Analysis of Indirect Economic Impacts of Earthquake Scenarios in British Columbia and Quebec

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Presentation Outline

- Study scenarios
- Analytical approach
- Adaptation of the Canadian Provincial input-output tables
- Economic resilience
- Economic impact analysis results
- SDA of the results

Study Scenario

- In this study, we analyze the indirect economic losses in BC and QC of two earthquake scenarios:
  - an earthquake scenario with a Richter magnitude of 9.0 in BC
  - an earthquake scenario with a Richter magnitude of 7.1 near Quebec City
- Economic consequence analysis is focused on business interruption losses from building/content damages and lifeline service disruptions.

Analytical Approach

- Use input-output analysis approach
- 24-sector I-O tables for the provinces of BC and QC are obtained from Statistics Canada
- Two versions are used:
  - Demand-side (upstream in supply-chain)
  - Supply-side (downstream in supply-chain)
- Approach to calculate the direct BI losses:
  - Based on AIR Model Results
  - Building damage: direct BI estimated from AIR Model
  - Utility lifeline disruption: $DOL_{i,n} = DailyOuput_i \times \%\ Affected \times \%\ Loss\ of\ Function$
  - Transportation infrastructure: ATC (1991) approach

Adaptation of the Canadian Provincial I-O Tables

- Combine Transportation Margins and Transportation Services sectors
- Other sectoral aggregation
- Estimate direct regional input coefficients and construct intra-regional transaction tables
  - StatsCan's provincial tables did not delineate between production inputs produced locally or outside of the province
  - To get intra-regional exchanges, use of imports need to be removed
  - Use formula $\rho = \frac{\mathbf{q} - \mathbf{e}}{\mathbf{q} - \mathbf{e} + \mathbf{m}}$ to calculate the vector of regional purchase coefficients (RPCs)
  - Multiply the original I-O table by the RPCs vector to obtain the intra-regional transaction table.

Defining Economic Resilience

- Static: Ability of a system to maintain function when shocked (efficient use of remaining resources at a given point in time).

- Dynamic: Speed of a system to recover from a shock (efficient use of resources over time for investment in repair and reconstruction).

Source: Rose, A. 2009. *Economic Resilience to Disasters*. Community and Regional Resilience Institute Research Report 8.

Measuring Econ Resilience of 9/11

- 95% of over 1,100 WTC area firms relocated after 9/11
- If all of firms in the WTC area went out of business, direct business interruption (BI) loss would = $58.4B
- If all relocation were immediate, then no BI
- Businesses relocated within 8 months , BI = $16.1B
- Resilience Metric: Avoided Loss ÷ Max Potential Loss

$42.3B ÷ $58.4B = 72%

Typical Resilience Tactics

- Use of inventories
- Conservation
- Input substitution
- Import substitution
- Utility unimportance
- Production recapture
- Transportation re-routing

Simulation Results

Economic Impacts of BC Earthquake Scenario (in millions 2012 CAN $)

	Case	Total Output Loss	Total Income Loss	Total Value-added Loss	Total Employment Impacts	Percentage Annual Total Output Loss
A.	Base Case (No Resilience)	24,157.6	7,972.0	12,811.5	155,099	6.58%
B.	With Lifeline Importance	21,295.4	7,055.2	11,298.2	138,768	5.80%
C.	With Conservation	24,056.9	7,939.8	12,758.2	154,523	6.55%
D.	With Transport Re-routing	23,880.4	7,891.0	12,673.3	153,688	6.50%
E.	With Production Recapture	5,235.9	1,849.6	2,715.4	40,532	1.43%
F.	With All Resilience Adjustments	4,403.4	1,574.9	2,296.2	35,187	1.20%

Simulation Results (cont'd)

Economic Impacts of QC Earthquake Scenario (in millions 2012 CAN $)

	Case	Total Output Loss	Total Income Loss	Total Value-added Loss	Total Employment Impacts	Percentage Annual Total Output Loss
A.	Base Case (No Resilience)	20,079.6	6,123.9	9,764.1	130,112	3.21%
B.	With Lifeline Importance	17,630.0	5,359.0	8,547.8	115,341	2.82%
C.	With Conservation	19,970.5	6,090.4	9,710.1	129,463	3.19%
D.	With Transport Re-routing	19,743.4	6,038.3	9,625.5	128,511	3.16%
E.	With Production Recapture	6,738.4	2,099.0	3,239.5	48,533	1.08%
F.	With All Resilience Adjustments	5,963.8	1,857.0	2,873.6	43,359	0.95%

Adjustment for Multiple Sources of BI

- Business may suffer shocks from multiple sources, and thus potential double-counting of losses
- Adjustment is made based on time periods for various sources of shocks
- Assume half of the cases when two or more shocks occurred simultaneously involved redundancies
- After adjustment,
  - gross output impacts reduce from $24.2 to $21.4 billion (w/o resilience) and from $4.4 to $4.1 billion (w/ resilience) for BC;
  - gross output impacts reduce from $20.1 to $17.1 billion (w/o resilience) and from $6.0 to $5.6 billion (w/ resilience) for QC;

Simulation Results (cont'd)

Output Losses from Various Sources for BC Earthquake Scenario

	Source of Impact	Total Output Impacts (w/o Resilience) (M $)	% Output Impacts (w/o Resilience)	Total Output Impacts (w/ Resilience) (M $)	% Output Impacts (w/ Resilience)
1	Building Damages	18,611.8	5.069%	3,802.3	1.036%
2	Oil Pipeline Disruption	34.15	0.009%	3.79	0.001%
3	Gas Pipeline Disruption	396.30	0.108%	12.77	0.003%
4	Water Supply Disruption	563.76	0.154%	32.17	0.009%
5	Power Supply Disruption	671.08	0.183%	86.49	0.024%
6	Telecom System Disruption	852.20	0.232%	48.57	0.013%
7	Airports Disruption	82.88	0.023%	41.44	0.011%
8	Seaports Disruption	110.56	0.030%	55.28	0.015%
9	Roads Disruption	43.62	0.012%	10.91	0.003%
10	Railroads Disruption	18.35	0.005%	9.17	0.002%
	Total	**21,384.7**	**5.824%**	**4,102.9**	**1.117%**

Simulation Results (cont'd)

Output Losses from Various Sources for QC Earthquake Scenario

	Source of Impact	Total Output Impacts (w/o Resilience) (M $)	% Output Impacts (w/o Resilience)	Total Output Impacts (w/ Resilience) (M $)	% Output Impacts (w/ Resilience)
1	Building Damages	13,996.6	2.237%	5,224.1	0.835%
2	Oil Pipeline Disruption	50.19	0.008%	4.72	0.001%
3	Gas Pipeline Disruption	239.79	0.038%	7.53	0.001%
4	Water Supply Disruption	384.82	0.062%	20.18	0.003%
5	Power Supply Disruption	1,314.85	0.210%	155.88	0.025%
6	Telecom System Disruption	738.43	0.118%	36.23	0.006%
7	Airports Disruption	31.87	0.005%	15.94	0.003%
8	Seaports Disruption	163.41	0.026%	81.71	0.013%
9	Roads Disruption	60.95	0.010%	11.39	0.002%
10	Railroads Disruption	97.15	0.016%	36.30	0.006%
	Total	**17,078.1**	**2.729%**	**5,593.9**	**0.894%**

Sectoral Impacts

- BC Scenario
  - In absolute terms, Finance, Insurance, Real Estate & Rental & Leasing sector is expected to have the highest impact
  - In percentage terms, Other Services sector and Educational Services sector are expected to have the highest impacts

- QC Scenario
  - In absolute terms, Manufacturing sector is expected to have the highest impact
  - In percentage terms, Education Services and Other Services sectors are expected to have the highest impacts

Structural Decomposition Analysis of the Impacts of the two Earthquake Scenarios

- Structural decomposition techniques are widely used to determine the underlying driving factors of the change (or difference) in a variable over time or across regions.
- Apply SDA to better understand the major causes of difference in the impact results of BC and QC scenarios
- Compare relative contributions from various factors, including resilience
- Using gross output impacts from building damage (with resilience adjustment) of the BC and QC scenarios as an example

Comparison of BC and QC Impact Results

Sector		with Resilience		
		BC	QC	Difference
1	Crop & Animal Production	30.00	80.61	-50.6
2	Forestry & Logging	62.69	23.59	39.1
3	Fishing, Hunting & Trapping	1.45	1.23	0.2
4	Support Activities for Agriculture & forestry	8.71	6.33	2.4
5	Mining and Oil & Gas Extraction	20.65	74.79	-54.1
6	Utilities	51.85	99.14	-47.3
7	Construction	196.65	530.80	-334.1
8	Manufacturing	114.32	997.15	-882.8
9	Wholesale Trade	120.66	197.19	-76.5
10	Retail Trade	225.95	309.69	-83.7
11	Transportation & Warehousing and Transportation Margins	849.03	585.08	264.0
12	Information & Cultural Industries	32.05	113.74	-81.7
13	Finance, Insurance, Real Estate & Rental & Leasing	320.31	480.02	-159.7
14	Professional, Scientific & Technical Services	135.27	201.63	-66.4
15	Administrative, Waste Management & Remediation Services	60.15	101.81	-41.7
16	Educational Services	39.50	26.58	12.9
17	Health Care & Social Assistance	228.20	168.41	59.8
18	Arts, Entertainment & Recreation	113.33	84.05	29.3
19	Accommodation & Food Services	333.28	242.58	90.7
20	Other Services (Except Public Administration)	354.60	264.54	90.1
21	Operating, Office, Cafeteria & Laboratory Supplies	52.26	90.88	-38.6
22	Travel, Entertainment, Advertising & Promotion	67.57	118.97	-51.4
23	Non-Profit Institutions Serving Households	87.37	72.65	14.7
24	Government Sector	296.42	352.63	-56.2
	Total	**3,802.29**	**5,224.07**	**-1,421.8**

SDA Formulas

$$\mathbf{x} = \mathbf{x}^{D} + \mathbf{x}^{S} - \mathbf{x}^{direct}$$

$$\mathbf{x} = \mathbf{Lf} + \mathbf{vG} - \mathbf{x}^{direct}$$

$$\mathbf{x}_{\mathbf{r}} = \mathbf{R}(\mathbf{Lf} + \mathbf{vG} - \mathbf{x}^{direct}) = \mathbf{RLf} + \mathbf{R}(\mathbf{vG}) - \mathbf{Rx}^{direct}$$

$$\Delta\mathbf{x}_{r} = (\mathbf{R}_{BC}\mathbf{L}_{BC}\mathbf{f}_{BC} - \mathbf{R}_{QC}\mathbf{L}_{QC}\mathbf{f}_{QC}) + [\mathbf{R}_{BC}(\mathbf{v}_{BC}\mathbf{G}_{BC}) - \mathbf{R}_{QC}(\mathbf{v}_{QC}\mathbf{G}_{QC})]$$
$$- (\mathbf{R}_{BC}\mathbf{x}_{BC}^{direct} - \mathbf{R}_{QC}\mathbf{x}_{QC}^{direct})$$

SDA Formulas

$$\Delta\mathbf{x} = (1/2)[\mathbf{R}_{BC}(\Delta\mathbf{L})\mathbf{f}_{QC} + \mathbf{R}_{QC}(\Delta\mathbf{L})\mathbf{f}_{BC}]$$
$$+ (1/4)(\mathbf{R}_{BC}\mathbf{L}_{BC} + \mathbf{R}_{QC}\mathbf{L}_{QC})(\Delta f)(\mathbf{B}_{BC} + \mathbf{B}_{QC})$$
$$+ (1/4)(\mathbf{R}_{BC}\mathbf{L}_{BC} + \mathbf{R}_{QC}\mathbf{L}_{QC})(f_{BC} + f_{QC})(\Delta\mathbf{B})$$
$$+ (1/2)(\Delta\mathbf{R})(\mathbf{L}_{BC}\mathbf{f}_{BC} + \mathbf{L}_{QC}\mathbf{f}_{QC})$$
$$+ (1/2)[\mathbf{R}_{BC}(\mathbf{v}_{BC}\Delta\mathbf{G}) + \mathbf{R}_{QC}(\mathbf{v}_{QC}\Delta\mathbf{G})]$$
$$+ (1/4)\{\mathbf{R}_{BC}[(\Delta v)(\mathbf{M}_{BC} + \mathbf{M}_{QC})]\mathbf{G}_{QC} + \mathbf{R}_{QC}[(\Delta v)(\mathbf{M}_{BC} + \mathbf{M}_{QC})]\mathbf{G}_{BC}\}$$
$$+ (1/4)\{\mathbf{R}_{BC}[(v_{BC} + v_{QC})(\Delta\mathbf{M})]\mathbf{G}_{QC} + \mathbf{R}_{QC}[(v_{BC} + v_{QC})(\Delta\mathbf{M})]\mathbf{G}_{BC}\}$$
$$+ (1/2)(\Delta\mathbf{R})(\mathbf{v}_{BC}\mathbf{G}_{BC} + \mathbf{v}_{QC}\mathbf{G}_{QC})$$
$$- (1/2)(\mathbf{R}_{BC} + \mathbf{R}_{QC})(\Delta\mathbf{x}^{direct})$$
$$- (1/2)(\Delta\mathbf{R})(\mathbf{x}_{BC}^{direct} + \mathbf{x}_{QC}^{direct})$$

Summary of SDA Results

	With Resilience	
	Level	Percent
Technology Difference	54.36	-4%
Final Demand Reduction Level	756.08	-53%
Final Demand Mix	113.11	-8%
Production Recapture—Demand-Side	-2,059.17	145%
Allocation Difference	28.85	-2%
VA Reduction Level	758.48	-53%
VA Mix	283.47	-20%
Production Recapture—Supply-Side	-2,124.78	149%
Direct Output Loss	-465.96	33%
Production Recapture—Direct Output Loss	1,233.78	-87%
Total	**-1,421.78**	**100%**

Conclusion

- Input-Output approach valid for S-R economic disruptions, if supplemented by resilience adjustments
- The BC earthquake scenario results in $21.4 billion output losses and QC earthquake scenario results in $17.1 billion output losses without resilience
- Resilience can reduce total losses for BC to $4.1 billion and QC to $5.6 billion
- Resilience Metric: Avoided Loss ÷ Max Potential Loss

  BC: $17.3B ÷ $21.4B = 81%

  QC: $11.5B ÷ $17.1B = 67%

Conclusion (cont'd)

- SDA indicates that resilience (production recapture in the building damages case) contributes the largest impacts to the difference in the gross output impact results of BC and QC
  - Shorter repair and reconstruction period in BC than in QC
  - Business capability of production recapture diminishes with length of disruption period
- Final demand and value-added level changes are the second largest contributor to the difference of impact results between the two provinces