Evaluation of economic disruptions from the 2016 Kumamoto Earthquake using a refined adaptive regional input-output model (electronic supplement)

Omar Issa[1], Tinger Zhu[2], Maryia Markhvida[2], Rodrigo Costa[3], and Jack W. Baker[2]

[1]Department of Civil and Environmental Engineering, Stanford University, Stanford, California, USA. Email: oissa@stanford.edu

[2]Department of Civil and Environmental Engineering, Stanford University, Stanford, California, USA.

[3]Department of Systems Design Engineering, University of Waterloo, Waterloo, Ontario, Canada.

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Local input-output table (LIO)

The input-output table (Figure S1), illustrates inter-industry relationships which influences ARIO-predicted recovery. The ARIO model assumes that the relationships in this table hold constant over the entire recovery period.

Fig. S1. Schematic local input-output table for Kumamoto in FY2015.

Pre-disaster fixed assets

Pre-disaster fixed assets (productive capital) for each sector are assumed to take the value of total replacement costs per claims data following the earthquake, provided to the authors by Sompo, Inc. While this provided dataset constitutes

a large portion of Kumamoto's productive capital, it does not represent the entire capital stock of the prefecture. To account for this, Sompo, Inc. provided the authors with adjustment factors R_i to increase (where necessary) the total values of the productive capital for each sector i. Using Equation S1, we treat the array of fixed asset inputs before entering into the ARIO model.

$$FA_i = \frac{RC_{i,raw}}{R_i} \tag{S1}$$

where:

FA_i = Fixed assets for sector i

$RC_{i,raw}$ = Aggregate replacement costs for sector i based on claims data

R_i = Adjustment factor

The final assumed values for fixed assets, aggregated at the sector level, are provided in Table S1. The number of buildings (or in some cases, building groups) represented in the dataset are provided, along with pre-disaster value added, as a reference.

Monetary losses

We estimate the direct (monetary) loss for each sector by aggregating building-level claims data provided to the authors by Sompo, Inc. As with fixed assets, the total direct losses generated by aggregating the provided data does not fully capture the actual loss across the prefecture. To address this, we leverage adjustment factors (identical to those in the previous section) to account for the assumed fractions of insured properties per sector, using Equation S1.

$$Loss_i = \frac{Loss_{i,raw}}{R_i} \tag{S2}$$

where:

$Loss_i$ = Direct losses for sector i

$Loss_{i,raw}$ = Direct losses for sector i based on claims data

R_i = Adjustment factor

Applying the adjustment factors generates a total direct loss to 1.76 trillion yen across all sectors. Individual values for direct monetary losses, aggregated at the sector level, are provided in Table S2. The number of buildings (or in some cases, building groups) represented in the dataset are provided, along with corresponding loss ratios, as a reference.

TABLE S1. Summary of pre-earthquake (i) fixed assets and (ii) value added data for each of the 37 sectors (plus housing) considered in the case study.

Code	Industry	Number of buildings	Fixed assets (billion Yen)*	Value added (billion Yen)	Ratio of fixed assets to value added
1	Agriculture + forestry + fishery	1008	15	194.6	0.1
6	Mining**	0	0	4.1	0.0
11	Beverages + foods	6596	210	169.3	1.2
15	Textile products	174	6	12.0	0.5
16	Pulp, paper + wooden products	2967	46	50.4	0.9
20	Chemical products	224	3	91.3	0.0
21	Petroleum + coal products	109	2	3.1	0.5
22	Plastic products + rubber products	24	10	62.4	0.2
25	Ceramic, stone + clay products	459	98	25.1	3.9
26	Iron + steel	109	1	8.7	0.2
27	Non-ferrous metals**	0	0	10.7	0.0
28	Metal products	992	23	58.1	0.4
29	General-purpose machinery	243	13	9.8	1.3
30	Production machinery**	0	0	173.5	0.0
31	Business oriented machinery	111	6	9.8	0.6
32	Electronic components	122	10	136.6	0.1
33	Electrical machinery	1294	30	64.9	0.5
34	ICT equipment**	0	0	5.8	0.0
35	Transportation equipment	6161	106	87.8	1.2
39	Misc. manufacturing products	283	5	30.7	0.2
41	Construction	3796	231	277.3	0.8
46	Electricity, gas + heat supply	102	18	104.2	0.2
47	Water supply	24	15	26.3	0.6
48	Waste management service	55	8	48.5	0.2
51	Commerce	5356	1365	570.0	2.4
53	Finance + insurance	624	44	188.9	0.2
55	Real estate	2124	122	659.5	0.2
57	Transport + postal services	9641	123	253.8	0.5
59	Information + communications	299	19	134.4	0.1
61	Public administration	1009	231	352.0	0.7
63	Education + research	1555	57	412.7	0.1
64	Medical, health care + welfare	6846	535	698.4	0.8
65	Membership-based associations	1537	343	31.4	10.9
66	Business services	234	16	365.0	0.0
67	Personal services	4534	379	285.3	1.3
68	Office supplies	558	11	37.4	0.3
69	Activities not elsewhere classified	2095	42	19.2	2.2
999	Housing	313317	5919	N.A.	N.A.

$*$ Estimated using Equation S1.

$**$ No data for these sectors was available for use in the case study.

All data was provided to the authors by Sompo, Inc.

TABLE S2. Summary of (i) monetary losses and (ii) time to 95% reconstruction for each of the 37 sectors (plus housing) considered in the case study.

Code	Industry	Number of buildings	Direct loss (billion Yen)	Loss ratio*)	Time to 95% reconstruction, t_{95}
1	Agriculture, forestry + fishery	1008	1.3	0.08	87
6	Mining**	0	0.0	0.00	0
11	Beverages + Foods	6596	37.0	0.18	115
15	Textile products	174	0.7	0.17	141
16	Pulp, paper + wooden products	2967	6.5	0.14	126
20	Chemical products	224	0.4	0.12	83
21	Petroleum + coal products	109	0.1	0.06	100
22	Plastic products + rubber products	24	0.1	0.06	60
25	Ceramic, stone + clay products	459	24.8	0.25	122
26	Iron + steel	109	0.1	0.07	43
27	Non-ferrous metals**	0	0.0	0.00	0
28	Metal products	992	2.7	0.12	95
29	General-purpose machinery	243	1.5	0.11	94
30	Production machinery**	0	0.0	0.00	0
31	Business oriented machinery	111	1.1	0.19	149
32	Electronic components	122	1.7	0.16	114
33	Electrical machinery	1294	3.7	0.12	92
34	Information + comm. equip.**	0	0.0	0.00	0
35	Transportation equipment	6161	16.3	0.15	136
39	Misc. manufacturing products	283	0.9	0.19	97
41	Construction	3796	25.7	0.21	126
46	Electricity, gas + heat supply	102	3.8	0.21	137
47	Water supply	24	1.6	0.16	65
48	Waste management service	55	0.3	0.23	87
51	Commerce	5356	63.2	0.17	112
53	Finance + insurance	624	6.1	0.25	133
55	Real estate	2124	15.3	0.22	153
57	Transport + postal services	9641	20.9	0.17	115
59	Information + communications	299	2.0	0.19	137
61	Public administration	1009	11.8	0.16	165
63	Education + research	1555	10.0	0.18	159
64	Medical, health care + welfare	6846	58.5	0.15	155
65	Membership-based associations	1537	6.9	0.14	123
66	Business services	234	0.6	0.14	96
67	Personal services	4534	28.6	0.15	90
68	Office supplies	558	1.8	0.16	120
69	Other activites	2095	7.4	0.17	85
999	Housing	313317	1061.0	0.18	149

$*$ Ratios represent the sector total loss divided by sector total replacement cost.
$**$ No data for these sectors was available for use in the case study.
All data was provided to the authors by Sompo, Inc.

Reconstruction time curves

We prepare sector-level reconstruction time curves using building-level reconstruction times provided to the authors by Sompo, Inc. These times, generated using an in-house, proprietary model by Sompo, Inc. (i) do not account for supply chain impacts that impede repair progress, and (ii) are provided at the individual building (or building group) level, labelled by sector. The sector-specific time to repair 95% of all damaged assets, t_{95} is provided in Table S2. Overall, we observe that for all sectors, t_{95} generally falls within 6 months of the initial shock. Individual reconstruction time curves for each sector, along with their derivative functions, are provided in Figures S2 and S3, respectively. They are used in the ARIO model for dynamic reconstruction rate calculations.

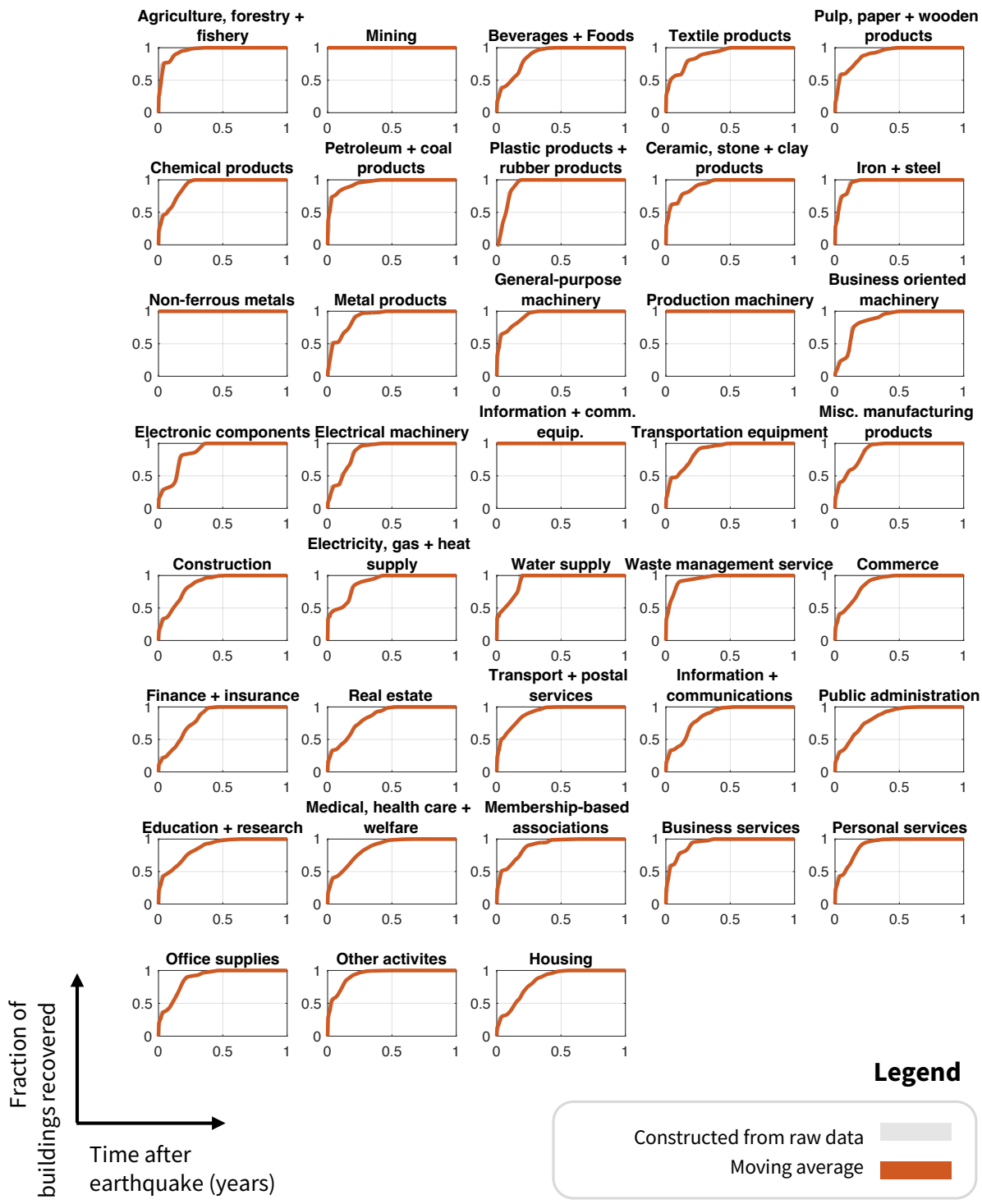

Fig. S2. Reconstruction time curves for each sector, constructed using provided asset-level reconstruction time data. The blue curve represents empirical data, while the orange curve is constructed using a 14-point moving average.

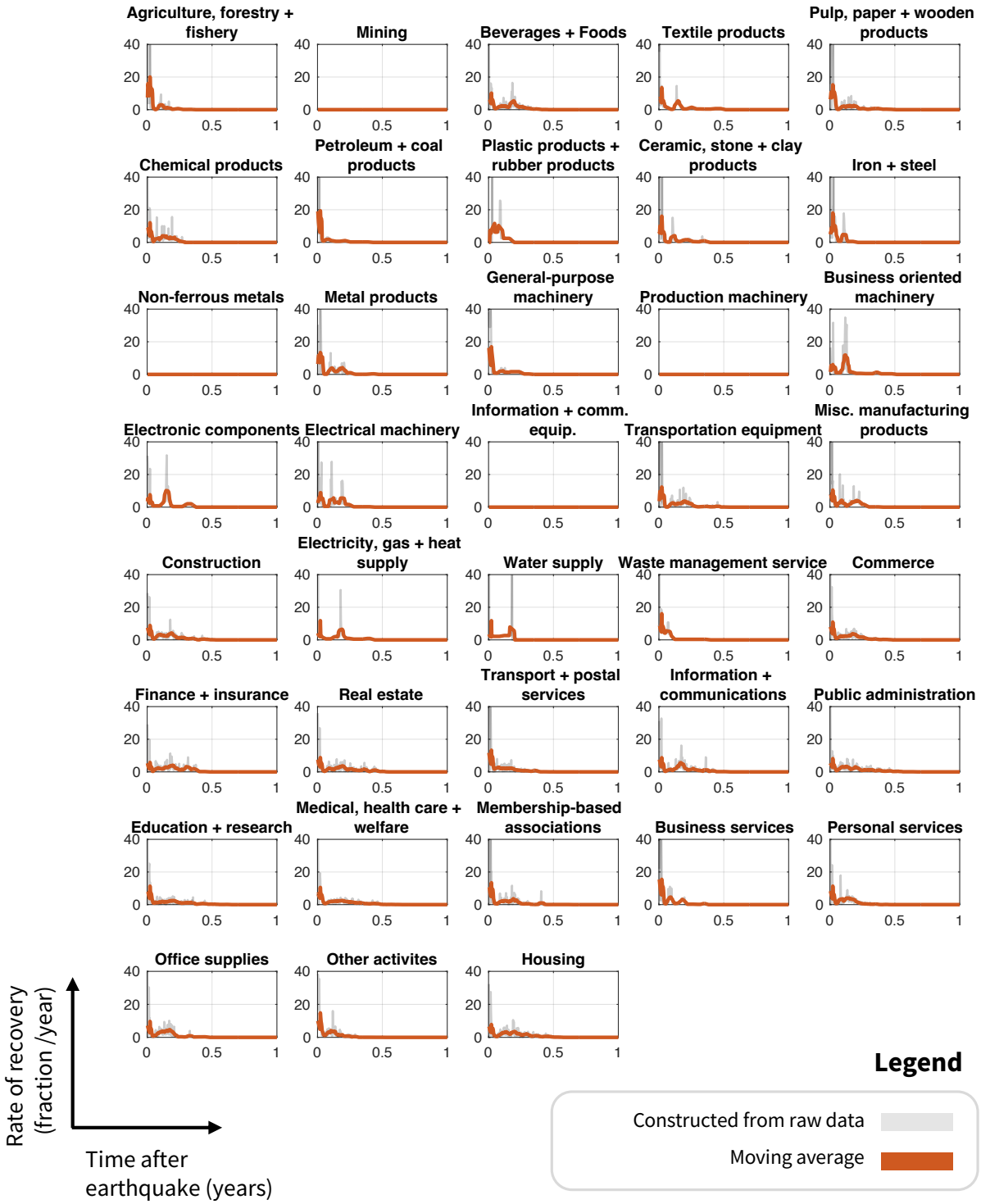

Fig. S3. Slopes of the reconstruction time curves (Figure S2) for each sector, constructed using provided asset-level reconstruction time data. The blue curve is developed using empirical data, while the orange curve is developed using a 14-point moving average.

Behavioral parameters

We provide the groupings of individual sectors within the Kumamoto economy in Table S3. These groupings are based on the seven categories introduced as part of the proposed behavioral parameter set in the main paper.

TABLE S3. Assigned sector categories.

Number	Sector	Assigned sector category
1	Agriculture, forestry and fishery	Agriculture
2	Mining	Mining
3	Beverages and Foods	Beverages+Food
4	Textile products	Manufacturing
5	Pulp, paper and wooden products	Manufacturing
6	Chemical products	Manufacturing
7	Petroleum and coal products	Manufacturing
8	Plastic products and rubber products	Manufacturing
9	Ceramic, stone and clay products	Manufacturing
10	Iron and steel	Manufacturing
11	Non-ferrous metals	Manufacturing
12	Metal products	Manufacturing
13	General-purpose machinery	Manufacturing
14	Production machinery	Manufacturing
15	Business oriented machinery	Manufacturing
16	Electronic components	Manufacturing
17	Electrical machinery	Manufacturing
18	Information and communication electronics equipment	Manufacturing
19	Transportation equipment	Manufacturing
20	Miscellaneous manufacturing products	Manufacturing
21	Construction	Construction
22	Electricity, gas and heat supply	Utilities
23	Water supply	Utilities
24	Waste management service	Utilities
25	Commerce	Services
26	Finance and insurance	Services
27	Real estate	Services
28	Transport and postal services	Services
29	Information and communications	Utilities
30	Public administration	Services
31	Education and research	Services
32	Medical, health care and welfare	Services
33	Membership-based associations, n.e.c.	Services
34	Business services	Services
35	Personal services	Services
36	Office supplies	Manufacturing
37	Activities not elsewhere classified	Services
38	Housing	Housing

CASE STUDY: ARIO MODEL OUTPUT

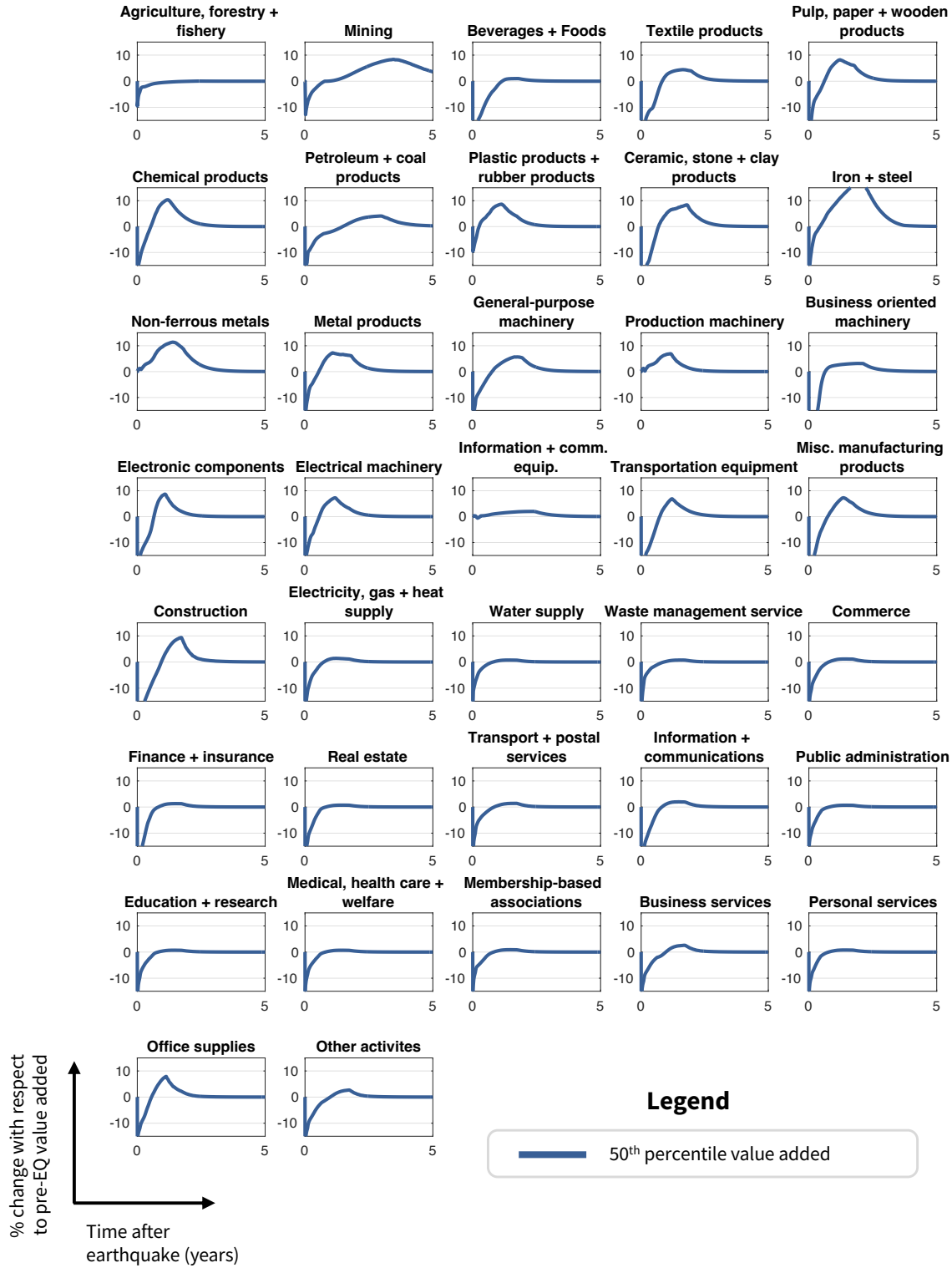

Fig. S4. 50th percentile sector-level results (1000 simulations): change in value added over a 5-year recovery period.

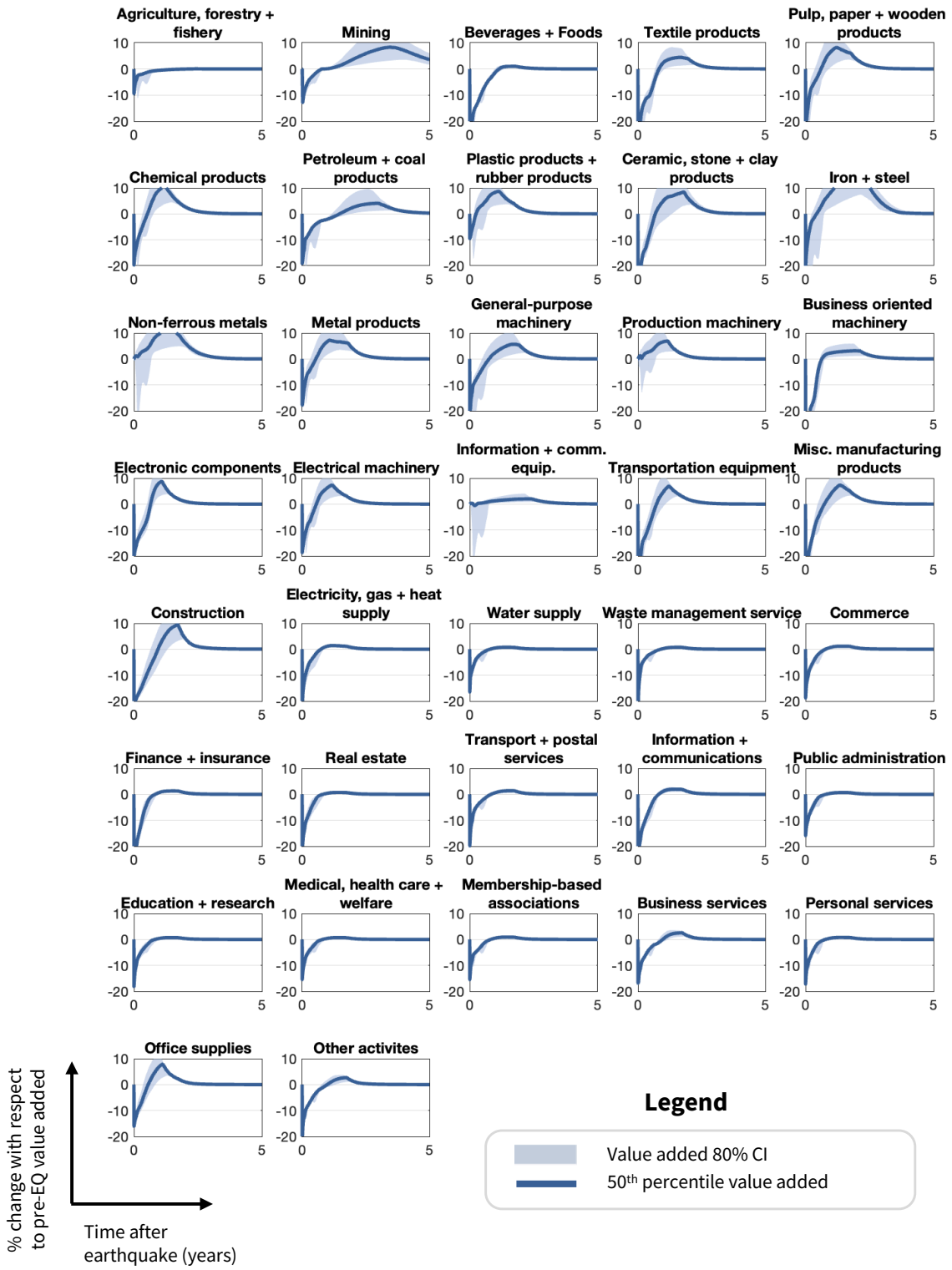

Fig. S5. 50th percentile sector-level results (1000 simulations): change in value added over a 5-year recovery period, along with 80% confidence interval (CI).

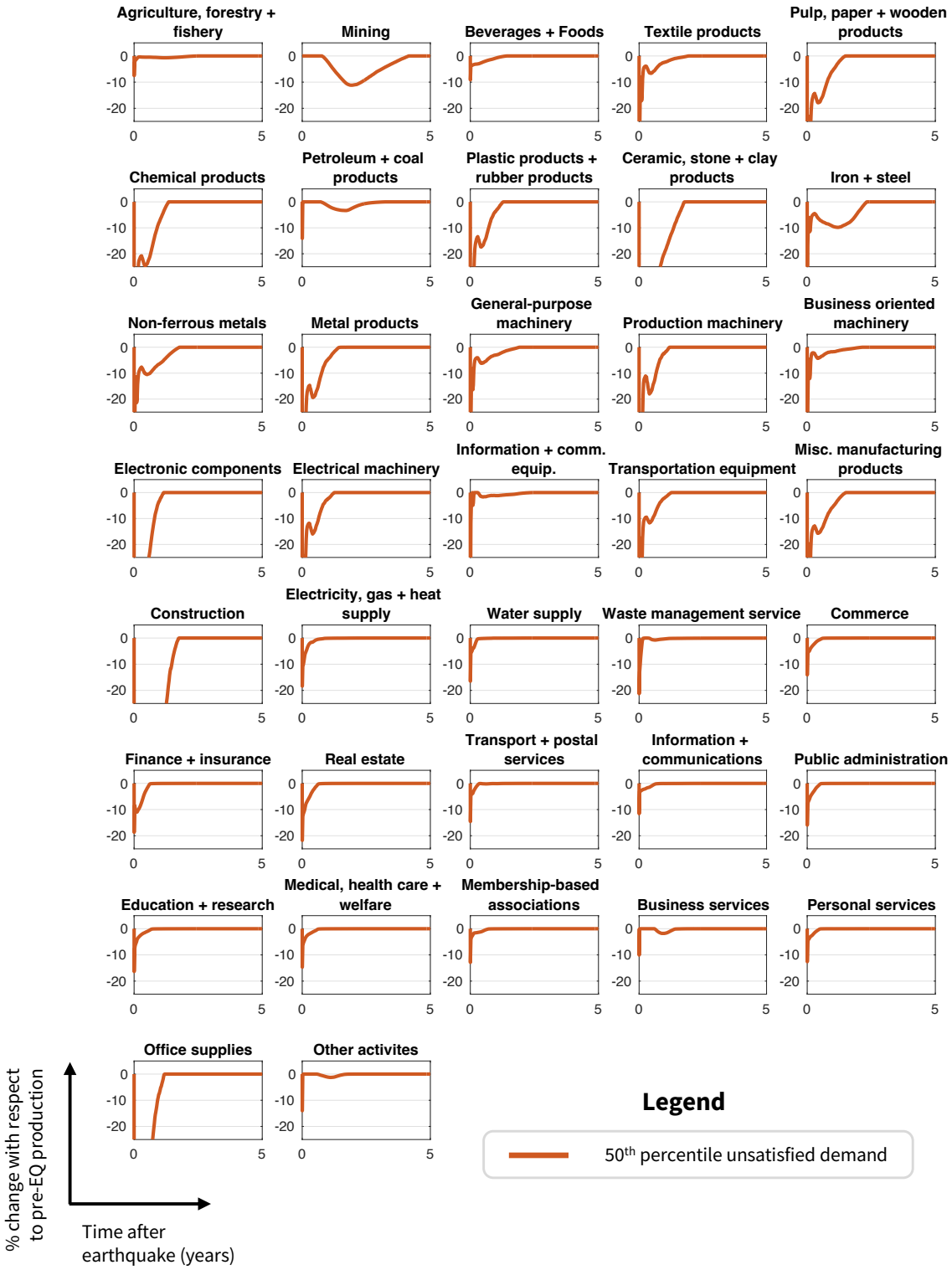

Fig. S6. 50th percentile sector-level results: change in demand unsatisfied over a 5-year recovery period.

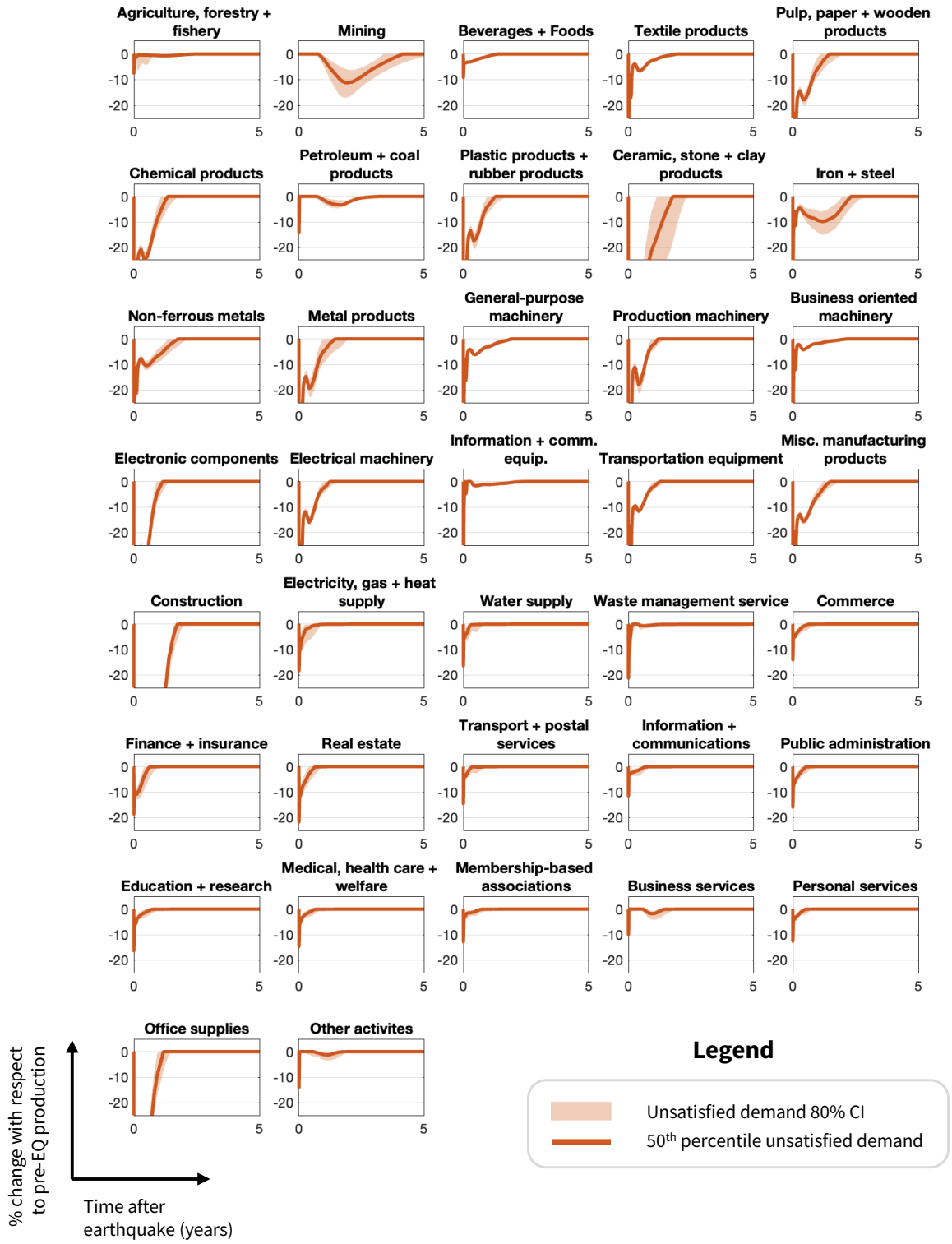

Fig. S7. 50th percentile sector-level results (1000 simulations): change in demand unsatisfied over a 5-year recovery period, along with 80% confidence interval (CI).

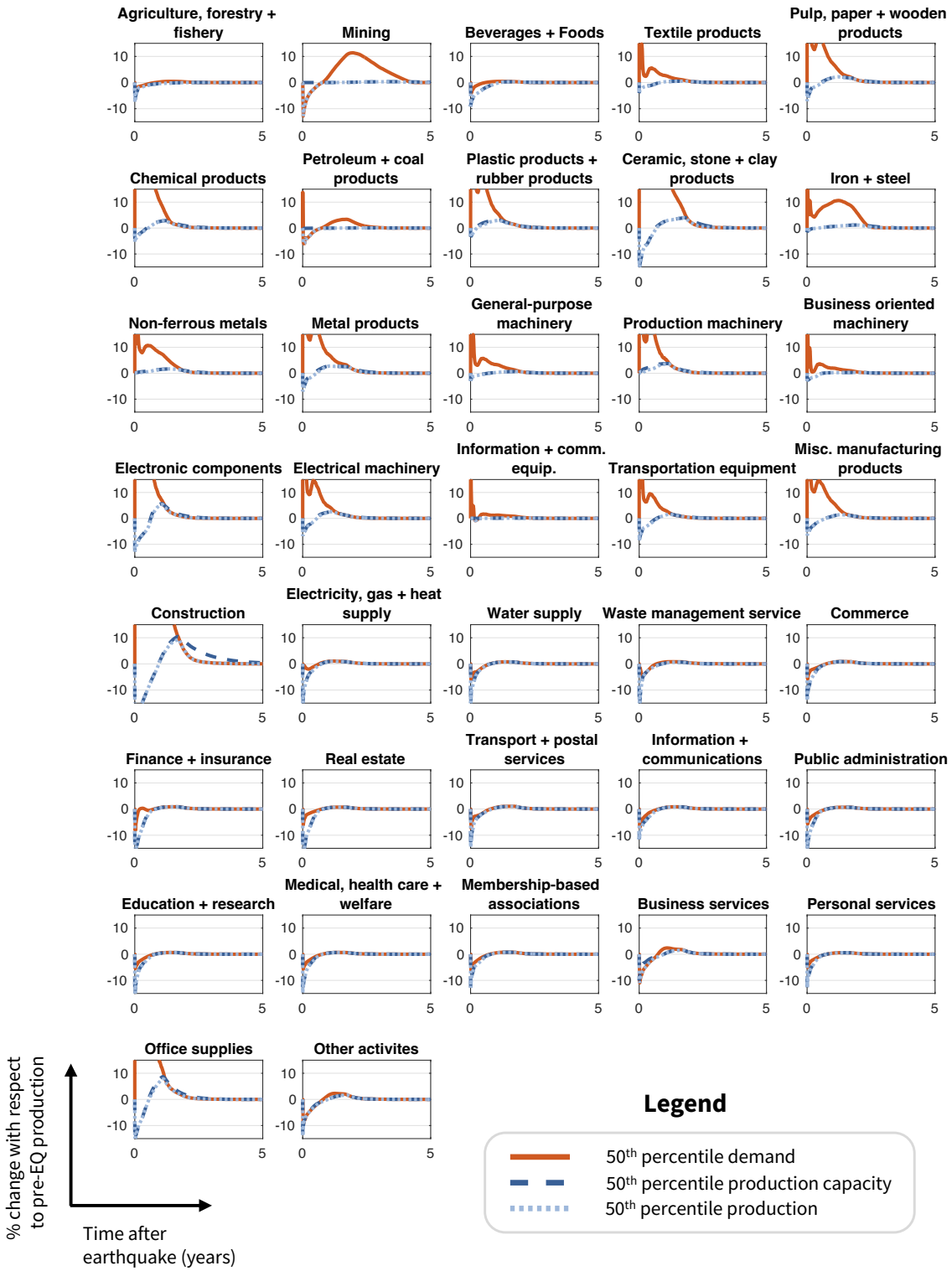

Fig. S8. 50th percentile sector-level results (1000 simulations): demand, production, and production capacity over a 5-year recovery period.

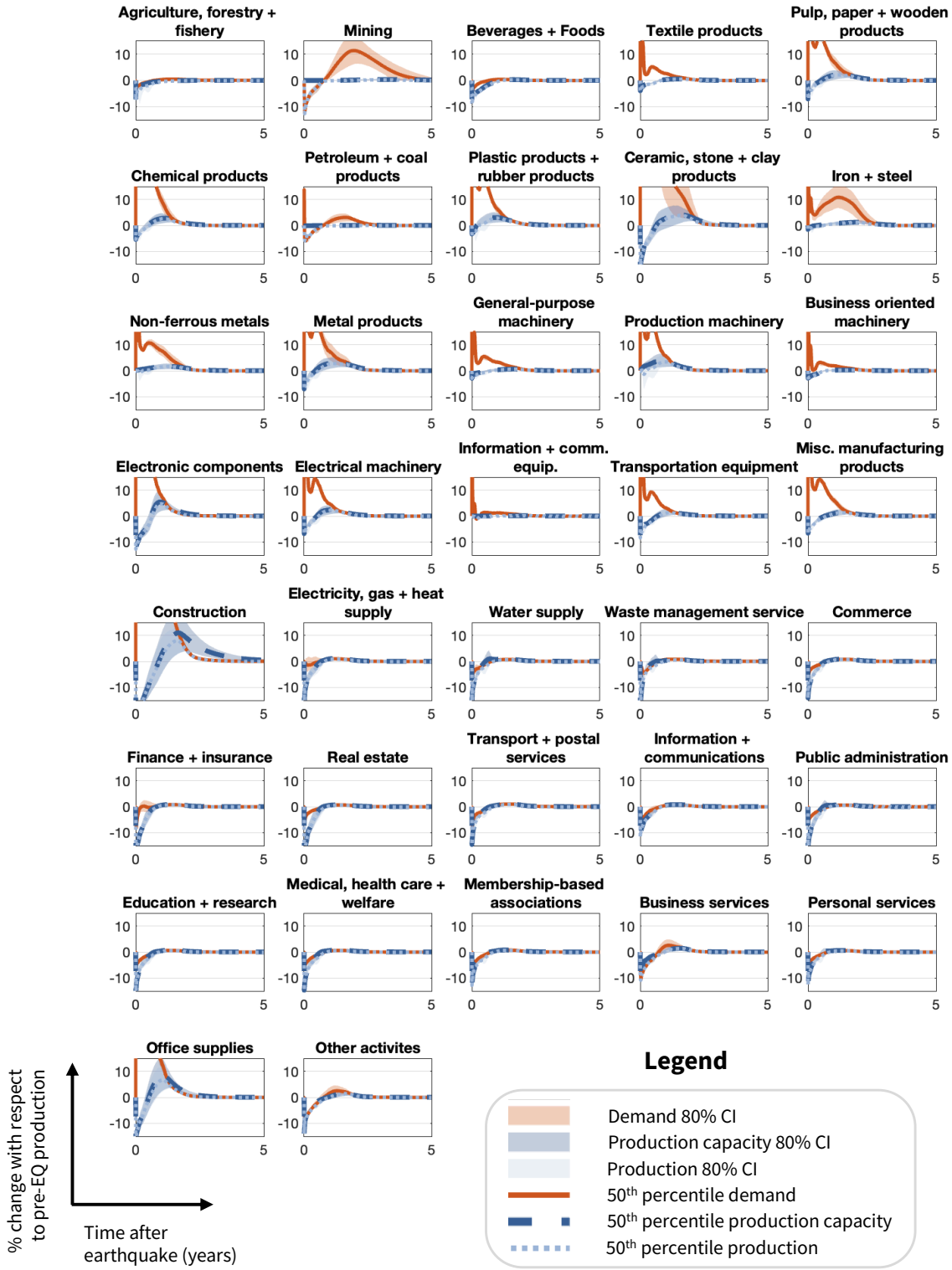

Fig. S9. 50th percentile sector-level results (1000 simulations): demand, production, and production capacity over a 5-year recovery period, along with 80% confidence interval (CI).

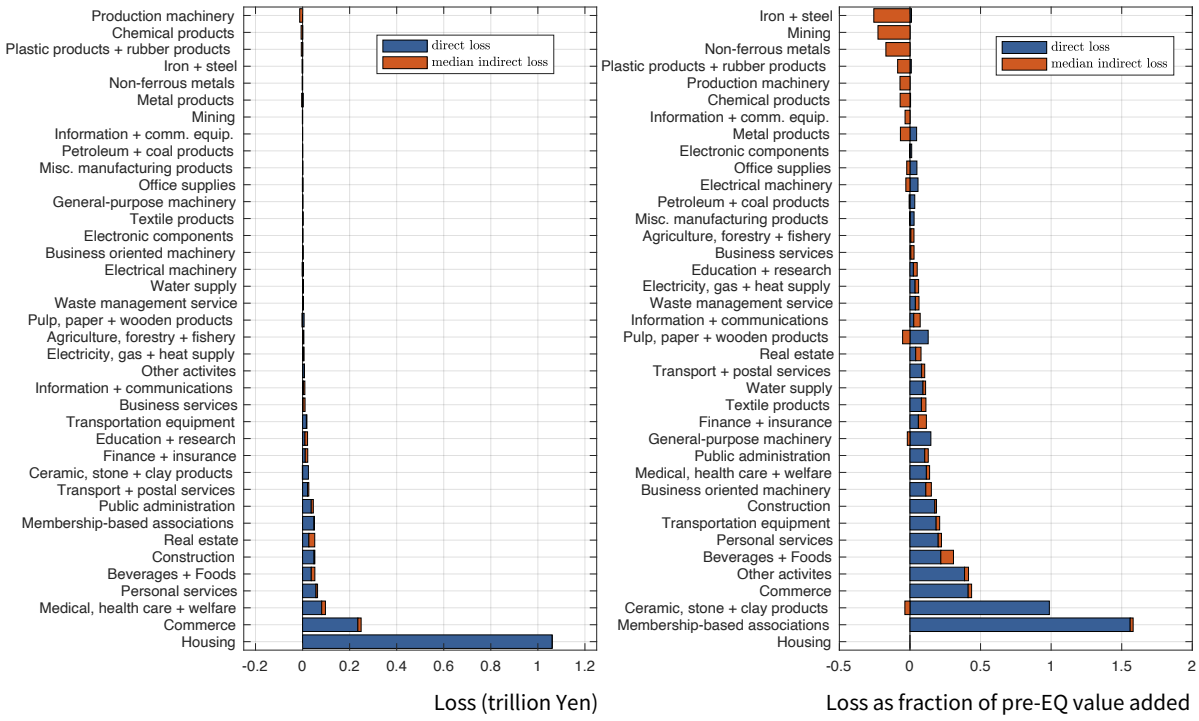

Fig. S10. 50th percentile direct and indirect losses (across 1000 simulations) for the 37 economic sectors (plus housing) in terms of absolute monetary value in trillion Yen (left) and fraction of pre- disaster value added, sorted by total economic losses.