Market Research on Michigan's Forest Product Sectors: Contribution, Competitive Advantage and Structural Path Analyses

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In 2013, MI Governor Snyder hosted a Forest Products Industry Summit in which participants helped identify five priorities for the state's forest products industry

1. Increase the industry's economic impact on state and regional economies from $14 billion to $20 billion.

2. Increase its export of value added by 50 percent.

3. Increase its jobs by 10 percent.

4. Support existing industry.

5. Encourage regionally-based industry development.

MI DEPTS OF AGRICULTURE AND RURAL DEVELOPMENT AND NATURAL RESOURCES RFP RE. MI FOREST PRODUCT INDUSTRY

1. Identify past and current
   - supply chain and practices,
   - purchasing trends and market growth

2. Identify future
   - potential new markets and customers
   - predict their growth
   - target opportunities

3. Make recommendations
   - identify the challenges
   - suggest ways to address them

Market Analyses for 27 Forest Product Sectors, U.S. and 50 States : 2007 to 2013

1. Contribution:
   Backward & Forward Linked Output by Sector

2. Competitive Advantage:
   SWOT Analysis bet'n Regions and over Time

3. Structural Paths:
   Supply Chains and Bottlenecks

Contribution:
Backward & Forward Linked Output by Sector

- Goal: To measure the output needed as—
  - a given sector helps other sectors produce their output
    - (forward linked, gross output, across the row), and
  - other sectors help a given sector produce its output
    - (backward linked, base output, down the column)
- Calculate:
  - [type II multiplier matrix] * [exogenous final demand diagonalized matrix]=[output matrix]
- Source: Waters, E. C., B. A. Weber, et al. (1999). "The role of agriculture in Oregon's economic base: Findings from a social accounting matrix." Journal of Agricultural and Resource Economics **24**(1): 266-280.

A Sector's Contributions:
Import Substitution & Export Expansion

- Gross output (forward links measured across the row):
  - A given sector's production used to produce the output of other sectors,
    i.e., <u>keeping</u> money in the region through import substitution.

- Base output (backward links measured down the column):
  - Other sectors' production used to produce the output of a given sector,
    i.e., <u>bringing</u> money into region through export expansion.

- Base and Gross value added:
  - returns to labor, capital, proprietors and government derived using value added to output ratios applied to above output.

Michigan's Output Matrix-- Eight Sectors & One Household: 2013

	Ag	M.U.C	Primary Wood	Secondary Wood	Primary Paper	Secondary Paper	Wood Furniture	Services	HH	Gross Output
Ag.	**4,666**	3,914	109	13	70	5	13	221	495	9,505
M.U.C	465	**330,938**	76	51	410	228	263	9,693	16,898	359,023
Primary Wood	2	269	**681**	32	33	1	48	43	56	1,167
Secondary Wood	2	312	3	**476**	16	1	19	62	88	978
Primary Paper	1	127	0	0	**2,195**	65	1	25	40	2,454
Secondary Paper	2	621	1	1	23	**2,304**	8	81	134	3,175
Wood Furniture	1	130	0	1	1	0	**2,182**	50	102	2,467
Services	2,098	135,015	427	313	1,257	1,073	1,383	**205,469**	166,695	513,729
Base Output	7,236	471,326	1,296	887	4,005	3,678	3,918	215,643	184,508	892,497
Net contribution	Keeping	Bringing	≈Equal	≈Equal	Bringing	Bringing	Bringing	Keeping	Bringing	

Michigan's Ten Important Forest Products Sectors: 2012

Sector ID and Label	Base Employ.	Gross Employ.	Base TVA	Gross TVA	Net Contribution
Michigan--Forest Products Total ($, millions)	75,058	54,614	$7,740	$5,690	Bring
1 Office Furniture	26,077	12,303	2,895	1,914	Bring
2 Paper mills	8,621	2,512	1,290	*909	Bring
3 Institutional furniture manufacturing	5,004	2,046	586	353	Bring
4 Showcase, partition, shelving, locker mfg.	5,866	2,802	583	*333	Bring
5 Paperboard container manufacturing	5,365	5,746	*497	577	≈Equal
6 Paperboard Mills	3,398	896	409	*242	Bring
7 Sawmills and wood preservation	1,779	2,199	100	*101	≈Equal
8 Veneer and plywood manufacturing	1,299	1,068	88	*75	≈Equal
9 Commercial logging	2,029	3,180	81	*79	≈Equal
10 Wood container and pallet manufacturing	1,225	2,071	73	98	Keep

* Key role suggested by supply chain

Competitive Advantage:
SWOT Analysis bet'n Regions and over Time

- If firms in a sector are increasing their competitive advantage, then
  - the entire sector's marginal contribution to value added in the economy increases.
  - A sector's increase in value added is measurable as an increasing share of value added.
  - The relative shares for a sector will change over time and between regions—a measure of changing competitive adv.

Competitive Advantage:
SWOT Analysis bet'n Regions and over Time

- Measuring a sector's change in competitive advantage-- over time:

$$\Delta \varepsilon_{\underbrace{N_{11}/N_{01}}_{\text{time 1}} - \underbrace{N_{10}/N_{00}}_{\text{time 0}}} = \frac{1}{2}\left(\frac{W_{i11}}{W_{11}} + \frac{W_{i01}}{W_{01}}\right) + \left(\frac{W_{i11}}{W_{11}} - \frac{W_{i01}}{W_{01}}\right) - \left(\frac{1}{2}\left(\frac{W_{i10}}{W_{10}} + \frac{W_{i00}}{W_{00}}\right) + \left(\frac{W_{i10}}{W_{10}} - \frac{W_{i00}}{W_{00}}\right)\right)$$

- between regions:

$$\Delta \varepsilon_{\underbrace{\overline{W}_{11}/\overline{W}_{10}}_{\text{region 1}} - \underbrace{\overline{W}_{01}/\overline{W}_{00}}_{\text{region 0}}} = \frac{1}{2}\left(\frac{W_{i11}}{W_{11}} + \frac{W_{i10}}{W_{10}}\right) + \left(\frac{W_{i11}}{W_{11}} - \frac{W_{i10}}{W_{10}}\right) - \left(\frac{1}{2}\left(\frac{W_{i01}}{W_{01}} + \frac{W_{i00}}{W_{00}}\right) + \left(\frac{W_{i01}}{W_{01}} - \frac{W_{i00}}{W_{00}}\right)\right)$$

- Source: Cooke, S. C. and B. A. Kulandaisamy (2010). "Wage Divergence between the Rocky Mountain States and the U.S.: Idaho Measures and Sources, 2001 to 2009." <u>The Review of Regional Studies</u> **40**(1): 99-124.
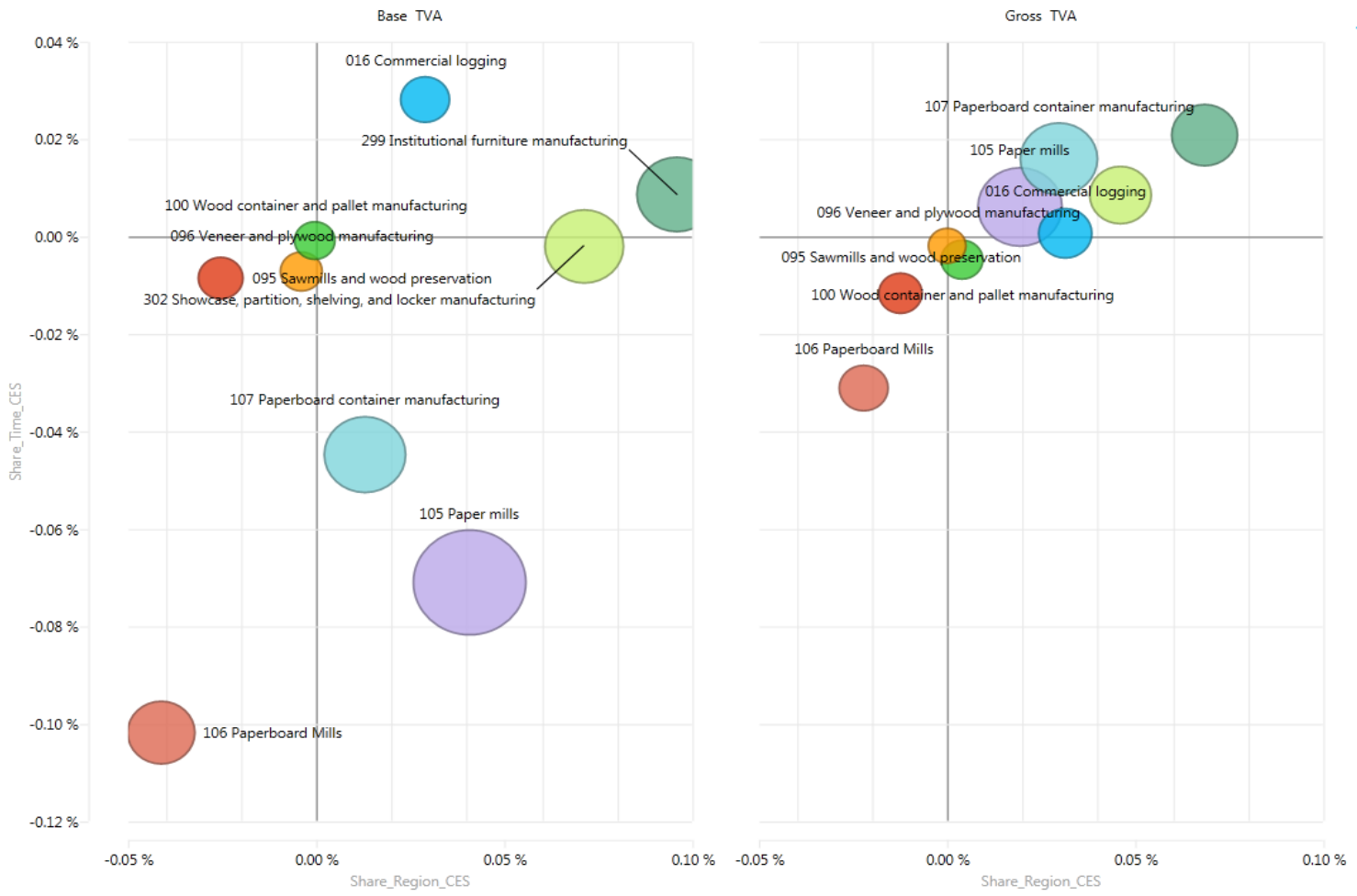
MI Forest Products: Avg. Wage for Important Sectors, 2013
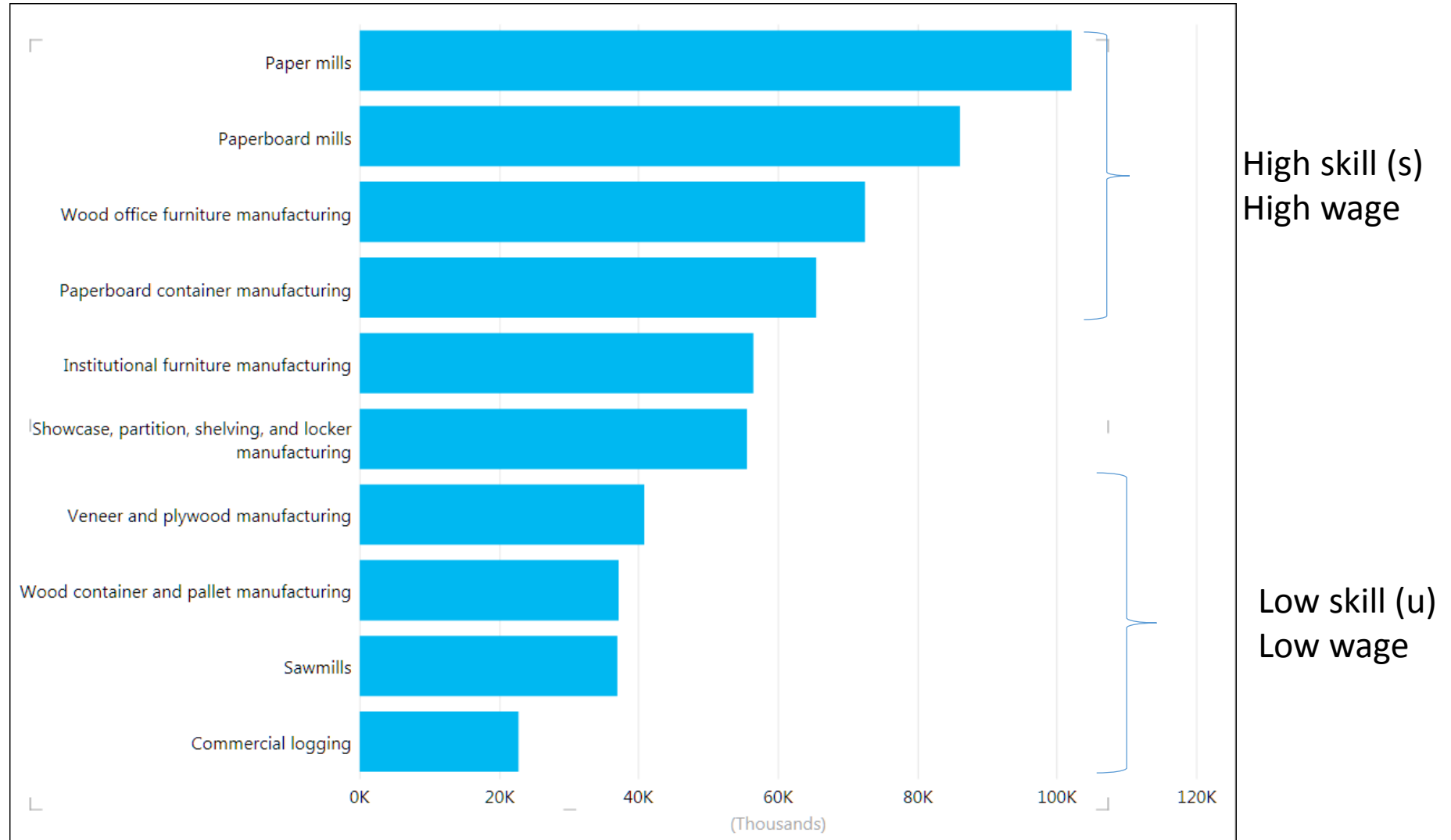
SWOT Analysis—2011-2013 Michigan's Forest Products Competitive Advantage compared to 2007 (y-axis) and U.S. (x-axis)
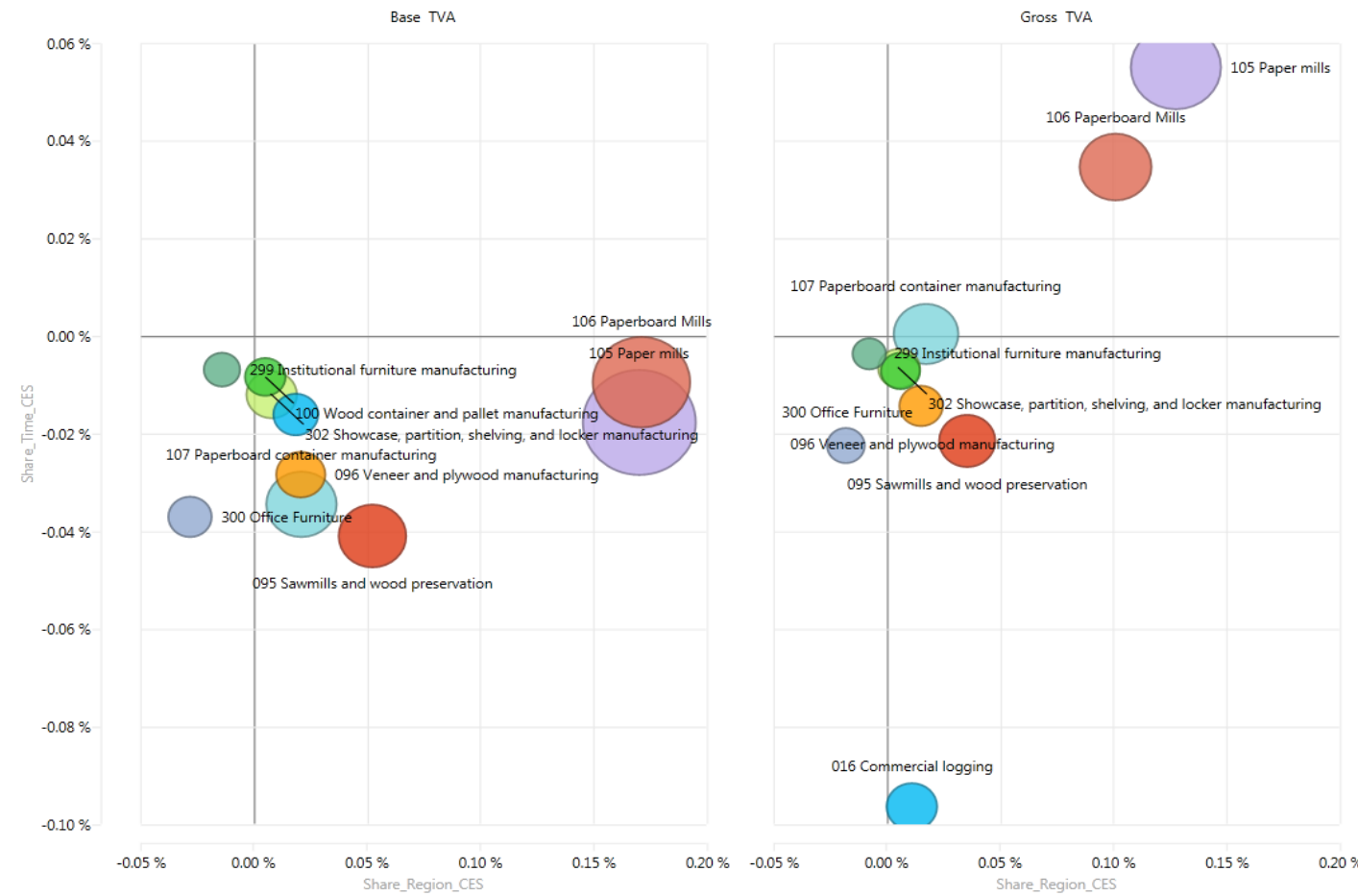
SWOT Analysis—2011-2013 Michigan's Forest Products Competitive Advantage compared to 2007 (y-axis) and U.S. (x-axis), (without office furniture)

SWOT Analysis—2011-2013 Great Lake State's Forest Products Competitive Advantage compared to 2007 (y-axis) and U.S. (x-axis), (without office furniture)

SWOT Analysis—2011-2013 Southeast State's Forest Products Competitive Advantage compared to 2007 (y-axis) and U.S. (x-axis)

SWOT Analysis—2011-2013 East-of-the-Mississippi State's Forest Products Competitive Advantage compared to 2007 (y-axis) and U.S. (x-axis)

Structural Paths:
Supply Chains and Bottlenecks

- Goal:
  - To identify sectors that may create bottlenecks to expanding forest product production.

- Calculate:
  - the cofactors of the induced effect multiplier reveal the supply chains within an economy,
  - To display the forest prod. supply chains as a set of networks with nodes and edges,
  - To measure bottlenecks as betw'ness centrality.

Structural Paths:
Supply Chains and Bottlenecks: A Slow Motion Inversion of an Induced Effect $(a_{3,1})$
Multiplier within a Symbolic 3x3 Matrix Closed with Household Spending

$$A := \begin{bmatrix} a_{1,1} & a_{1,2} & a_{1,3} \\ a_{2,1} & a_{2,2} & a_{2,3} \\ a_{3,1} & a_{3,2} & a_{3,3} \end{bmatrix}$$

$$IminusA := \begin{bmatrix} 1-a_{1,1} & -a_{1,2} & -a_{1,3} \\ -a_{2,1} & 1-a_{2,2} & -a_{2,3} \\ -a_{3,1} & -a_{3,2} & 1-a_{3,3} \end{bmatrix}$$

$$IminusA\_Trans := \begin{bmatrix} 1-a_{1,1} & -a_{2,1} & -a_{3,1} \\ -a_{1,2} & 1-a_{2,2} & -a_{3,2} \\ -a_{1,3} & -a_{2,3} & 1-a_{3,3} \end{bmatrix}$$

$$Adjoint\_Cofactor\_31 = \left(-1^{i+j}\right)\left(a_{32}a_{21} + a_{31}(1-a_{22})\right)$$

$$Inverse\_IminusA\_Mult\_31 = Adj\_Cofactor\_31 / Det\_D$$

$$Inverse\_IminusA\_Mult\_31 = \underbrace{a_{32}a_{21}}_{direct\_path}\underbrace{\left(\frac{1}{Det\_D}\right) + a_{31}\left(\frac{1-a_{22}}{Det\_D}\right)}_{path\_multiplier}$$

$$\begin{aligned} Det\_D := &-a_{1,1}a_{2,2}a_{3,3} + a_{1,1}a_{2,3}a_{3,2} \\ &+ a_{1,2}a_{2,1}a_{3,3} - a_{1,2}a_{2,3}a_{3,1} \\ &- a_{1,3}a_{2,1}a_{3,2} + a_{1,3}a_{2,2}a_{3,1} \\ &+ a_{1,1}a_{2,2} + a_{1,1}a_{3,3} - a_{1,2}a_{2,1} \\ &- a_{1,3}a_{3,1} + a_{2,2}a_{3,3} - a_{2,3}a_{3,2} \\ &- a_{1,1} - a_{2,2} - a_{3,3} + 1 \end{aligned}$$

Defourny, Jacques and Erik Thorbecke. "Structural Path Analysis and Multiplier Decomposition within a Social Accounting Matrix Framework." *The Economic Journal* 94, no. 373 (1984): 111-136.

Structural Paths:
Supply Chains and Bottlenecks: Income Flows from Office Furniture Sector (OFF) to Low Income Households (HH_L): MI, 2013

origin	destin	global	nodes of the path	edge wt. (%)
OFFF.	HH_L.	0.0904	OFF. LABR. HH_L.	62.79
			OFF. WHOL. LABR. HH_L.	3.23
			OFF. PROF. LABR. HH_L.	2.76
			OFF. MANG. LABR. HH_L.	1.53
			OFF. FINI. LABR. HH_L.	1.12
			OFF. TRAN. LABR. HH_L.	1.12
			OFF. PRPR. HH_L.	1.06
			OFF. RETL. LABR. HH_L.	1.05
			OFF. MANU. LABR. HH_L.	1.02
			OFF. LABR. HH_H. HH_L.	0.92

Structural Paths:
Supply Chains and Bottlenecks: MI Forest Products: 2013

Destination→ *Source↓	Saw Mills	Pallets	Veneer	Paper Mills	Office Furniture	Instit'l Furniture	Paper board Containers
Logging	X	X	X	X			
Saw Mills	--	X			X	X	
Pallets		--		X			
Veneer			--		X		
Shelving					X		
Paper Mills				--			X
Paperboard Mills							X

*The source sector's output is used as an input to make the destination sector's output.
Source: Oshita, Y. and Y. Kikuchi. Flow Analysis on Products of Agriculture, Forestry, Fisheries Industry using Structural Path Analysis., IIOA, Lisbon, Portugal, 2014.

Algorithm for Betweenness Centrality:
Number of shortest paths joining two nonadjacent nodes w/ & w/o "b"
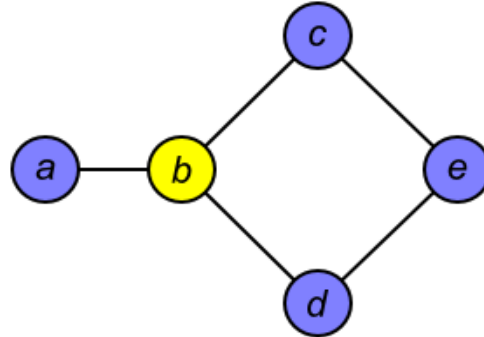
$$C_b(b) = \left[\left(\sigma_{ac}(b)/\sigma_{ac} \right) + \left(\sigma_{ad}(b)/\sigma_{ad} \right) + \left(\sigma_{ae}(b)/\sigma_{ae} \right) + \left(\sigma_{cd}(b)/\sigma_{cd} \right) + \left(\sigma_{ce}(b)/\sigma_{ce} \right) + \left(\sigma_{de}(b)/\sigma_{de} \right) \right] / N'_{s \neq n \neq t}$$

$$= \left[(1/1) \quad\quad + (1/1) \quad\quad + (2/2) \quad\quad + (1/2) \quad\quad + 0 \quad\quad + 0 \right] / 6$$

$$= 3.5/6 = 0.583$$

$$\text{where} \quad N'_{s \neq n \neq t} = \frac{(N-1)(N-2)}{2} = \frac{(5-1)(5-2)}{2} = 6$$

Source: Oshita, Y. "Identifying critical supply chain paths that drive changes in CO2 emissions." Energy Economics **34**(4): 1041-1050.

MI Network of Structural Paths for Top Ten Forest Products Sectors, Ranked Clockwise by Betweenness Centrality: 2013

	18 Backward-Linked Base Sectors
119 Oser	Other services
120 HH_H	High Income household
121 Mang	Management of companies
122 Admn	Administrative & waste services
123 Govt	Government & non NAICs
124 Ent	Government enterprise
125 Cons	Construction
126 HH_L	Low income households
127 Pbox	Paperboard container manufacturing
128 Acco	Accommodation & food services
129 Info	Information
130 Retl	Retail trade
131 Inst	Institutional furniture manufacturing
132 Offf	Wood office furniture manufacturing
133 Slog	Support activities for agriculture and forestry
134 Flog	Forestry, forest products, and timber tract production
135 Recw	Reconstituted wood product manufacturing
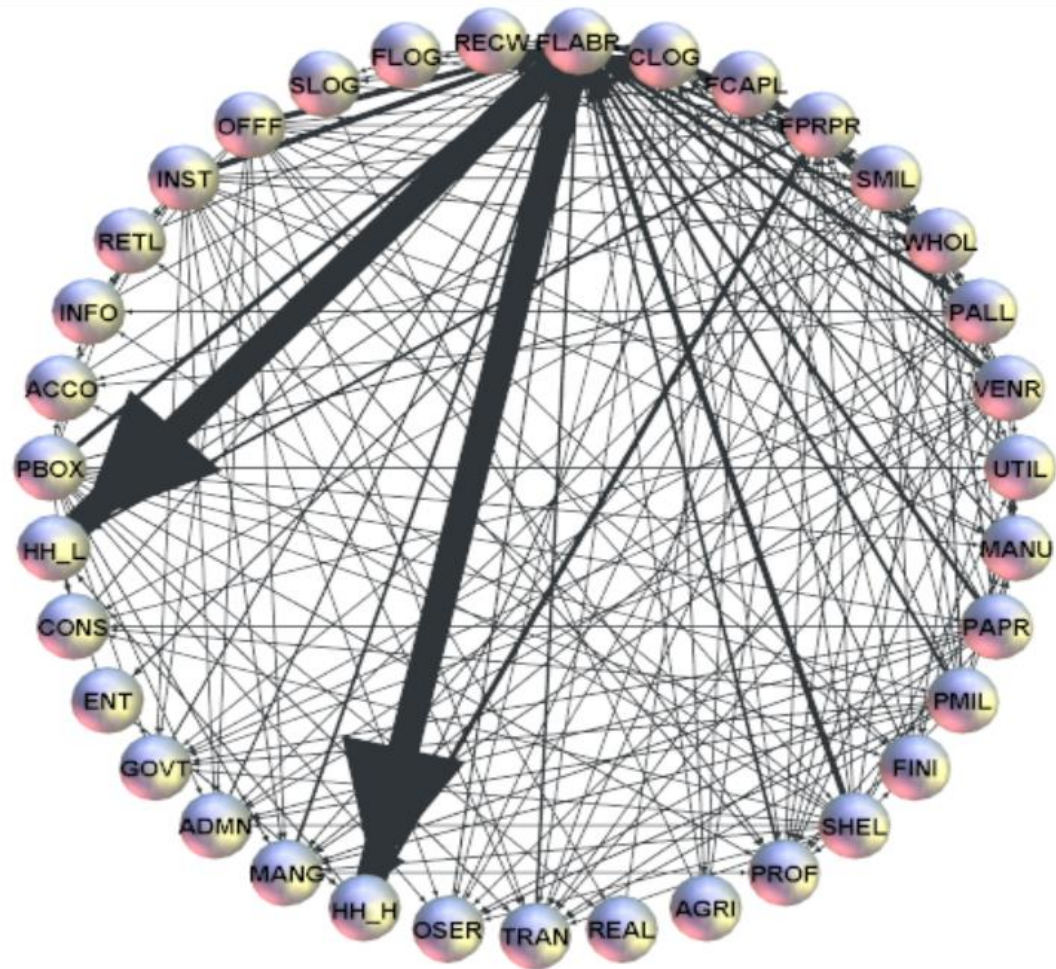
	18 Forward-Linked Gross Sectors
101 Labr	Labor
102 Clog	Commercial logging
103 Capl	Other Property Type Income
104 Prpr	Proprietor Income
105 Smil	Sawmills
106 Whol	Wholesale Trade
107 Pall	Wood container and pallet manufacturing
108 Venr	Veneer and plywood manufacturing
109 Util	Utilities
110 Manu	Manufacturing
111 Papr	Paper mills *
112 Pmil	Paperboard mills
113 Fini	Finance & insurance
114 Shel	Showcase, partition, shelving, and locker manufacturing *
115 Prof	Professional- scientific & tech svcs
116 Agri	Ag, Forestry, Fish & Hunting
117 Real	Real estate & rental
118 Tran	Transportation & Warehousing

Michigan Forest Products "Betweenness" Rank out of 35:
(A Low Number Implies Greater Betweenness, i.e., potential bottleneck in local production)

2013 Betweenness	Rank	2012 Betweenness	Rank	2007 Betweenness	Rank
Logging	2	Logging	3	Logging	3
Saw Mills	5	Saw Mills	5	Saw Mills	4
Pallets	7	Pallets	9	Reconstituted	16
Veneer	8	Veneer	10	Veneer	9
Paper Mills	11	Paper Mills	7	Paper Mills	7
Paperboard Mills	12	Paperboard Mills	6	Paperboard Mills	6
Shelving	14	Forestry	11	Forestry	10

Summary and Conclusions:
Roles of Top Ten MI Forest Product Sectors

- Four significant forward-linked import-substituting sectors:
  logging, sawmills, pallets and veneer mfg.

- Three both important backward-linked export-expanding &
  significant forward-linked import-substituting sectors:
  paper mills, paperboard mills, shelving.

- Three important backward-linked export-expanding sectors :
  **office and institutional furniture,
  paperboard container manuf.**

- The only MI forest product sector w/ strong growth
  in competitive advantage both over time and among regions:
  office furniture.