

Unraveling the Internal Complexity of a Metropolitan Economy

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Why is the Internal Structure Important?

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- **City-Suburb Tensions:** “We do not need the city” – a comment often made by suburban mayors – how economically integrated is the internal structure of a metropolitan economy?
- **Inequality and Development:** Most US cities characterized by significant degree of inequality; in Chicago, a development organization, Chicago United, asked us to explore the impacts of development on the South side of Chicago: are there spillovers on the rest of the metropolitan economy?
- **Multi-level Analysis:** Fiscal federalism has promoted the idea of devolution of responsibility for the provision of public goods to lower tiers of government so people can “vote with their feet” – but is this always optimal at the metropolitan level?

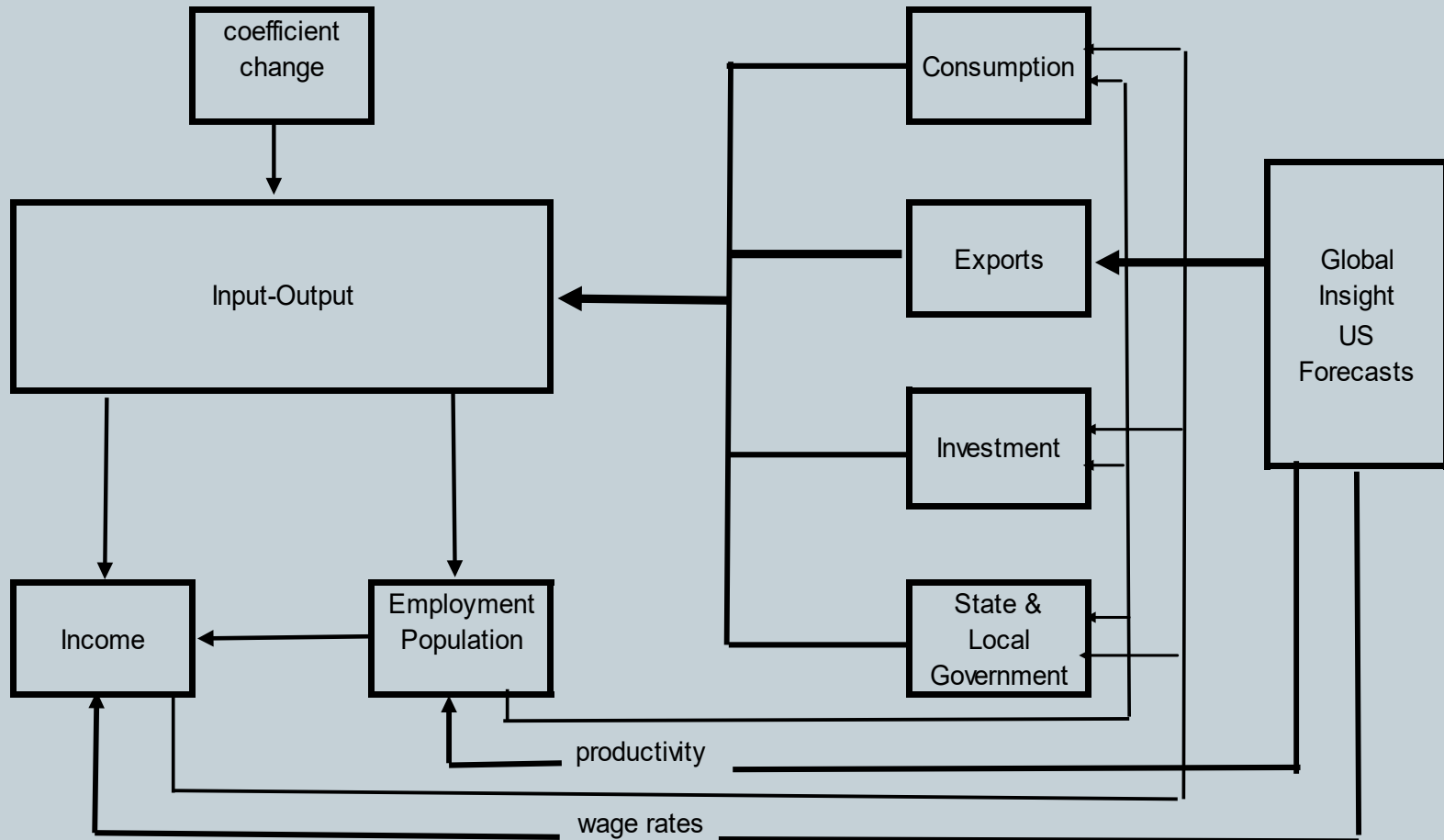
The Modeling System I

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- The Region Econometric Input-output Model [REIM] generates forecasts of an economy on an annual basis, with the forecast horizon extending up to 25 years (currently to 2050).
- The model is comprised of two major components, an input-output module and an econometric module
- **Chicago model is a system of linear and nonlinear equations formulated to predict the behavior of 251 endogenous variables, and consists of 223 behavioral equations, 28 accounting identities, and 68 exogenous variables.**
- **REIM identifies 45 industries and two government sectors.**
- **For each industry, there are forecasts of output, employment, and earnings.**
- **Of 250 equations, only 47 relate to the linear input-output components.**
- Other variables depicted by the model are:
 - gross regional product, personal consumption expenditures, investment, state and local government expenditures, exports,
 - labor force, unemployment rate, personal income, net migration, population (by cohort), and the consumer price index.
 - The input-output module was constructed from establishment-level data obtained from the U.S. Bureau of the Census, but is endogenously updated each year

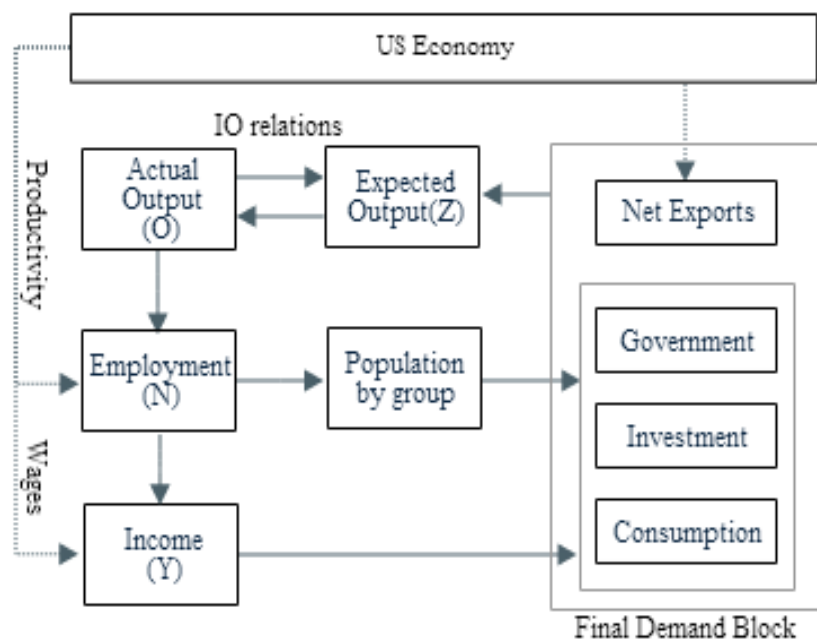
The Modeling System II

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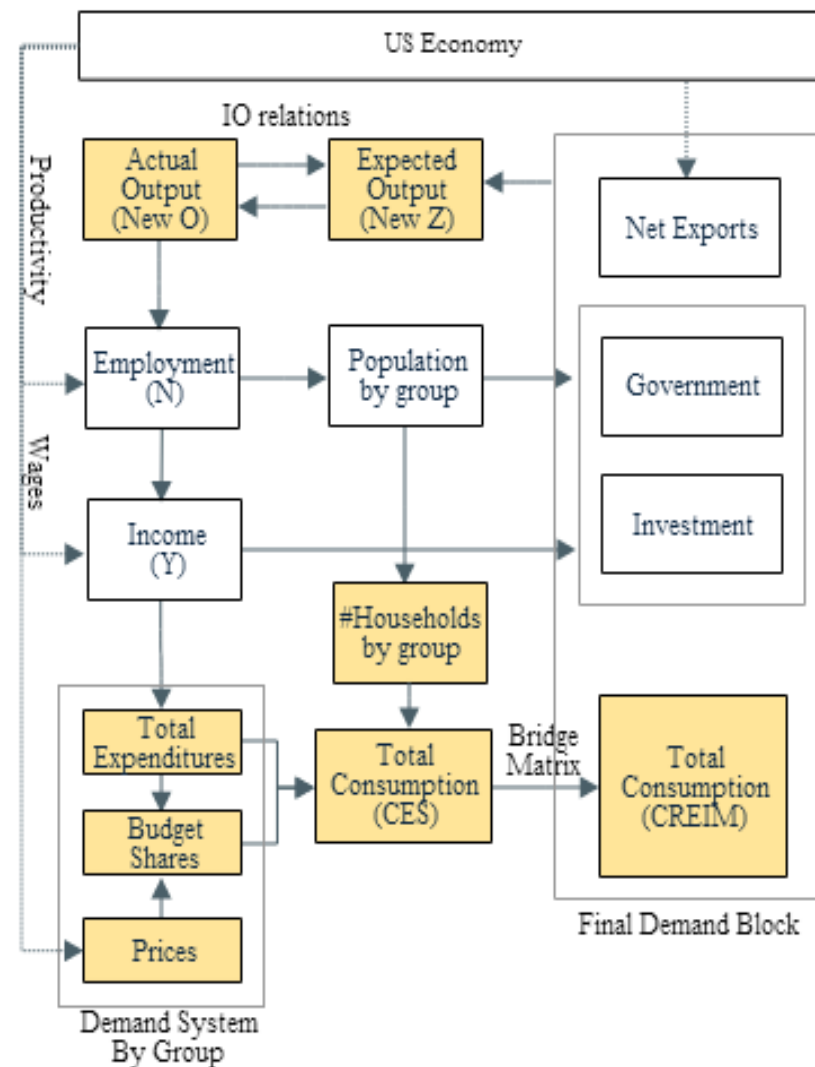


The Modeling System III: Household Disaggregation

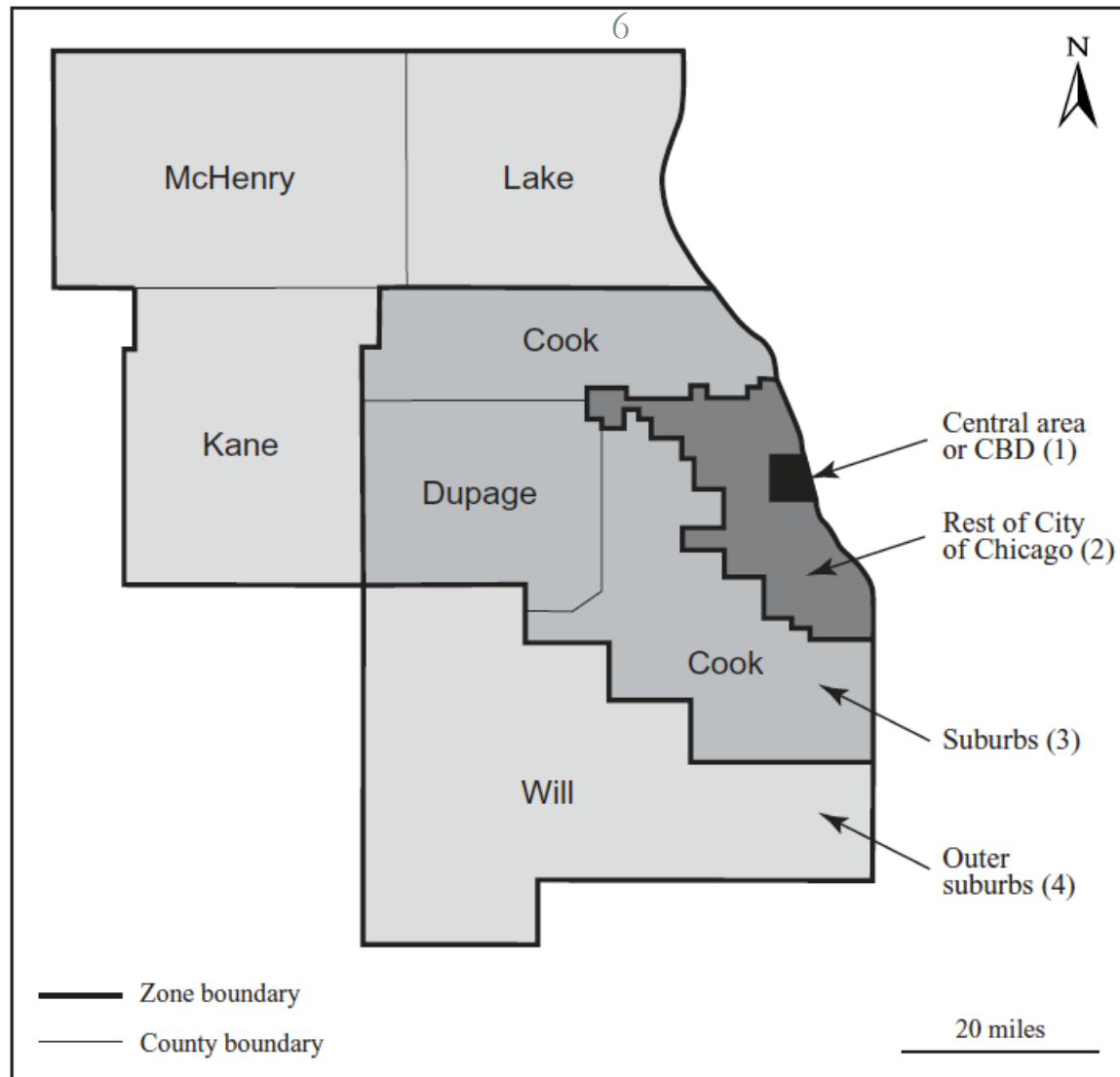
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Disaggregation:
Spatially
By income level
By age



Spatial Division of Chicago



Chicago Intra Metropolitan Flows

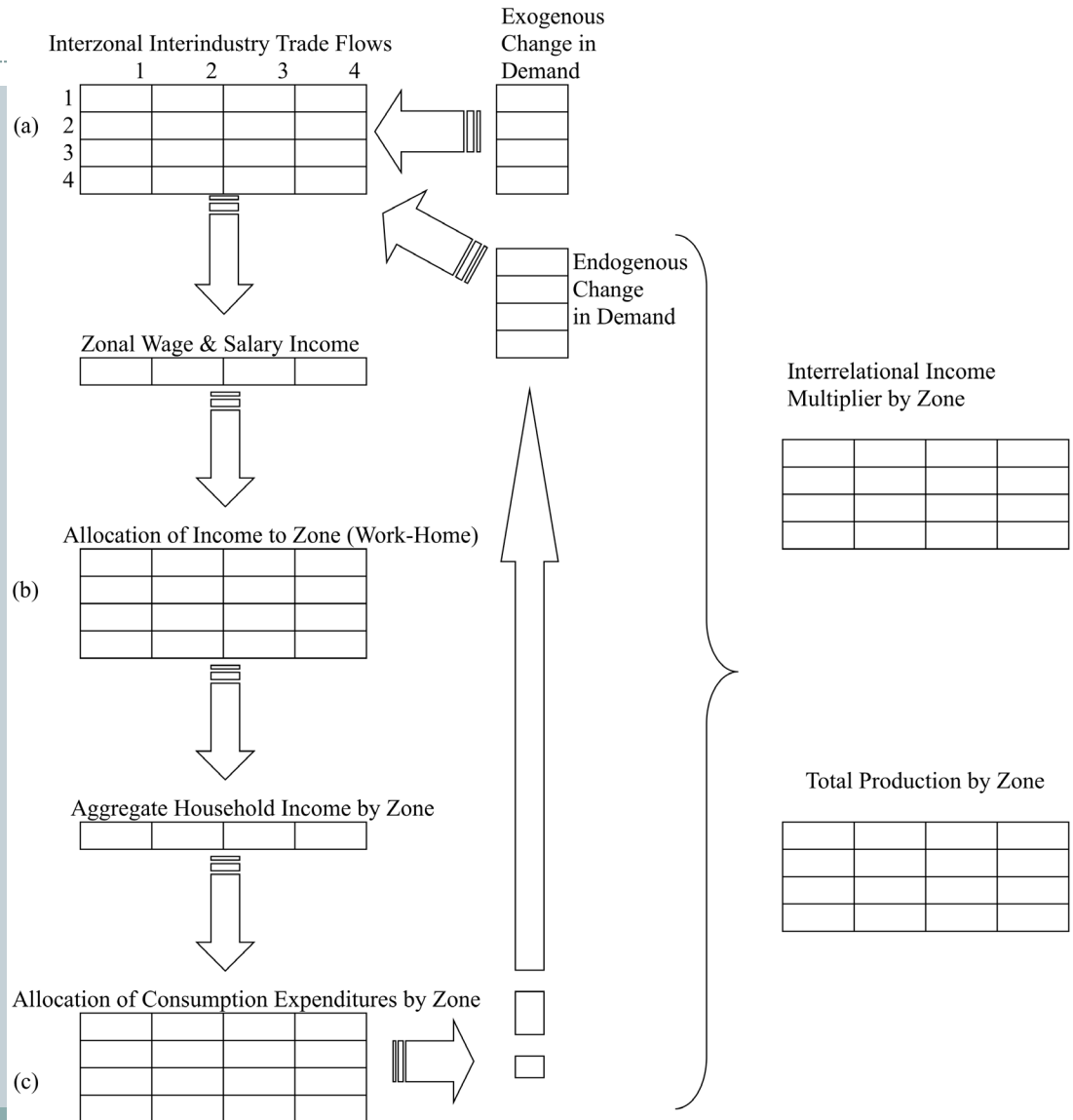
Goods and Services
Flows

Wages and salaries

Flows of commuters and
their incomes by zone

Household expenditures

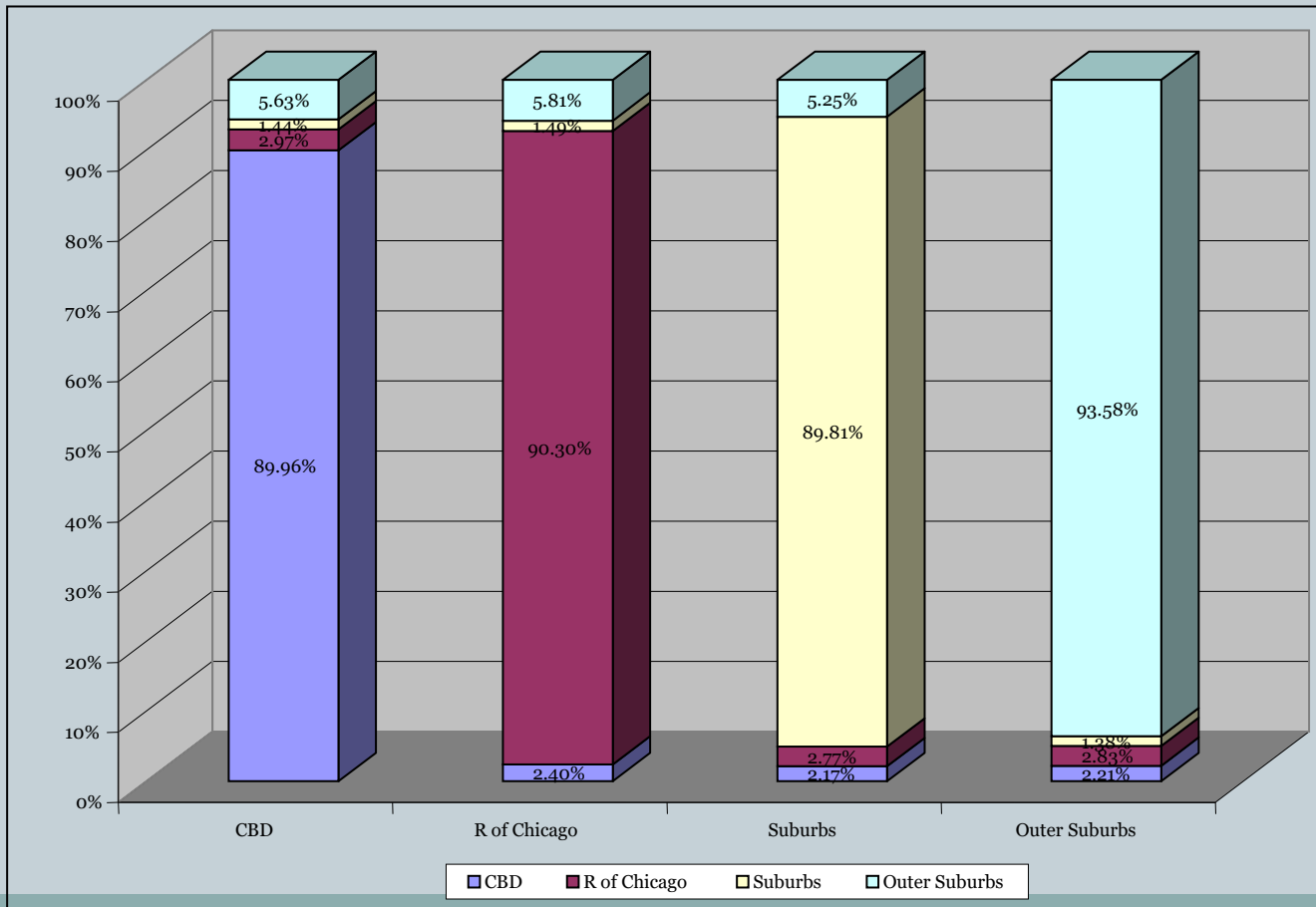
Flows of total
expenditures by zone



Interindustry Interdependence

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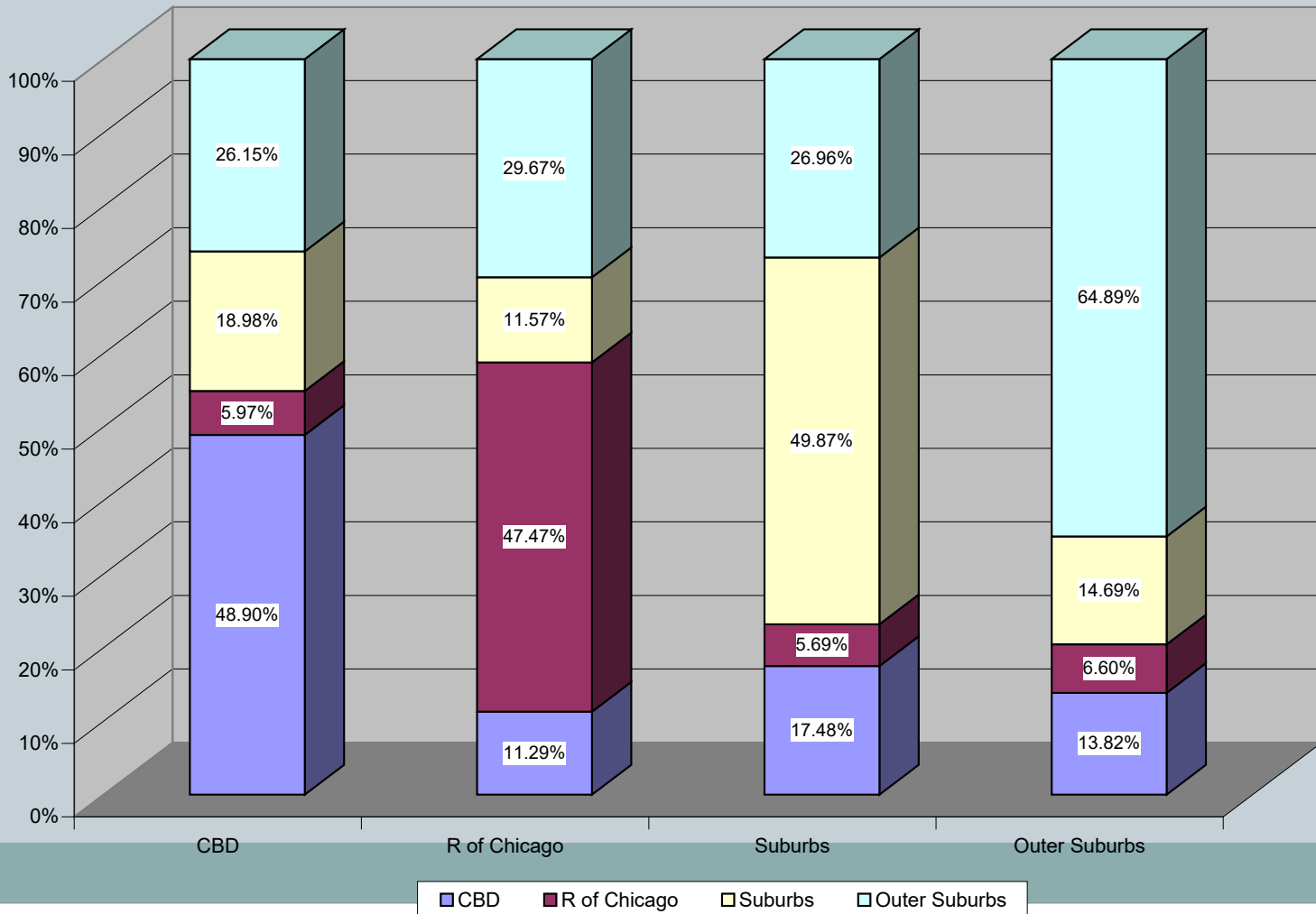
- Limited connections across regions



Total Spatial Interdependence

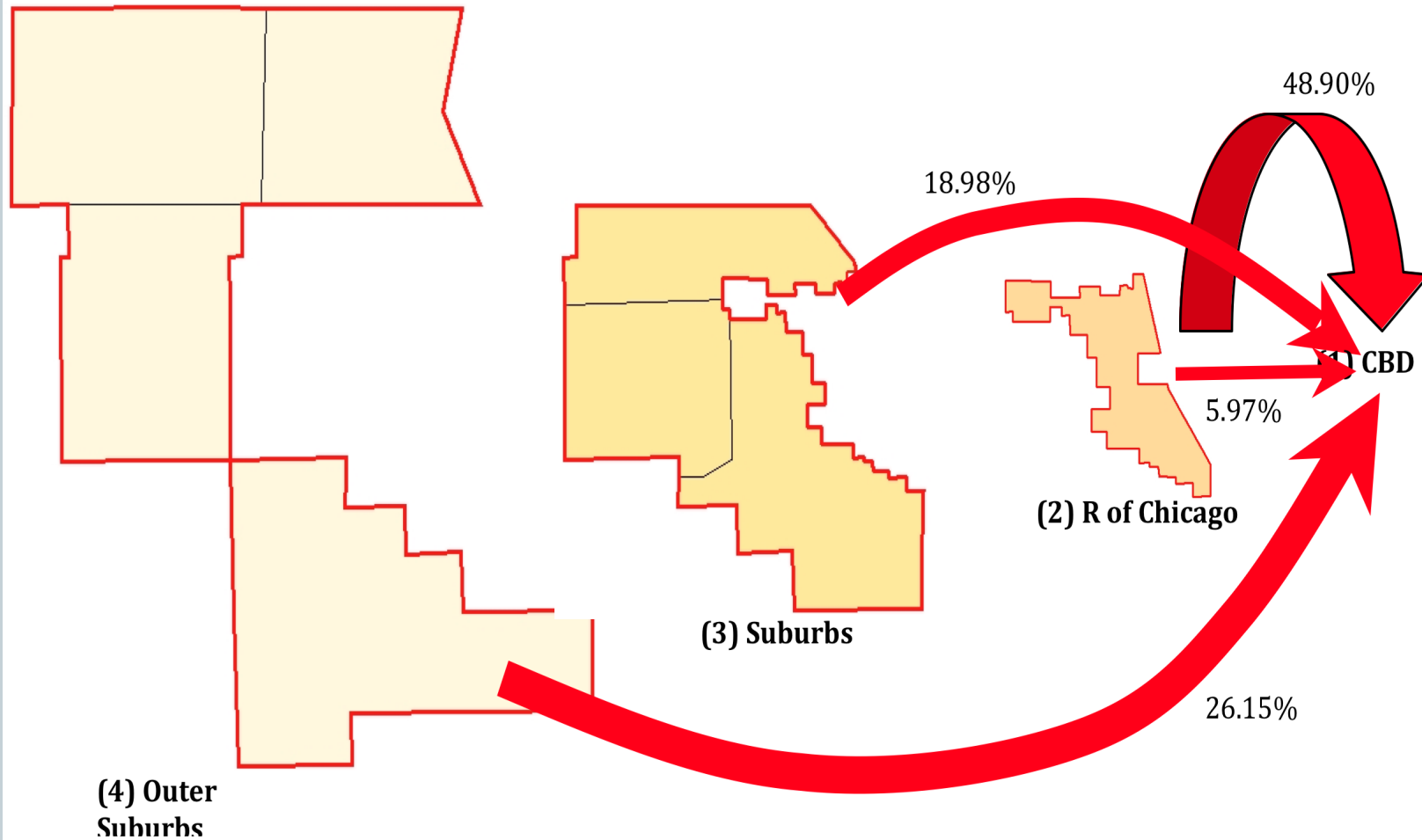
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- Substantial interdependence when all interactions considered



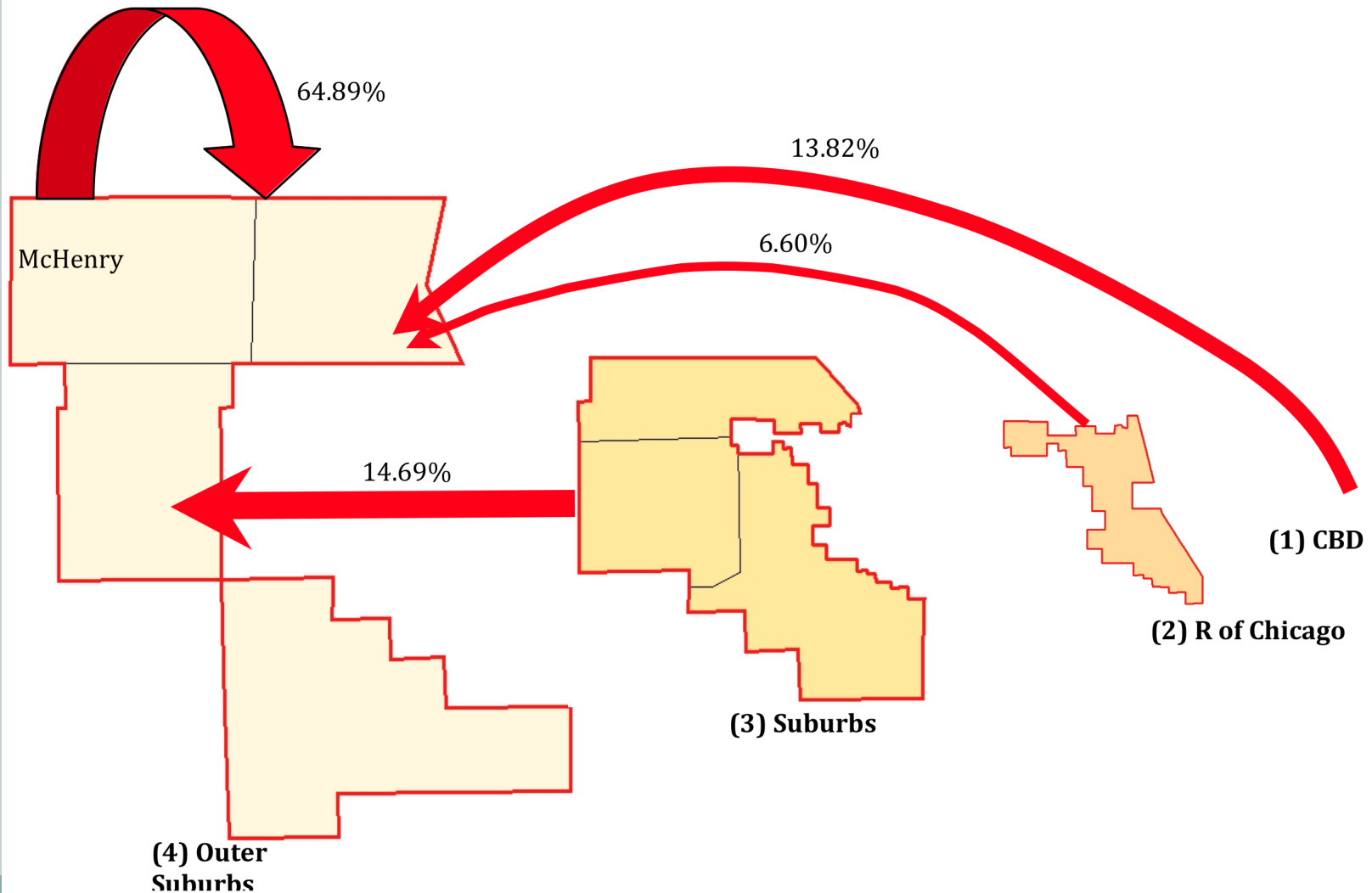
Interzonal Impacts as Percentage of Total Impacts: CBD

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Interzonal Impacts as Percentage of Total Impacts: Outer Suburbs

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Changes in the Nature of Dependence as Complication Increases

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- **Layer 1**
 - Intrazonal flows dominate the production relationships in the assembly of \$479 billion worth of goods and services.
 - Somewhere between 90% and 94% of the direct and indirect effects of trade remain within the zone
- **Layer 4**
 - With the exception of zone 4, less than 50% of the total production impacts can be traced, directly and indirectly, to activity that is generated within the zone
 - Almost 14% of the impact in zone 4 (outer suburbs) can be traced to zone 1 (the central area or CBD) with a further 6% traced to zone 2 (rest of the City of Chicago)
- About 45-48% of the total impacts derived from income-consumption impacts

Extended Demo-Economic Modeling

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- One of the most important contributions of Miyazawa (1976) was his analysis of the structure of income.
- Parallel development to the demo-economic models of Batey and Madden
- Example of an “onion-skin” approach to demographic-economic (hereafter, demo-economic) impact analysis
- Link the demographic and economic parts of an economy, revealing the effects of:
 - changes in economic actions on income distribution, status in the labor force or migration behavior on the one hand and
 - the effects of changes in consumption spending, employment status and so forth on economic activities.

Extended Demo-Economic Modeling (2)

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- Miyazawa considered the following block matrix:

$$M = \left(\begin{array}{c|c} A & C \\ \hline V & 0 \end{array} \right)$$

where A is a block matrix of direct input coefficients, V is a matrix of value-added ratios for some r -fold division of labor and non-labor categories and C is a corresponding matrix of consumption coefficients for the r -types of households.

In the open IO model only focus on A

Extended Demo-Economic Modeling (3)

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- Decomposing the Miyazawa matrix, M , yields:

$$\begin{aligned}(I - M)^{-1} &= \left(\begin{array}{c|c} I & BC \\ \hline 0 & I \end{array} \right) \left(\begin{array}{c|c} I & 0 \\ \hline 0 & K \end{array} \right) \left(\begin{array}{c|c} B & 0 \\ \hline VB & I \end{array} \right) = \\ &= \left(\begin{array}{c|c} \frac{B(I + CKVB)}{KVB} & BCK \\ \hline & K \end{array} \right)\end{aligned}$$

Where $B = (I - A)^{-1}$ is the Leontief inverse matrix

BC is a matrix of production induced by **endogenous** consumption

VB is a matrix of **endogenous** income earned from production

$L = VBK$ is a matrix of expenditures from endogenous income

Extended Demo-Economic Modeling (4)

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- The most important component:

$$K = (I - L)^{-1} = (I - VBC)^{-1}$$

is the **Miyazawa interrelational income multiplier** or the generalized Keynesian multiplier

- Traces how income earned in one region or by one group generates income to other regions or groups
- Is it symmetrical or asymmetrical – impact of income generated by region R on region S may be larger/smaller than the impact of S on R ?

Application to Chicago

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- In this climate, inner city development is often seen as a zero-sum game, providing little demonstrable benefit to parts of the metropolitan region outside the targeted areas and commanding public resources with high opportunity costs that might be more effectively directed to other parts of the region.
- **Yet, if there are gains from trade and interdependence in general between nations or between regions within a nation, should there not be some expectation of similar findings within a metropolitan region?**
- Chicago analysis attempted to develop an understanding and appreciation of the magnitudes of the economic relationships and economic interdependence between inner-city communities and the rest of the metropolitan area

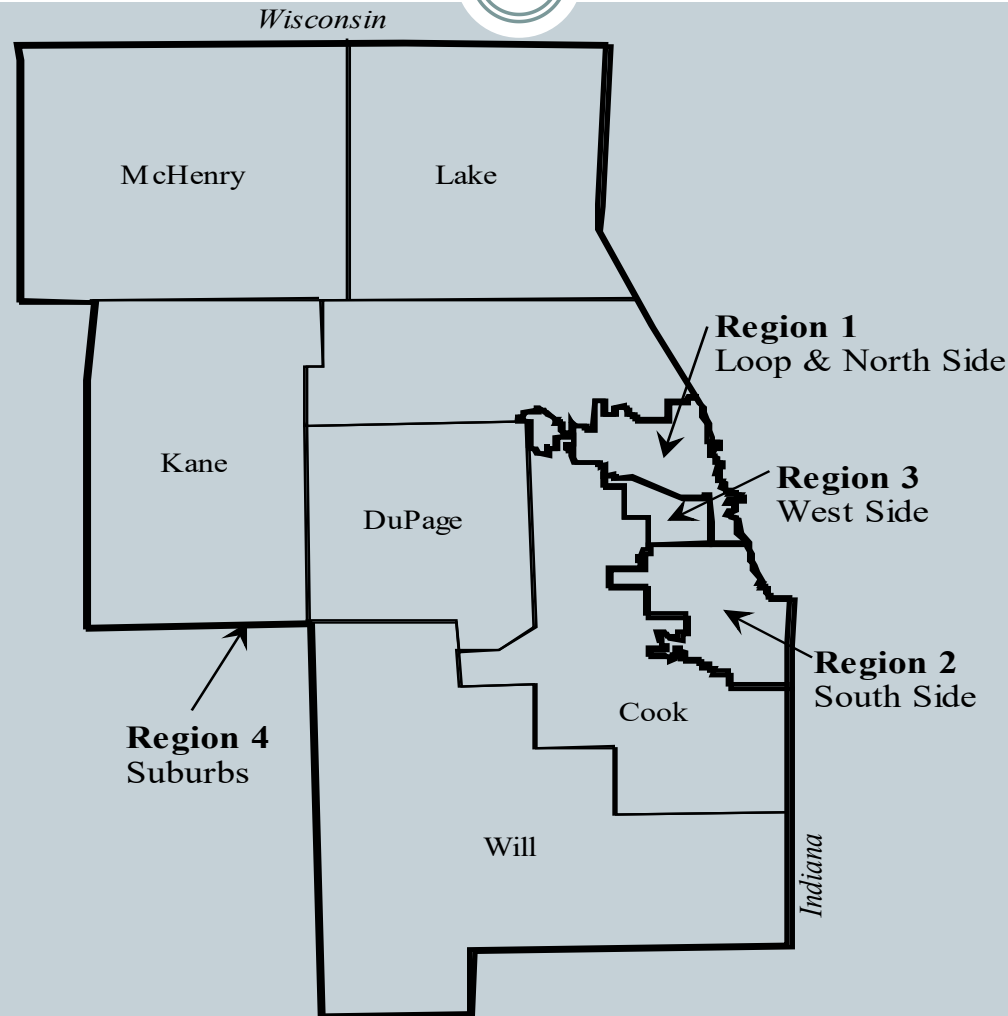
Application to Chicago (3)

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- Unlike trade between nations, this interdependence depends not only on:
 - the **movement of goods and services** but also on the:
 - ✦ **movement of labor**, i.e., commuting and the
 - ✦ associated **income flows** (income earned in one part of the city is taken home to another part) and the
 - ✦ movement of consumers in the **spending of this income**
- In order to illustrate the complex interdependencies within a metropolitan area a 4-region multiregional input-output model was constructed using Miyazawa's (1976) extended framework.

Divisions of the Chicago Metropolitan Region

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Unexpected Result: The Miyazawa Interrelational Income Multiplier

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Miyazawa's Interrelational Income Multipliers

	region of income origin			
	Region 1	Region 2	Region 3	Region 4
Region 1	1.23	0.12	0.16	0.07
Region 2	0.11	1.28	0.13	0.05
Region 3	0.03	0.03	1.06	0.01
Region 4	0.44	0.56	0.50	1.77
Total	1.81	1.99	1.85	1.90

- Region 2 – least prosperous but generated largest income multiplier (theory suggests that *apc* higher for lower income households)
- Significant asymmetric spillovers – suburbs benefit more from income growth in other regions than vice versa

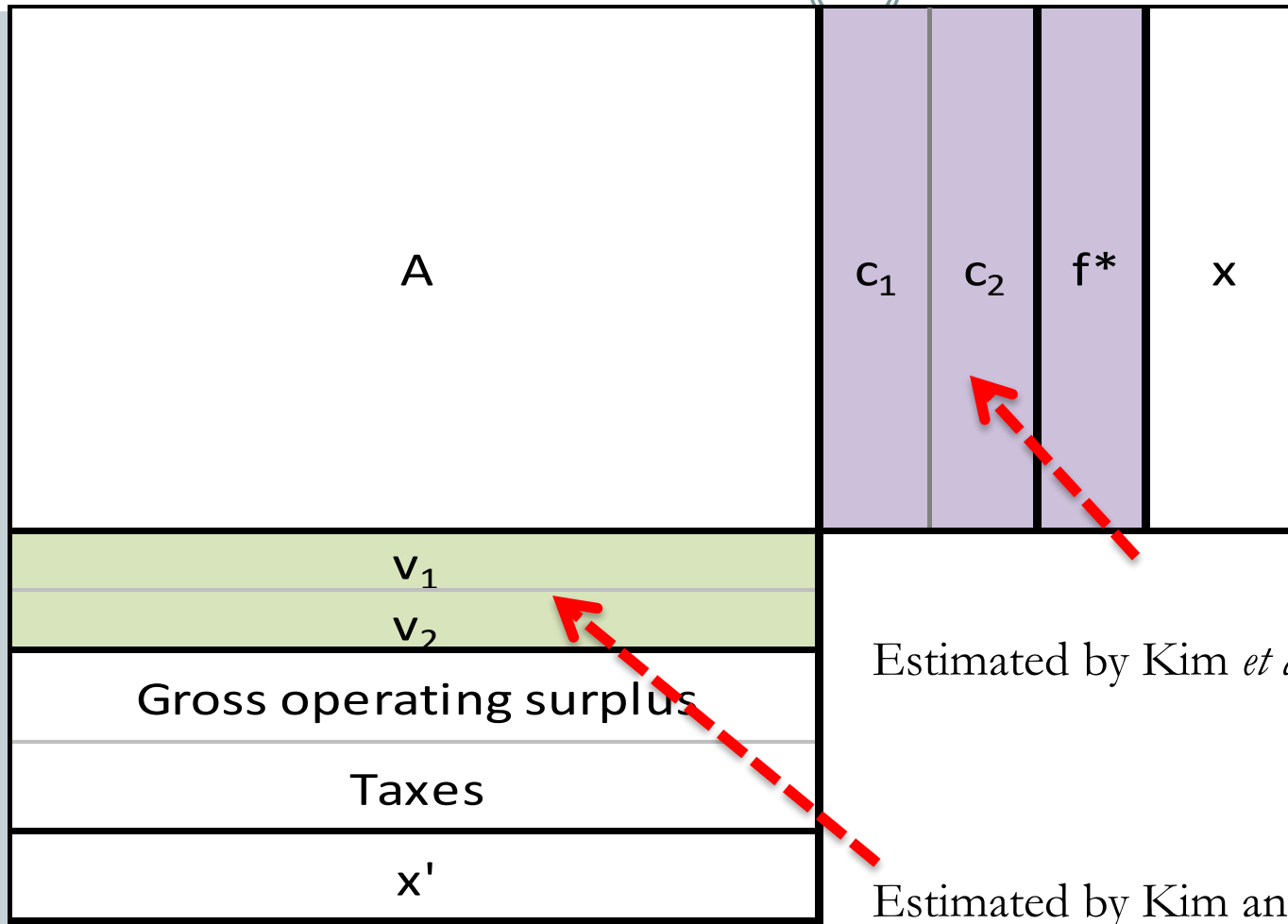
Interpretation and a Problem

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- The policy intervention centered around increasing development in the south side (Region 2); the analysis in the previous table showed significant interregional spillovers
- However, if development (e.g. to reduce the “retail desert”) occurs thus generating **trade diversion** (residents shop locally), this would reduce interregional spillovers
- New jobs in Region 2 would increase the volume of spending and while the *share spent locally* might increase, given American shoppers love of variety, there is every expectation that the amounts spent outside the region would increase – a retail analogy to **gains from trade** – Region 2 would increase share of high frequency retail goods (e.g., food) while Region 4 would continue to specialize in low frequency (e.g., clothes)
- Without empirical evidence, this was difficult to demonstrate

Endogenizing Households

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Estimated by Kim *et al.* (2015)

Estimated by Kim and Hewings (2019)

Move from Spatial to Household Interdependence

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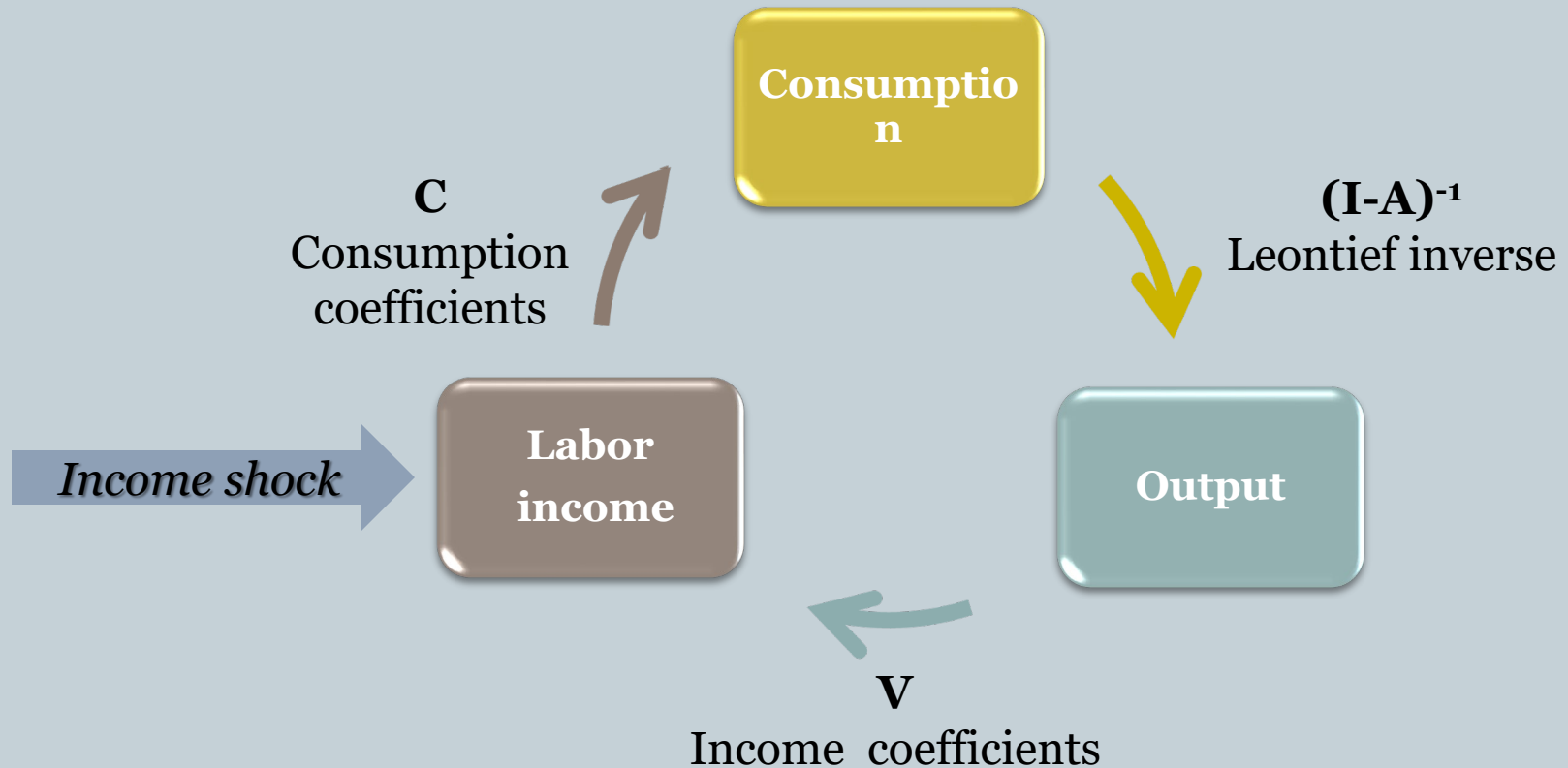
- Income equality in the US has been deteriorating over the past several decades in large part due to:
 - declining middle-income family shares and, as Piketty reminds,
 - the increase in the share of non wage and salary income in total income.
- Supply-side proponents claim that lower taxes on the rich will lead to significant income gains to lower income households – the so-called “trickle-down effect”
- Despite the growing global- and nation-wide concerns about deepening income inequality, the same issue at the sub-national level has not been investigated as comprehensively as at higher geographical levels – hundreds of papers but few explore the *system-wide implications*
- Explored income interdependence on basis of age and income levels

Interrelational income multipliers (K matrix)

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$$K = \left[I - V(I - A)^{-1} C \right]^{-1} = (I - L)^{-1} = I + L + L^2 + \dots$$

Indicates how a unit income increase in one group generates income in other groups



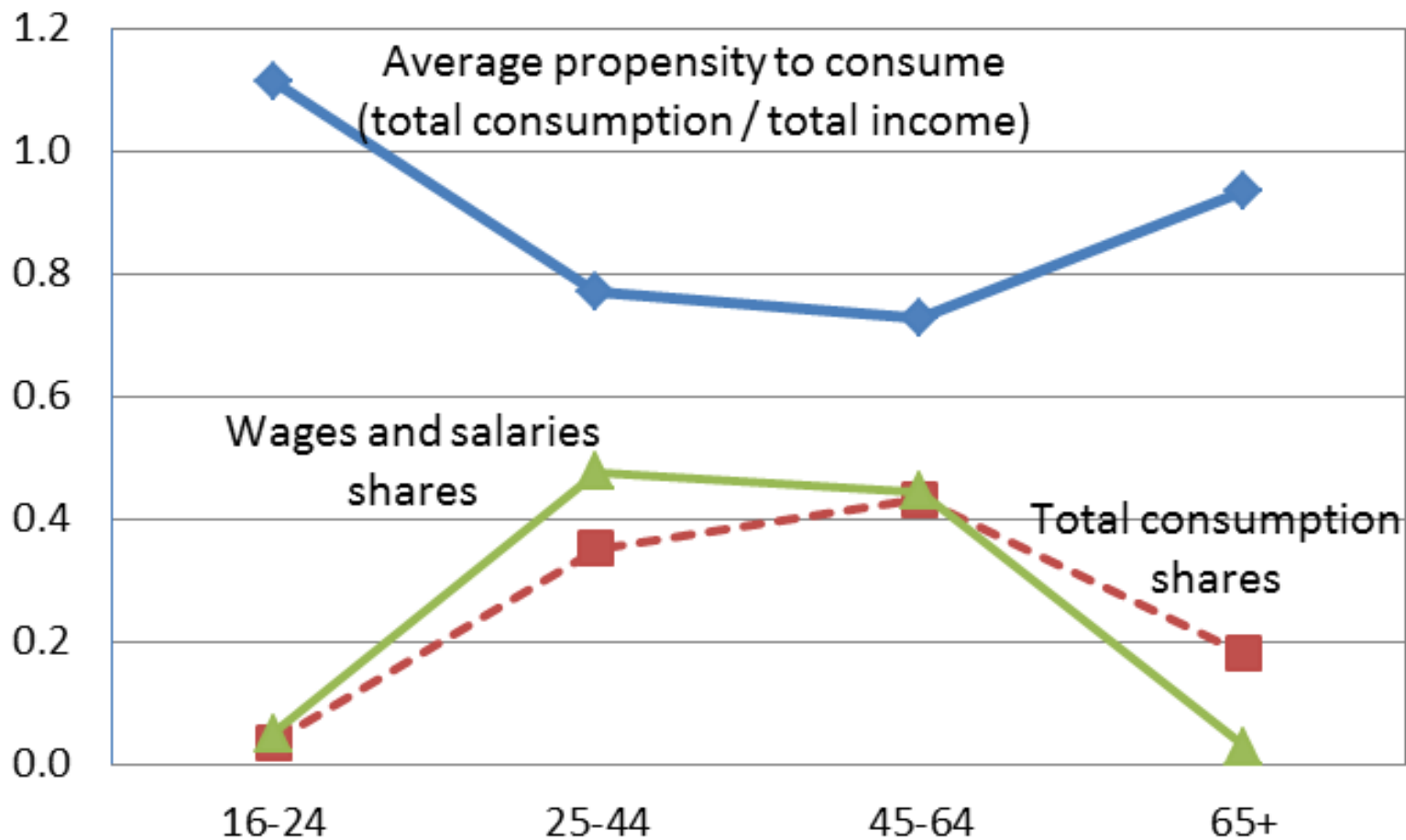
Data for Miyazawa framework

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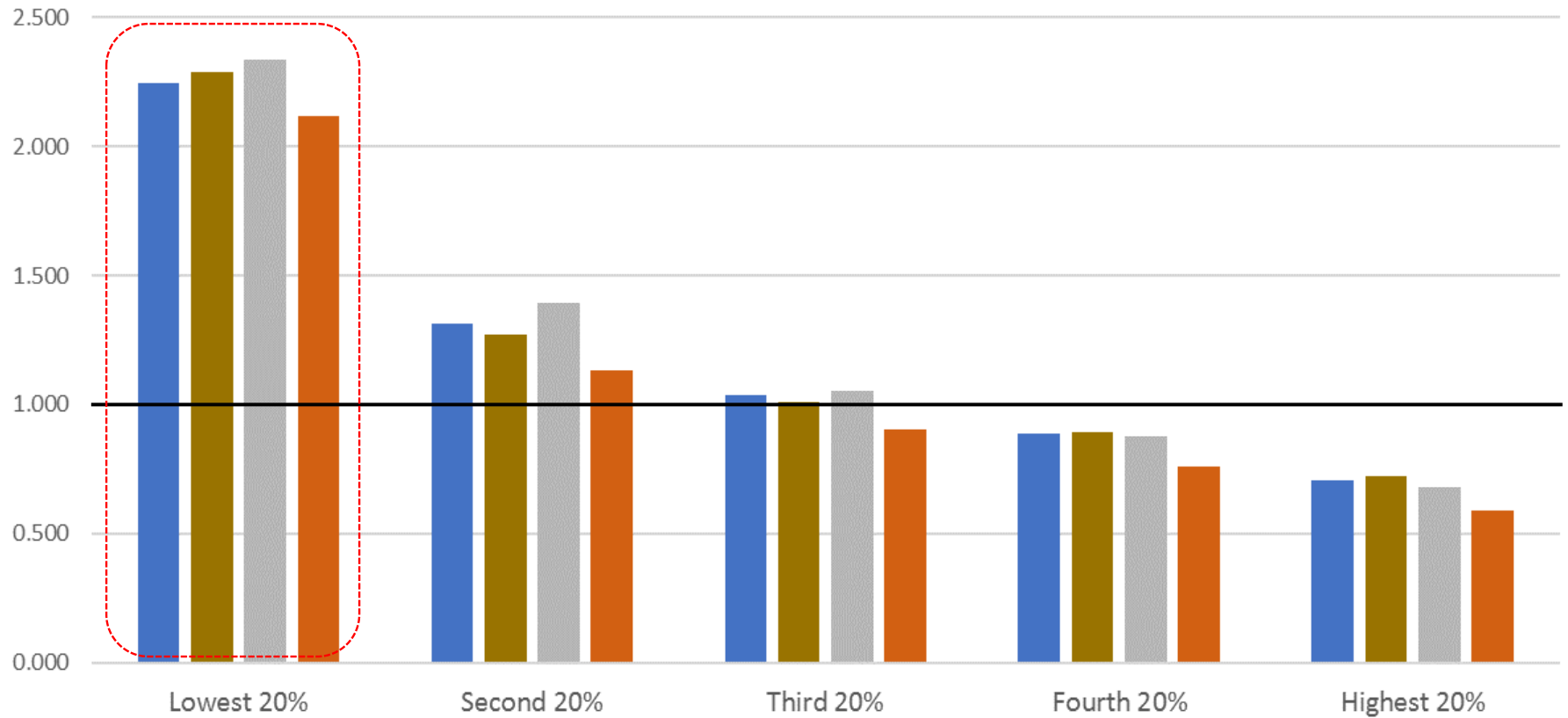
- An input-output table for Chicago with the base year of 2009 (the econometric IO model updates the table each year – see Israilevich *et al.*, *JRS*, 1997)
- Labor income coefficients matrix (V)
 - Estimated labor cost shares by age group for *Illinois* using the Bayesian SUR model (Kim and Hewings, 2019) solved using the Metropolis-Hastings algorithm
- Consumption coefficients matrix (C)
 - Estimated almost ideal demand system (AIDS) by age group (Kim, Kratena and Hewings, 2014) for Chicago
 - Average propensity to consume by age group: US Consumer Expenditure Survey

Consumption and income patterns by age group

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Average Propensity to Consume by quintile



Plus Hewings' sons and
Eduardo Haddad's daughters
apc >> 1.0!)

■ 1987 ■ 1990 ■ 2000 ■ 2010

The effects of changes in age distribution

- Interrelational income multipliers (K matrix)

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	Age group of income origin				
	16-24	25-44	45-64	65+	Total
Age group of income receipt: 2009					
16-24	1.055	0.037	0.035	0.045	1.172
25-44	0.423	1.292	0.286	0.383	2.384
45-64	0.378	0.263	1.259	0.349	2.249
65+	0.030	0.021	0.021	1.028	1.100
Total	1.886	1.612	1.601	1.806	6.905
Age group of income receipt: 2020					
16-24	1.043	0.028	0.027	0.035	1.133
25-44	0.362	1.249	0.244	0.326	2.182
45-64	0.440	0.304	1.299	0.404	2.447
65+	0.040	0.028	0.027	1.036	1.131
Total	1.884	1.610	1.598	1.801	6.892
Changes in indirect & induced impacts (%): 2020-2009					
16-24	-22.3	-22.7	-22.8	-22.7	-22.6
25-44	-14.4	-14.6	-14.6	-14.9	-14.6
45-64	16.3	15.7	15.5	15.5	15.8
65+	30.7	30.9	31.1	31.3	31.0
Total	-0.25	-0.48	-0.55	-0.58	-0.45

Average propensity to consume

Age composition of employment

Indirect effects “moving” from younger to older age groups over the period 2009-2020

Evolution of interrelational income multipliers in Chicago

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Income group of income origin

1980	Q1	Q2	Q3	Q4	Q5	Row Sum
Q1	1.18	0.11	0.08	0.07	0.06	1.49
Q2	0.88	1.52	0.41	0.35	0.28	3.45
Q3	1.55	0.92	1.73	0.62	0.49	5.31
Q4	2.31	1.37	1.08	1.93	0.73	7.42
Q5	3.51	2.08	1.65	1.41	2.12	10.78
Col. Sum	9.43	5.99	4.97	4.39	3.67	28.45

Income group of income origin

1990	Q1	Q2	Q3	Q4	Q5	Row Sum
Q1	1.14	0.08	0.06	0.05	0.04	1.37
Q2	0.65	1.36	0.29	0.25	0.20	2.76
Q3	1.20	0.66	1.52	0.47	0.38	4.22
Q4	1.87	1.03	0.82	1.73	0.59	6.03
Q5	3.22	1.78	1.41	1.26	2.02	9.69
Col. Sum	8.08	4.91	4.09	3.77	3.23	24.07

Income group of income origin

2000	Q1	Q2	Q3	Q4	Q5	Row Sum
Q1	1.24	0.14	0.11	0.09	0.07	1.65
Q2	0.94	1.57	0.43	0.36	0.28	3.56
Q3	1.65	1.00	1.75	0.63	0.49	5.52
Q4	2.61	1.58	1.19	1.99	0.77	8.13
Q5	4.89	2.96	2.24	1.87	2.45	14.42
Col. Sum	11.33	7.25	5.71	4.94	4.05	33.28

Income group of income origin

2010	Q1	Q2	Q3	Q4	Q5	Row Sum
Q1	1.12	0.07	0.05	0.04	0.03	1.32
Q2	0.46	1.25	0.20	0.17	0.13	2.20
Q3	0.83	0.45	1.36	0.30	0.24	3.17
Q4	1.33	0.72	0.58	1.49	0.38	4.50
Q5	2.68	1.46	1.18	0.99	1.79	8.09
Col. Sum	6.42	3.93	3.36	2.99	2.57	19.28

Percentage changes in indirect impacts

1990-1980	Q1	Q2	Q3	Q4	Q5	Row Sum
Q1	-23.3	-28.6	-29.0	-25.6	-24.4	-25.8
Q2	-25.8	-30.8	-31.1	-27.9	-26.5	-28.1
Q3	-22.8	-28.1	-28.3	-25.0	-23.5	-25.2
Q4	-18.9	-24.5	-24.8	-21.3	-19.7	-21.5
Q5	-8.3	-14.5	-14.8	-10.8	-8.8	-11.1
Col. Sum	-16.0	-21.7	-22.0	-18.3	-16.6	-18.7

2000-1990	Q1	Q2	Q3	Q4	Q5	Row Sum
Q1	73.9	91.0	82.4	70.3	64.2	77.2
Q2	42.9	56.7	49.4	39.5	34.3	45.3
Q3	38.1	51.3	44.2	34.7	29.5	40.3
Q4	39.4	52.8	45.6	36.1	30.9	41.7
Q5	51.9	66.5	58.6	48.2	42.5	54.4
Col. Sum	45.9	59.9	52.3	42.3	36.9	48.2

2010-2000	Q1	Q2	Q3	Q4	Q5	Row Sum
Q1	-48.6	-54.4	-51.3	-51.1	-50.3	-50.9
Q2	-51.2	-56.6	-53.7	-53.4	-52.6	-53.3
Q3	-49.9	-55.3	-52.3	-52.0	-51.1	-51.9
Q4	-48.9	-54.4	-51.3	-50.9	-50.0	-50.9
Q5	-45.2	-50.9	-47.4	-46.9	-45.9	-47.1
Col. Sum	-47.5	-53.1	-49.8	-49.4	-48.4	-49.5

Focus of 2010 Interrelational Income Multipliers

2010	Q1	Q2	Q3	Q4	Q5	Row Sum
Q1	1.12	0.07	0.05	0.04	0.03	1.32
Q2	0.46	1.25	0.20	0.17	0.13	2.20
Q3	0.83	0.45	1.36	0.30	0.24	3.17
Q4	1.33	0.72	0.58	1.49	0.38	4.50
Q5	2.68	1.46	1.18	0.99	1.79	8.09
Col. Sum	6.42	3.93	3.36	2.99	2.57	19.28

2010	Q1	Q5
Q1	2.21%	1.91%
Q2	8.49%	8.28%
Q3	15.31%	15.29%
Q4	24.54%	24.20%
Q5	49.45%	50.32%

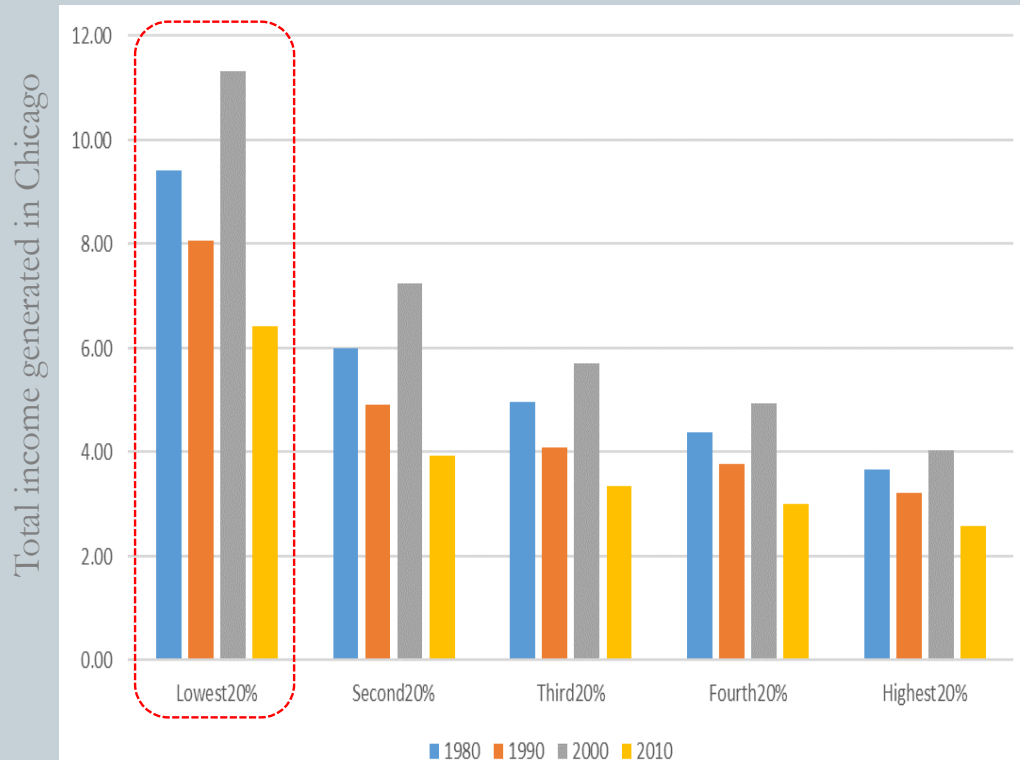
- The full matrix is shown on the left
- To highlight the asymmetry, the distribution of spillover effects is shown on the right
- **Lowest Income Group (1):**
 - Intra-group spillover very small (<3%)
 - Very large spillover to highest income groups (25% and 49%)
- **Highest Income Group (2):**
 - Intra-group spillover very large (>50%)
 - Very small spillover to lowest group (<2%)

Evolution of interrelational income multipliers in Chicago (2)

Economy-wide income impact is the largest when an income shock originates from the lowest 20 percent income group.

The lowest income group generate 2.5 to 3 times as high total income as the highest income group does.

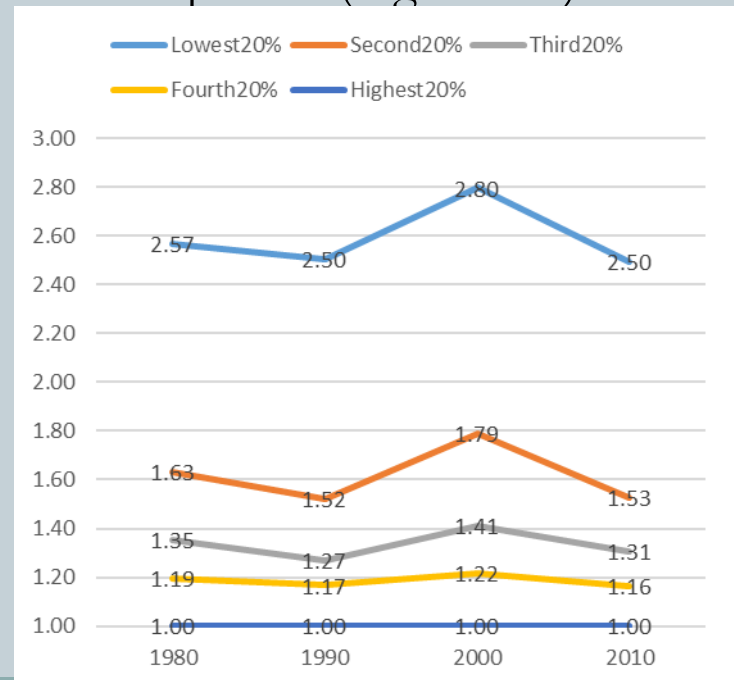
Total income generated by income origin quintile



Origin of one unit of income shock

Note: Column sums of interrelational income multipliers

Ratios of total income generated by income origin quintile (highest=1)

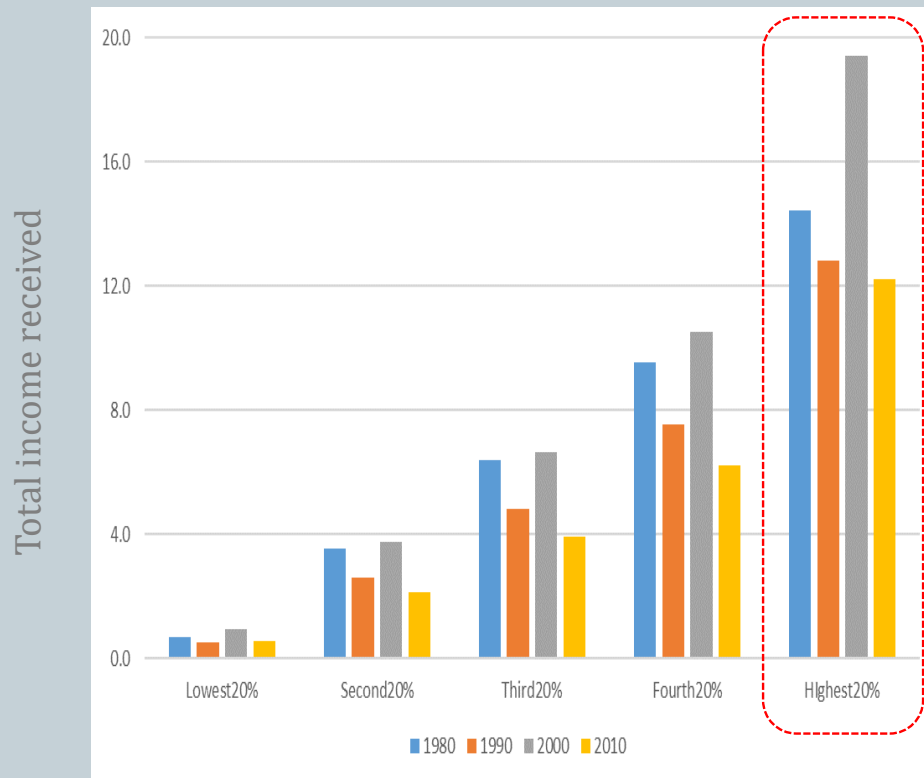


Evolution of interrelational income multipliers in Chicago (3)

- The highest 20% group receives the highest income generated when all income groups get one unit of income shock.
- When all income groups get equal income shocks, the relative amount of income received by the highest income group rose over the last three decades while those by the rest groups fell.

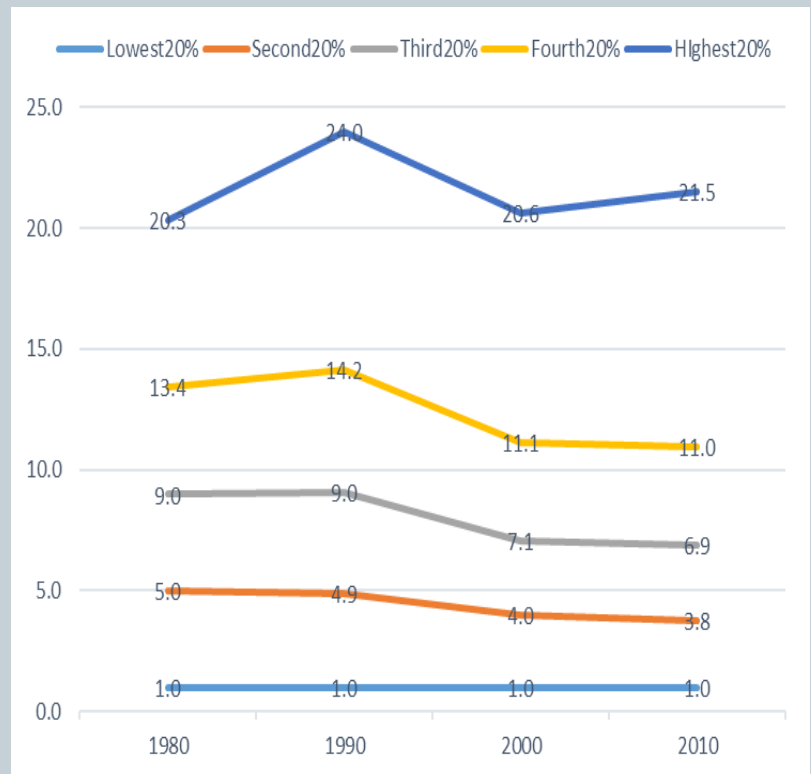
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Total income generated by one unit of income shock to all income groups



Group of income receipt

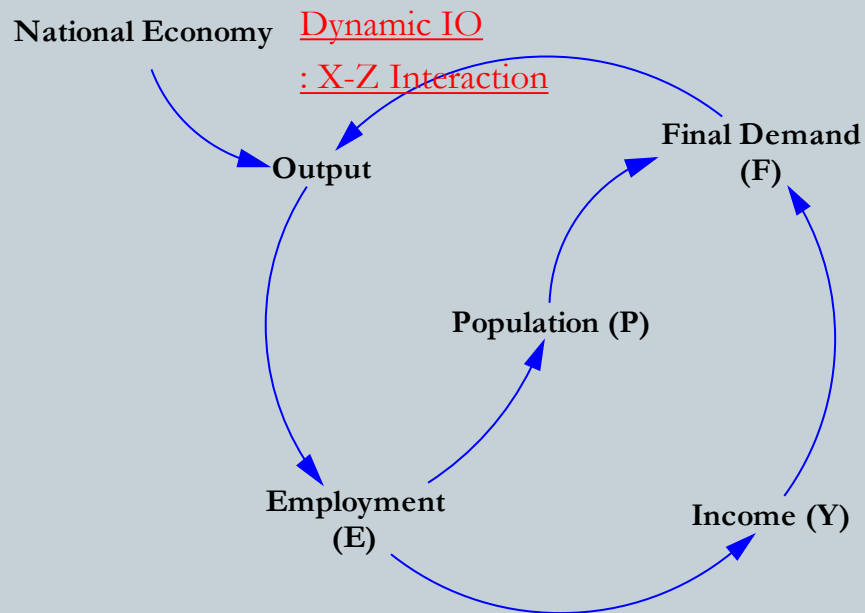
Ratios of total income generated by one unit of income shock to all income group (lowest=1)



Note: **Row sums** of interrelational income multipliers

Spatial Disaggregation inside the REIM

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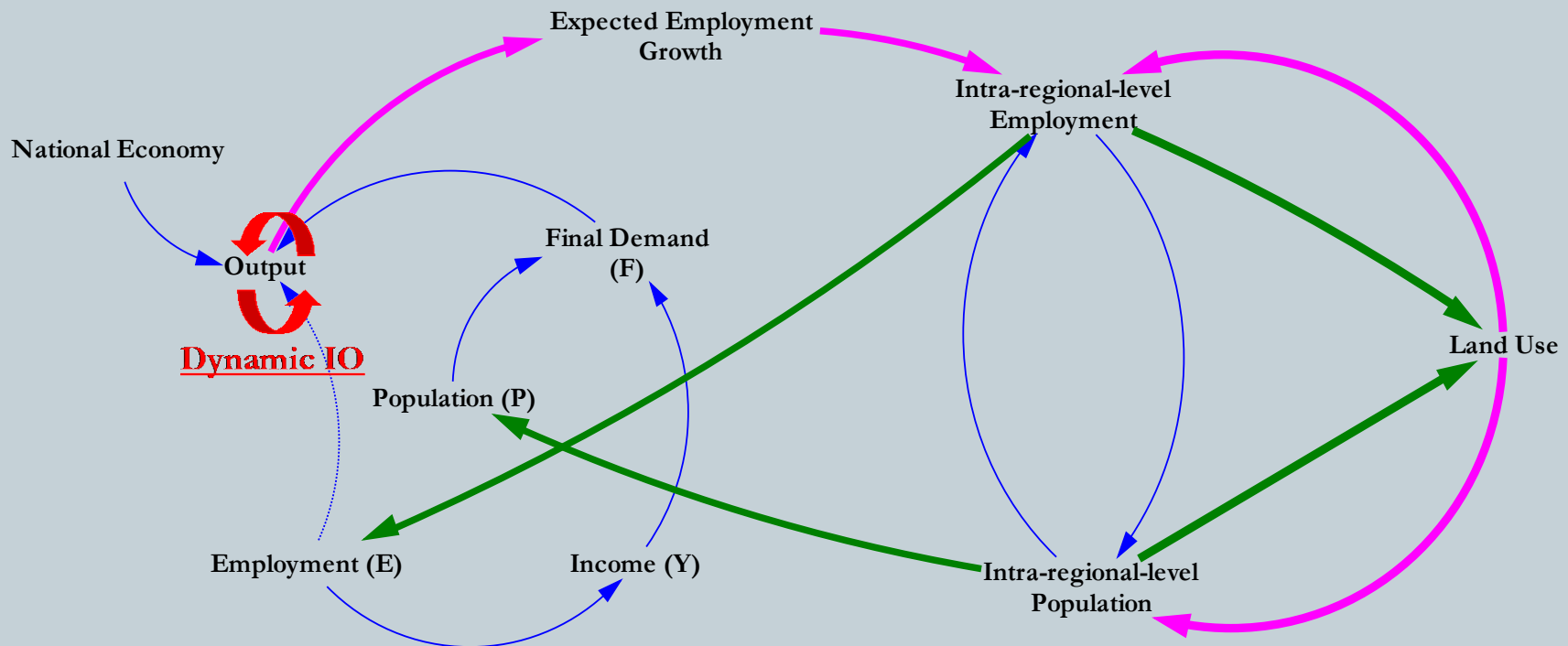


- Dynamic IO coefficients
- Forecasting with the consideration of disaggregated industrial structure
- Advanced Impact Analysis Framework
- Non-Spatial

Spatial Disaggregation inside the REIM

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Region Municipalities Cell*



*Cell data and initial forecasts provided by LEAM (www.lead.illinois.edu)

Sub-Regional Growth Modeling I

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- Regional Disequilibrium Adjustment Model
(with some modifications of dependent variables)
- Pioneered by Steinnes & Fisher (1974) and Carlino & Mills (1987)
- Extended (Spatial econometric version) by Boarnet (1994)
- Underlying Settings for the Formulation:

$$P_{i,t}^* = f(\bar{E}_{i,t}^*, H_{i,t})$$

$$E_{i,t}^* = g(\bar{P}_{i,t}^*, B_{i,t})$$

$$\Delta P_{i,t} = \lambda_p \cdot (P_{i,t}^* - P_{i,t-1})$$

$$\Delta E_{i,t} = \lambda_E \cdot (E_{i,t}^* - E_{i,t-1})$$

$$\bar{P}_{i,t} = (I + W) \cdot P_{i,t}$$

$$\bar{E}_{i,t} = (I + W) \cdot E_{i,t}$$

Sub-Regional Growth Modeling II

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- The Formulation of the Sub-regional Module: Spatial cross-regressive simultaneous equation system

$$\Delta P_{i,t} - (ZP_{i,t} - P_{i,t-1})$$
$$= H_{i,t} \cdot \lambda_p \cdot \beta_p + \lambda_p \cdot \theta_p \cdot (I + W) \cdot E_{i,t-1} + \frac{\lambda_p \cdot \theta_p}{\lambda_E} \cdot (I + W) \cdot \Delta E_{i,t} - \lambda_p \cdot P_{i,t-1} + u_{i,t}$$

where $ZP_{i,t}$: Expected level of population in zone i at time t

H : Household location factors

$$\Delta E_{i,t} - (ZE_{i,t} - E_{i,t-1})$$
$$= B_{i,t} \cdot \lambda_E \cdot \beta_E + \lambda_E \cdot \theta_E \cdot (I + W) \cdot P_{i,t-1} + \frac{\lambda_E \cdot \theta_E}{\lambda_P} \cdot (I + W) \cdot \Delta P_{i,t} - \lambda_E \cdot E_{i,t-1} + v_{i,t}$$

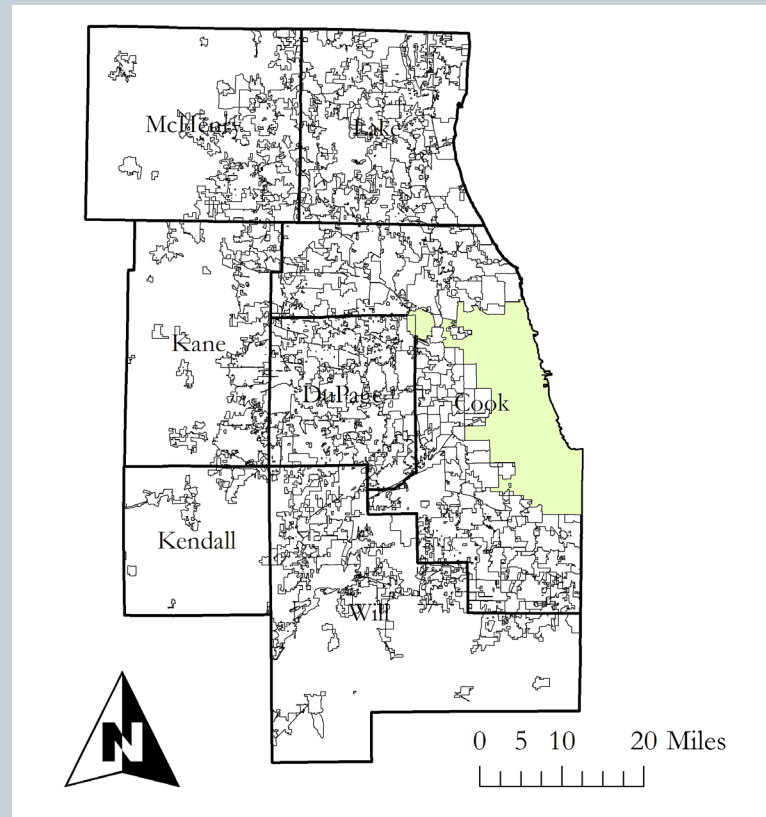
where $ZE_{i,t}$: Expected level of employment in zone i at time t

B : Household location factors

Application to Chicago Metropolitan Area

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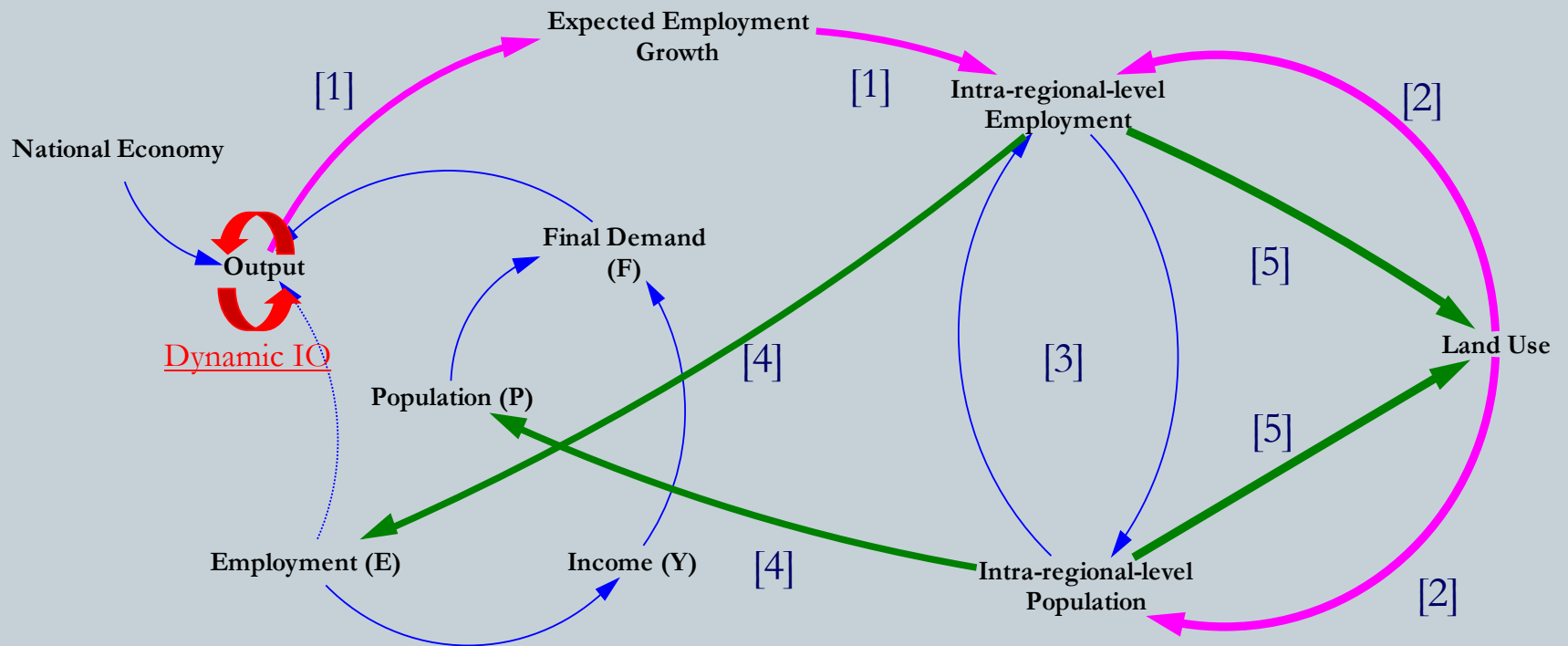
- Unit of Sub-regional Modeling: Municipalities
 - $n = 303$
 - ✦ 296 Cities & Towns
 - ✦ 7 unincorporated areas
- Extending the 2008 Version Chicago REIM
 - ✦ Coupling-type REIM
 - ✦ 45 NAICS-based Sectors
 - ✦ Forecasting up to 2040



Model Solving Loops

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Region Municipalities Cell



Comparison of Constrained vs Unconstrained Population Growth

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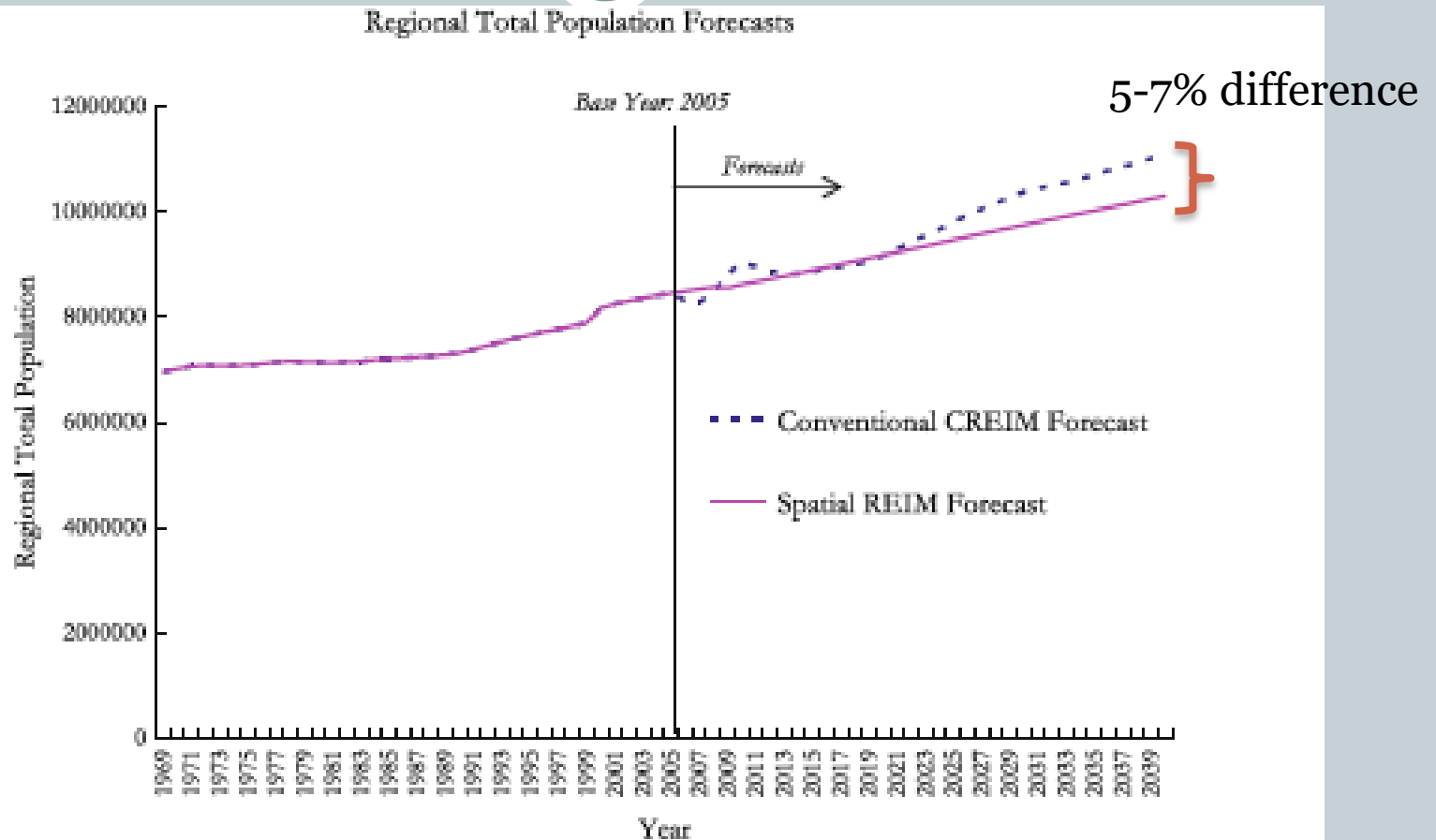


Fig. 5 Conventional CREIM versus spatial REIM: regional population forecasts

Comparison of Constrained vs Unconstrained Employment Growth

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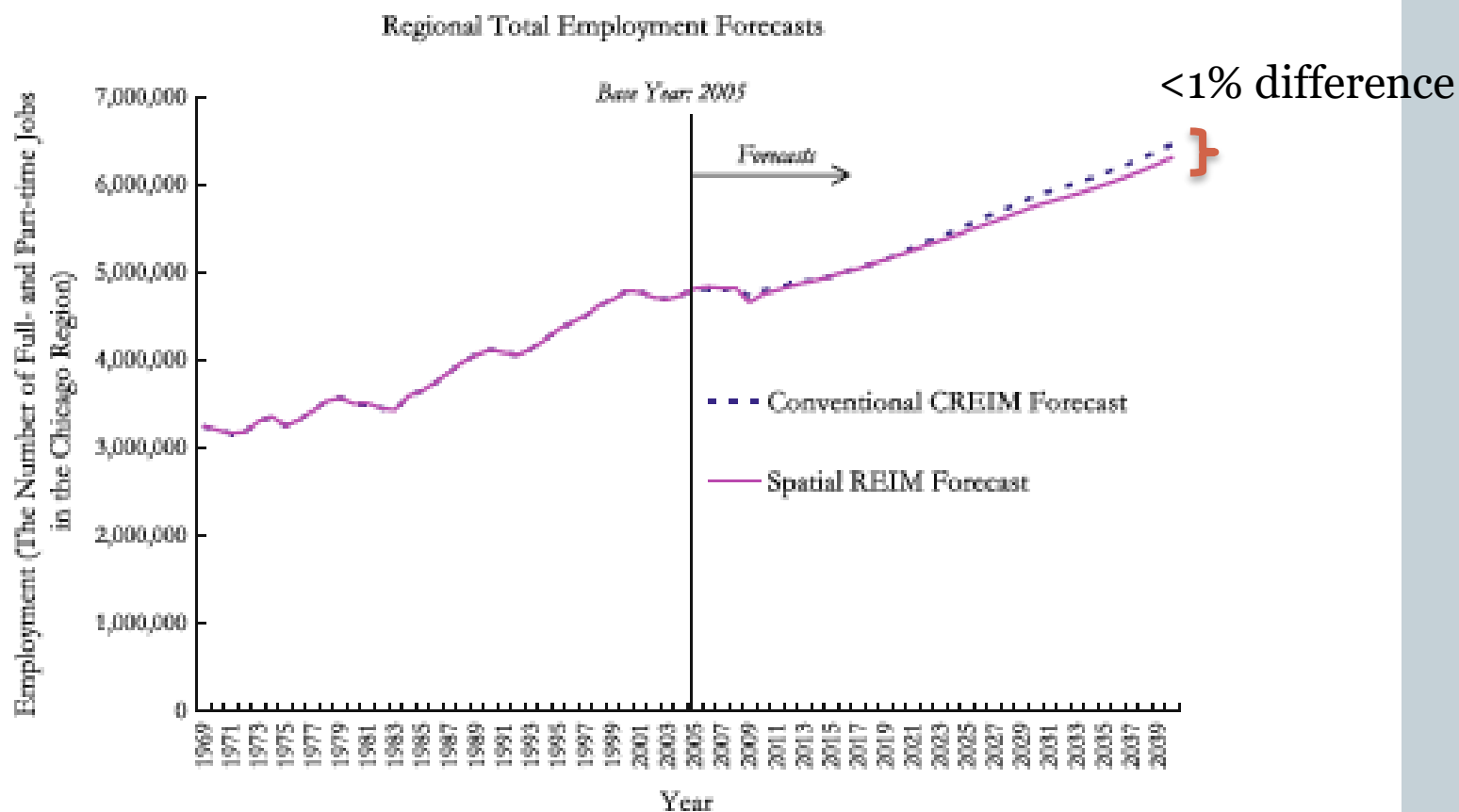


Fig. 6 Conventional CREIM versus spatial REIM: regional total employment forecasts

Summary

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- Important spatial and household heterogeneities that serve to exacerbate income inequalities over time; optimal intervention policy is complicated by feedbacks that may unravel initial expectations
- The systems of networks uncovered in this research point to enhanced levels of interdependence within metropolitan areas
- The fiscal federalism ideals need to be explored more effectively to capture both positive and negative externalities raising difficult questions about the spatial scale at which concerns about welfare gains/losses need to be evaluated

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