRF ACROSS REGIONS AND OVER TIME. THE REGIONS ARE ORDERED FROM LEFT TO RIGHT ACCORDING TO THEIR "CLOSENESS" TO TOHOKU (ACCORDING TO THE THREE MEASURES OF ECONOMIC DISTANCE). IF "CLOSENESS" RESULTS IN HIGHER SPILLOVERS, THEN WE SHOULD SEE A DECLINING PATTERN IN THE GRAPHS. AS THE REGIONS BECOME FURTHER FROM TOHOKU, EFFECTS OF THE TOHOKU SHOCK SHOULD DISSIPATE.

OUR CLOSENESS MEASURES DON'T CAPTURE PROPAGATION OF SHOCKS PERFECTLY FOR REGIONAL IP.

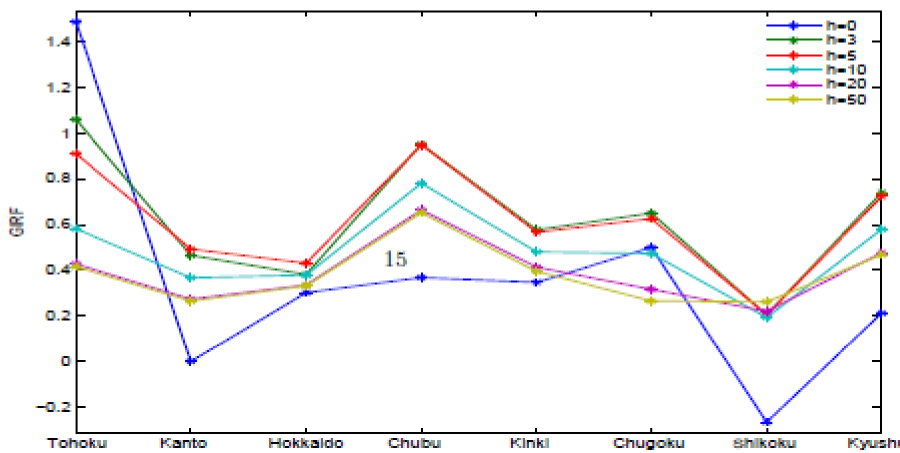
FOR ALL TIME PERIODS, CHUBU RESPONDS THE MOST TO A TOHOKU SHOCK, FOLLOWED BY KINKI.



(b). Mutual Buying Matrix



(c). Contiguity Matrix



THERE WERE MANY OTHER SHOCKS HITTING JAPAN FOLLOWING 2011 SHOCK.
DECLINE IN CONSUMPTION ACCORDING TO NEGATIVE CONSUMER SENTIMENT. FORCED CONSERVATION OF ELECTRICAL POWER USAGE THROUGHOUT JAPAN.
IMPULSE RESPONSES FROM THE SHOCK TO TOHOKU SHOULD BE ORTHOGONAL TO THESE OTHER FACTORS.

TO FOCUS MORE ON THE ROLE OF TOHOKU IN SUPPLYING INTERMEDIATE PARTS, WE LOOK AT TWO IMPORTANT PARTS INDUSTRIES IN TOHOKU: **ELECTRICAL MACHINERY AND TRANSPORT EQUIPMENT.**

SHOCKS TO THE ELECTRICAL MACHINERY INDUSTRY HAD LARGE AND IMPORTANT EFFECTS ON THE ELECTRICAL MACHINERY INDUSTRY ALL OVER JAPAN, EXCEPT FOR THE HUGE REGIONS OF KANTO AND KINKI.

Figure 10: Shock on Electric Machinery based on Electric Machinery Mutual Buying Matrix

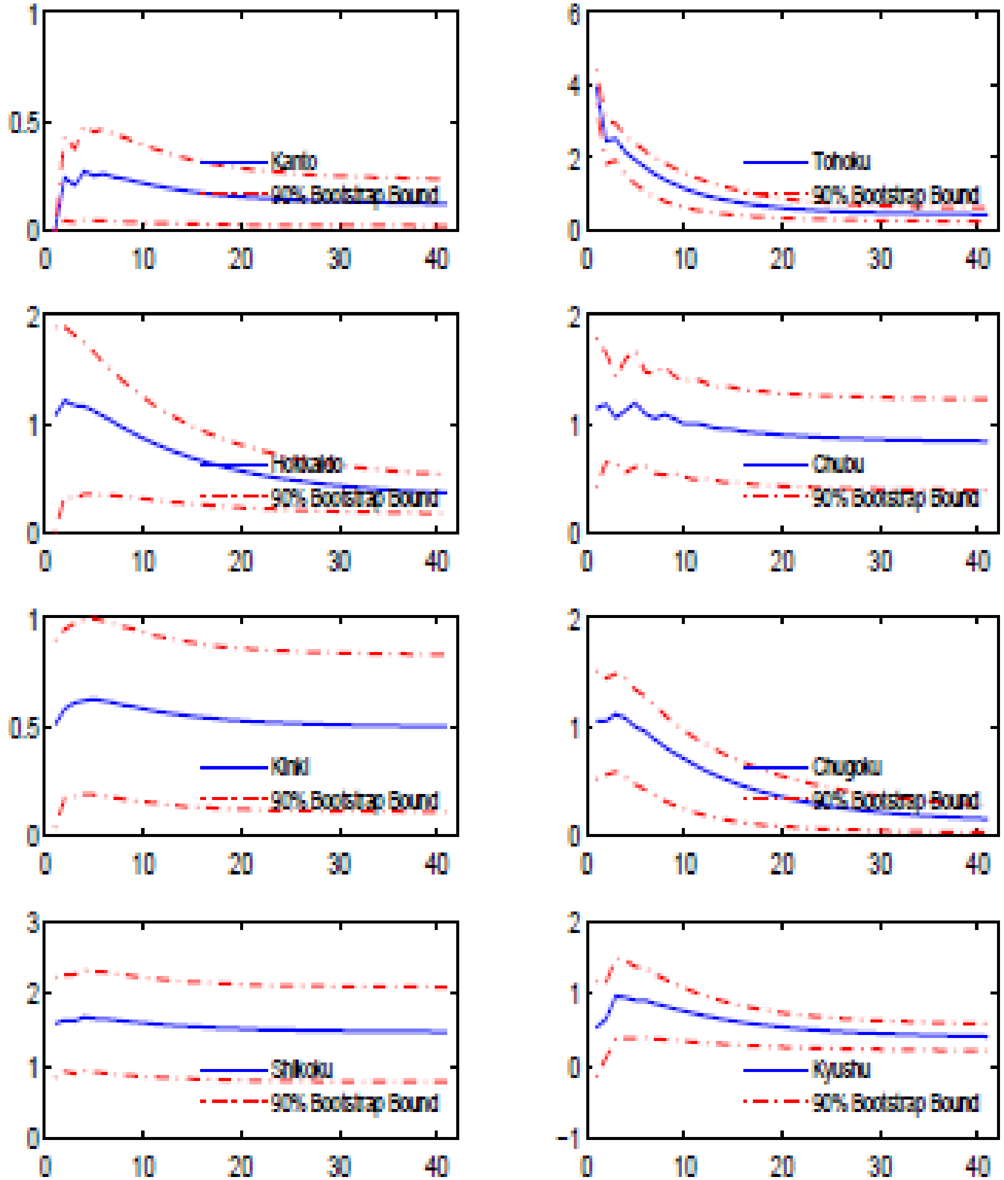
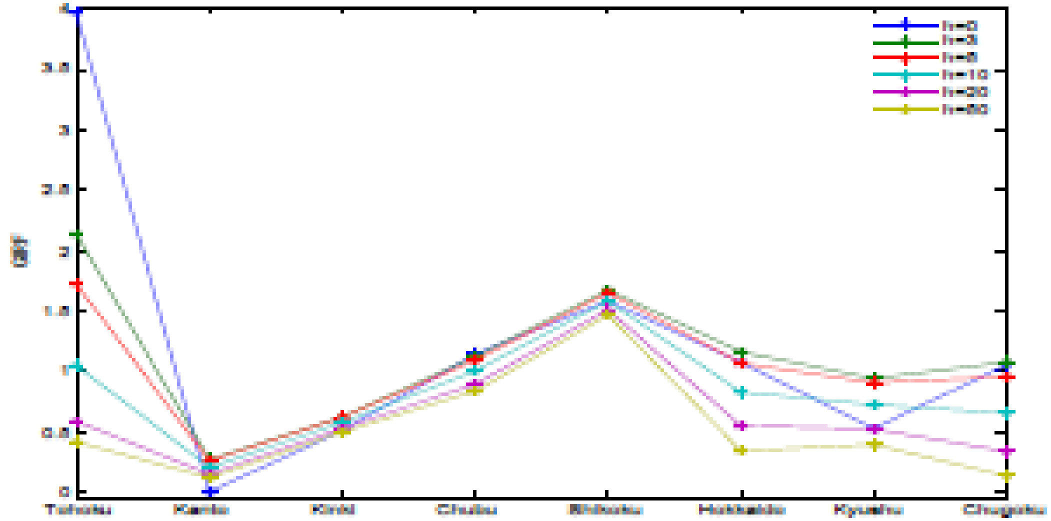
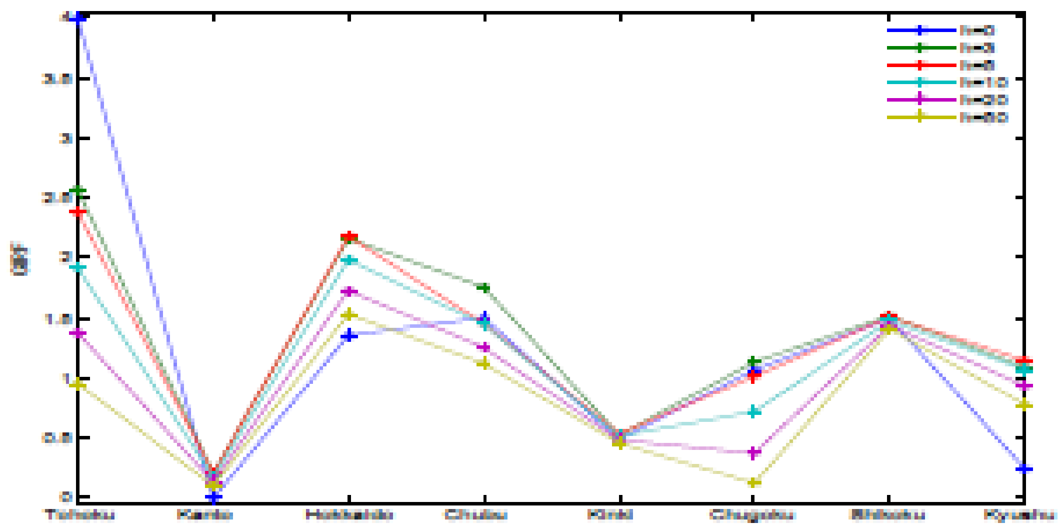


Figure 12: GIRF of Electric Machinery by 1 unit shock on Tohoku

(a). Electric Machinery Mutual Buying Matrix



(b). Contiguity Matrix



SAME RESULTS FOR THE TRANSPORTATION INDUSTRY, LARGE EFFECTS ON CHUBU REGION

RESULT

Figure 13: Shock on Transportation based on Transportation Mutual Buying Matrix

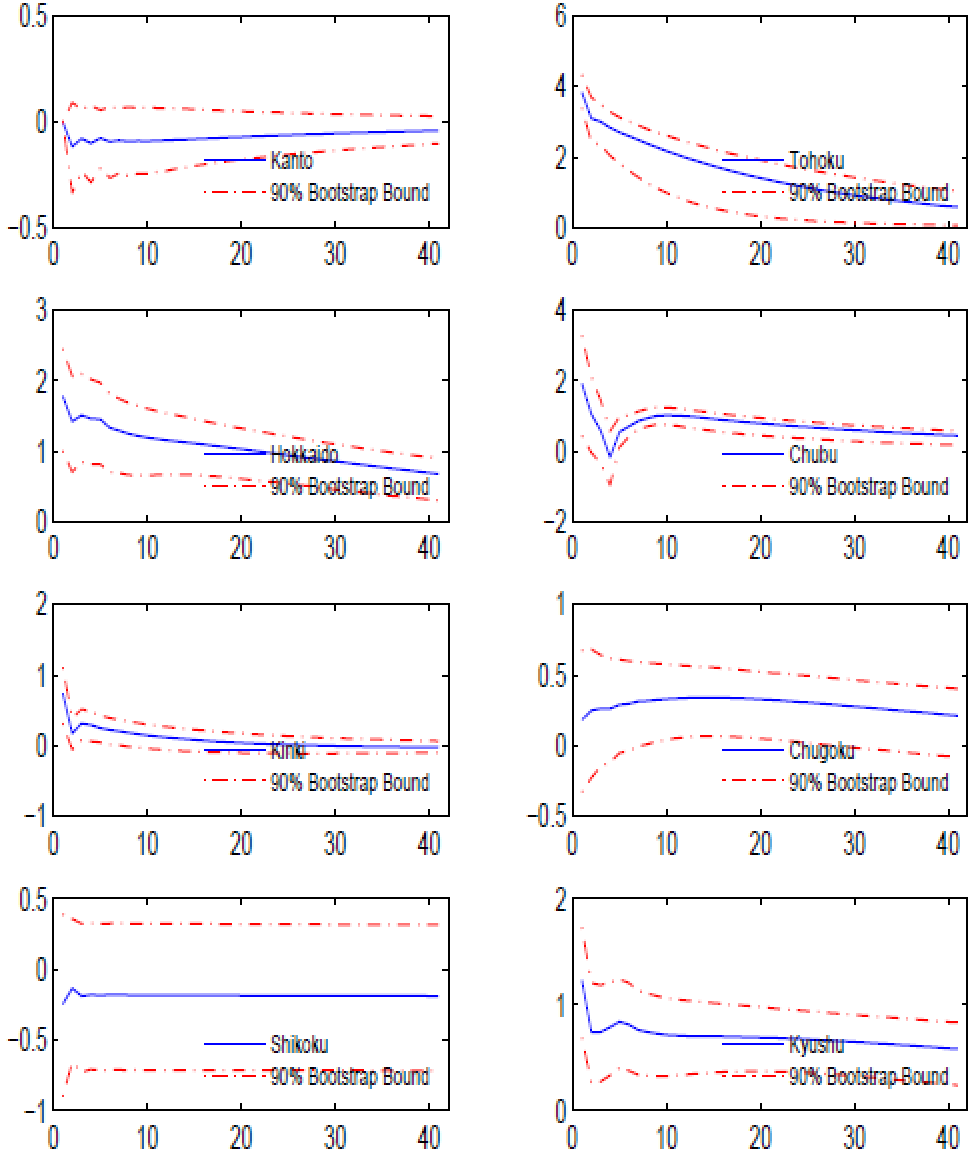
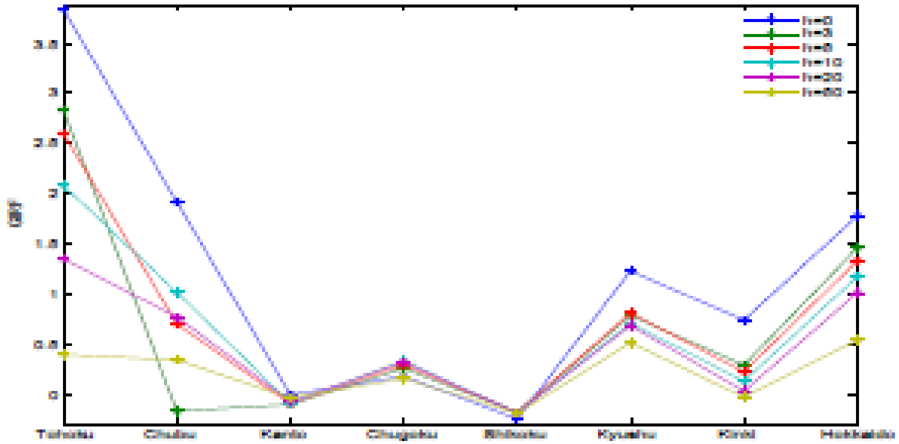
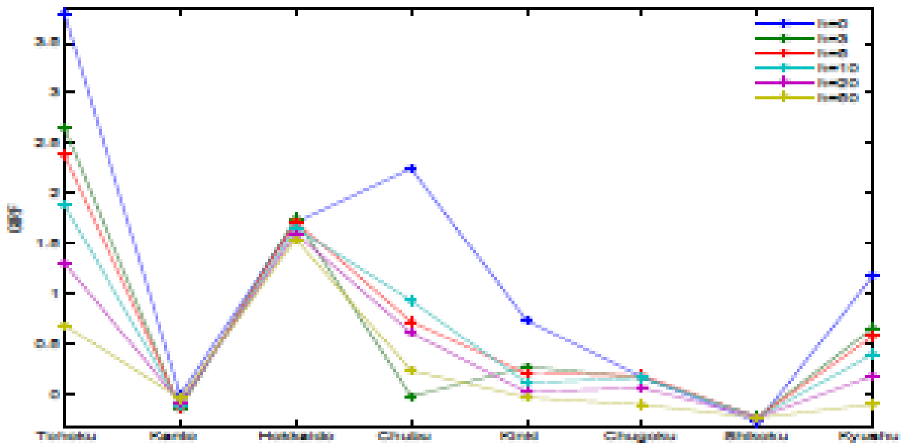


Figure 15: GIRF of Transportation by 1 unit shock on Tohoku

(a). Transportation Mutual Buying Matrix



(b). Contiguity Matrix



QUANTIFICATION

RETURNING TO THE AGGREGATE IP.

WHAT IS THE IMPACT OF EARTHQUAKE SHOCK TO TOHOKU ON AGGREGATE GDP?

TOHOKU SHOCK WAS ABOUT 3 SD SHOCK TO TOHOKU IP.

CAN READ OFF MULTIPLIERS TO REGIONAL IP FOR EACH TIME HORIZON, EG, KANTO IN 6 MONTHS.

CAN WEIGH THE REGIONAL IP RESPONSES BY REGIONAL SHARE OF AGGREGATE IP. EG. KANTO IP 0.40 PERCENT OF AGGREGATE IP

1 MONTH, 6 PERCENT NEGATIVE SHOCK TO AGGREGATE IP.

6 MONTHS, 12 PERCENT NEGATIVE SHOCK TO AGGREGATE IP.

20 MONTHS, 9.6 PERCENT NEGATIVE SHOCK TO AGGREGATE IP.

ACTUAL IP DECLINE SMALLER BECAUSE OF FISCAL POLICY, ETC.

CONCLUSIONS

Look at other plausible “interaction” or economic distance measures.

Tohoku shock Response similar across measures.

Maximal response less than one year.

Chubu aggregate IP responds the most to Tohoku shock.

Draw implications for Macro. and Trade.