

# toward an empirical network macro-economics

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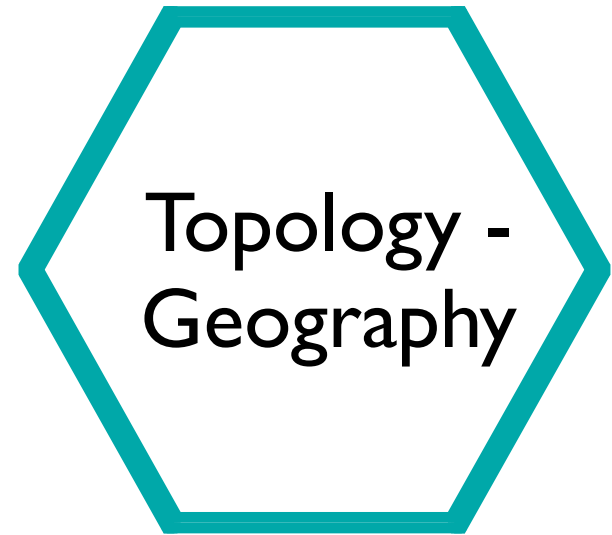
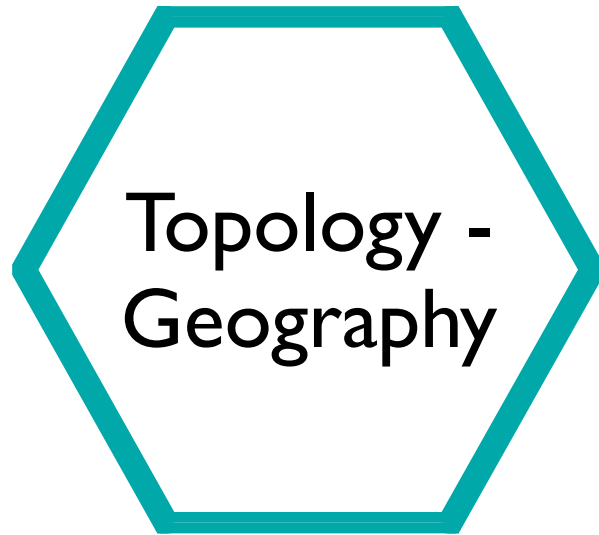
# research agenda

- Internet public interests?
- How are we doing? Getting better or worse over time, by what measure?
- Underperforming, or over -- by what standard?
- Why? What are the causes of change in relevant measures?

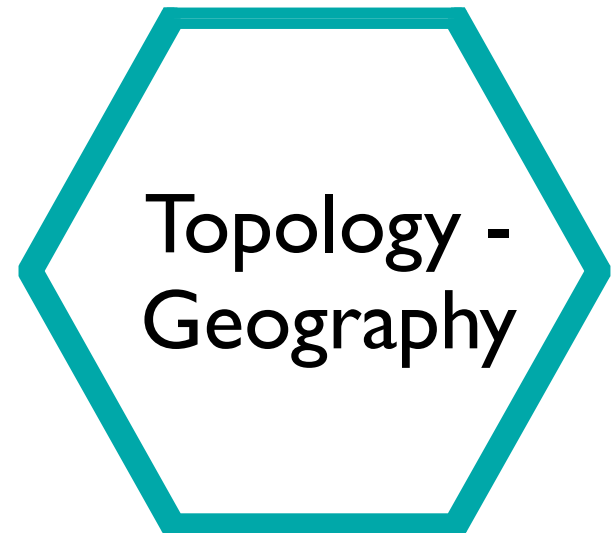
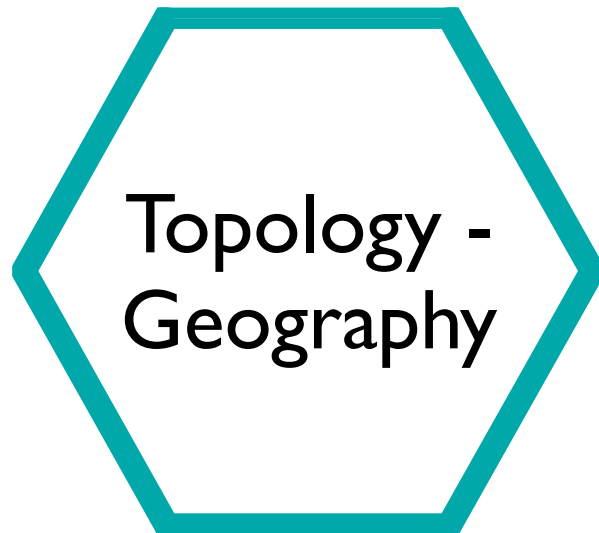
# (current) unit of analysis

- **Countries:** vertical silos that influence or directly control all sorts of relevant factors
- Control many levers to change conditions, for good or ill
- Because higher level of analysis not meaningful, lower levels of analysis not sustainable, or sportsmanlike
- “National network economies”

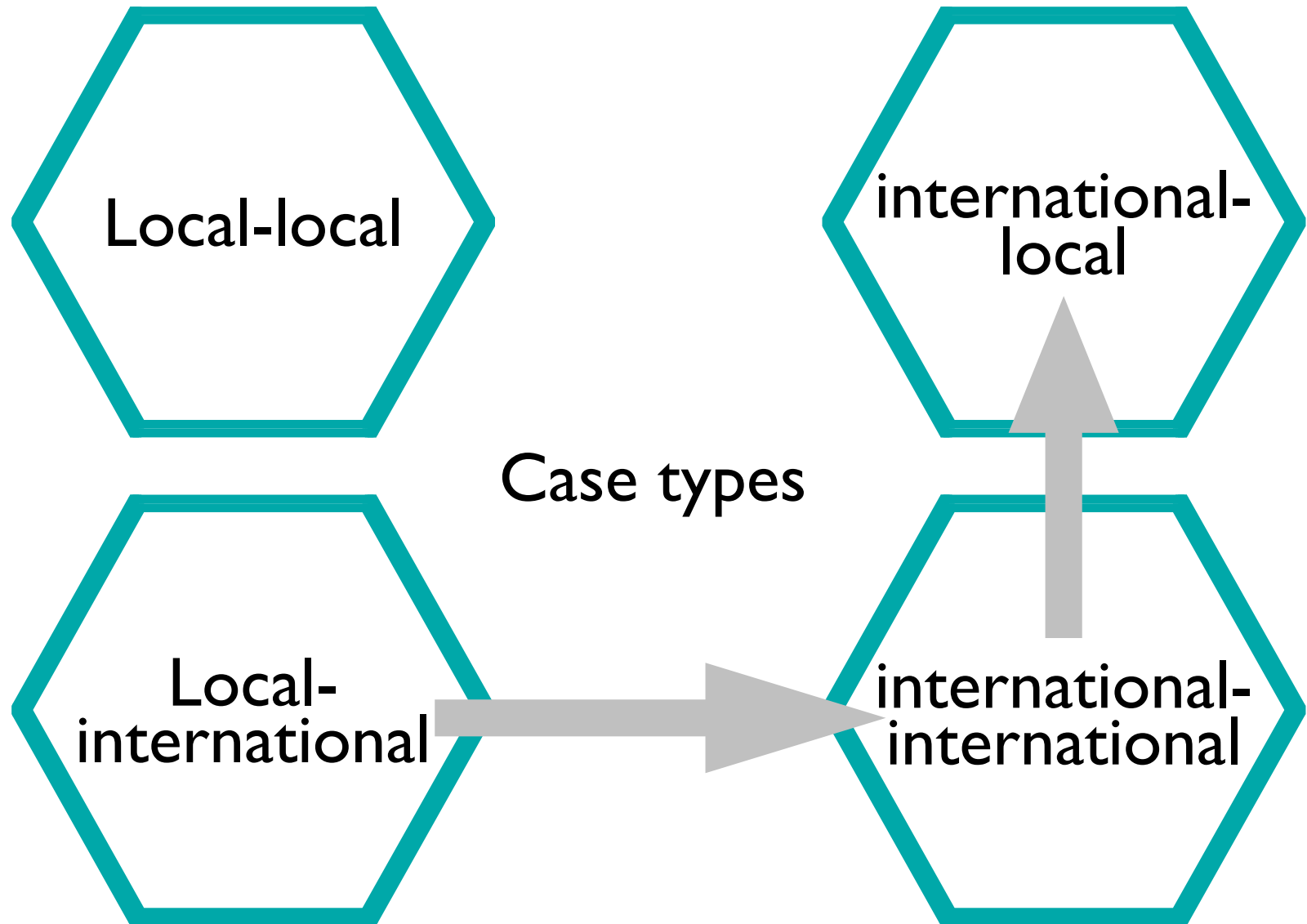
# The Internet “relatively insensitive to national borders”...



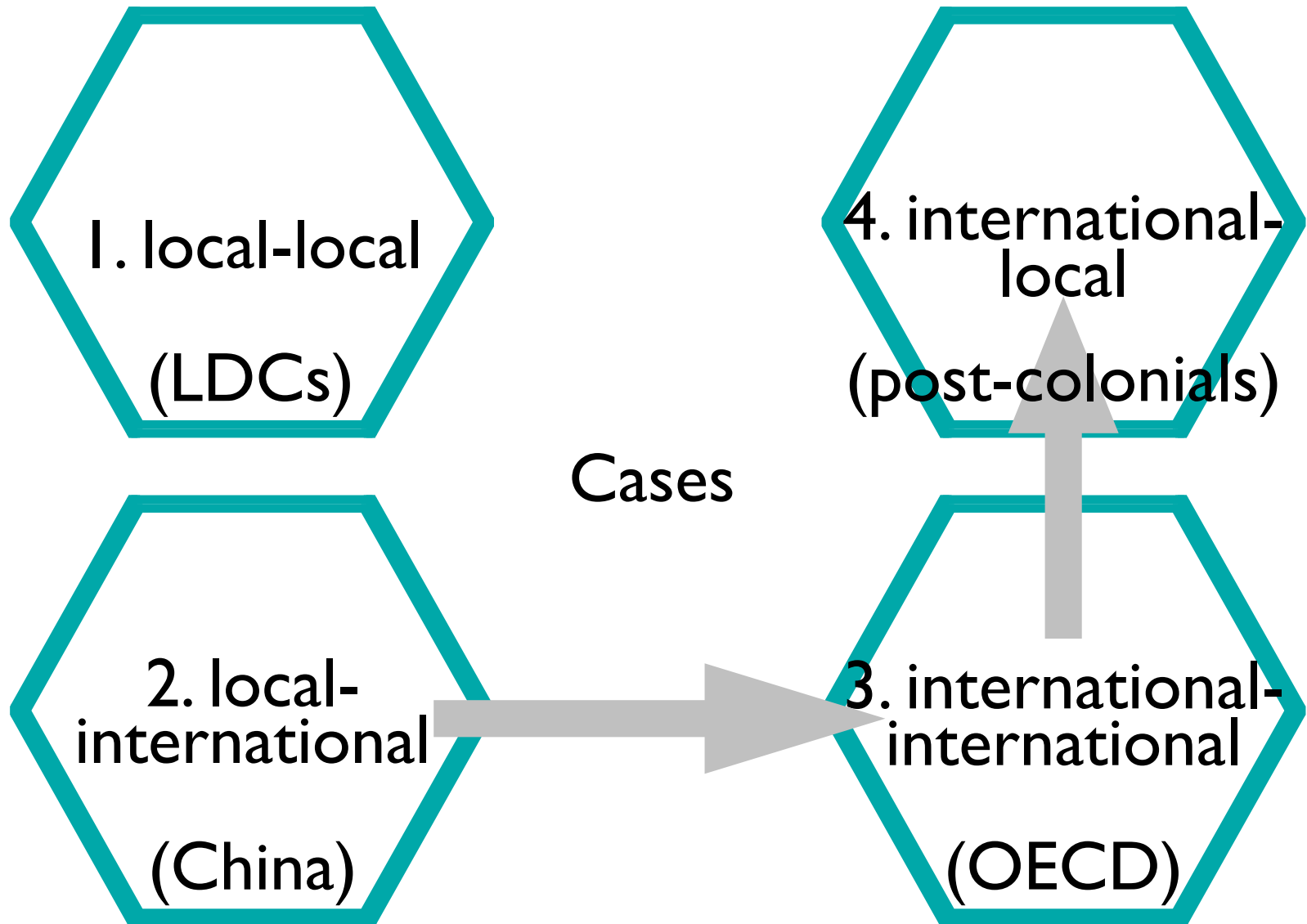
Case types



...but only relatively, and kinds of insensitivities are few and identifiable



# Cross-border production



# metric

- **“Internet production”** aka unique public routed IP
- Represents promises fulfilled to deliver more “users, usage, uses” -- why? Because that’s what we tell the RIRs in order to justify the allocations
- Modulated by sensitivity to policy era (pre-RIR, changing RIR policies), scale (HD ratio), bias in favor of diversity, public interoperability...
- “Naive institutional realism” (tm)  
+ law of large numbers  
= plausible ~~deniability~~ assertability

# measurement device

- **Autonomous Systems:** point of attachment for new users, usage, uses -- things that policy makers care about
- Running an AS has a cost-point that has some relationship to size/scale of operation
- Below that point, network outsourcing: operations/growth differentially accrue to someone else's AS. Afterward, network insourcing: more benefits internalized.

# measurement device

- **Micro-dynamics:** Each AS represents a (different) solution to a (different) problem, combining different technology inputs, target missions/markets, pricing strategies, external relationships (Maltz, Xie, Zhan, Zhang)
- Some “work” and survive or even grow; others stagnate, disappear, or are assimilated into other ASes. 300 +/- new ones appear every month, 100 +/- disappear, (mostly) forever (Uijterwaal, Wilhelm)
- Familiar-looking industrial dynamics

# measurement device

- **Macro-dynamics:** AS break-even point varies relative to cost of critical inputs for running an AS -- infrastructure, interconnection etc. -- many of which are determined at national level.
- Some NNEs may be attractive for Internet production, but inhospitable to new independent network creation, resulting in few, large ASNs -- should NNE constituents (or trade partners) care?
- In some cases, better terms to be had elsewhere, leading to offshoring and/or cross-border outsourcing: divergent NNE growth rates... again, should this matter to anyone?

# accounting conventions

- “Internet production” attributed to origin AS, regardless of actual location
- Origin AS attributed to self-provided ISO 3166 country code
- Arguably more “accurate” (definitely more complete) than any other dimension of whois
- Inconsistent semantics maybe (UBO, admin, legacy, chauvinism, etc. etc.) -- but similar to MNCs in other sectors, and susceptible to improvement over time

# benchmarks

- How well is a NNE doing now/over time, relative to the past, since milestone (x), compared to other NNEs, *all things remaining equal?*
- Other measured phenomena often benchmarked against GDP, population, etc.
- Old benchmark for comms was “main lines” i.e., DS0s connected to end user premises; proxy for sunk investment by incumbents -- still the family jewels for PSTNs (i.e, Powerful STNs)
- Together with coax infrastructures (also measurable), still the layer one access platform for 99.9% of Internet users

# testable hypotheses one

- Industry structure as an independent variable explaining differential NNE growth rates
- Is the presence of significant market power (SMP) associated with faster/slower NNE growth, all things remaining equal?
- Null hypothesis: Presence/absence has no effect, or measurement ambiguities preclude answer, or national-level treatment invalidates the question

# Theory behind H.I

- “Logical multiplexing” -- systems-level version of statmux; multiple ASes operating across common communications facilities (i.e., “infrastructure-based competition”) delivers more/faster Internet growth for any given set of inputs.
- Alternately: Cost and complexity of multiple operators makes provider diversity less efficient than monopoly service provision
- Null hypothesis: Neither clearly better, or measurement ambiguities preclude answer, or national-level analysis

# methodology I:

## The Herfindahl-Hirschman Index (HHI)

- HHI provides a single value measure of the number and size of firms in relationship to a given industry, and suggests the mix of competition/market power that characterizes the industry overall.
- Calculated by summing the squared market shares of each individual firm in a given market. Can range from 1 (1:1 firm / market share ratio) to 10,000 (single monopoly provider).
- Decreases in the HHI generally indicate a loss of pricing power and an increase in competition, whereas increases imply the opposite

# HHI policy interpretations

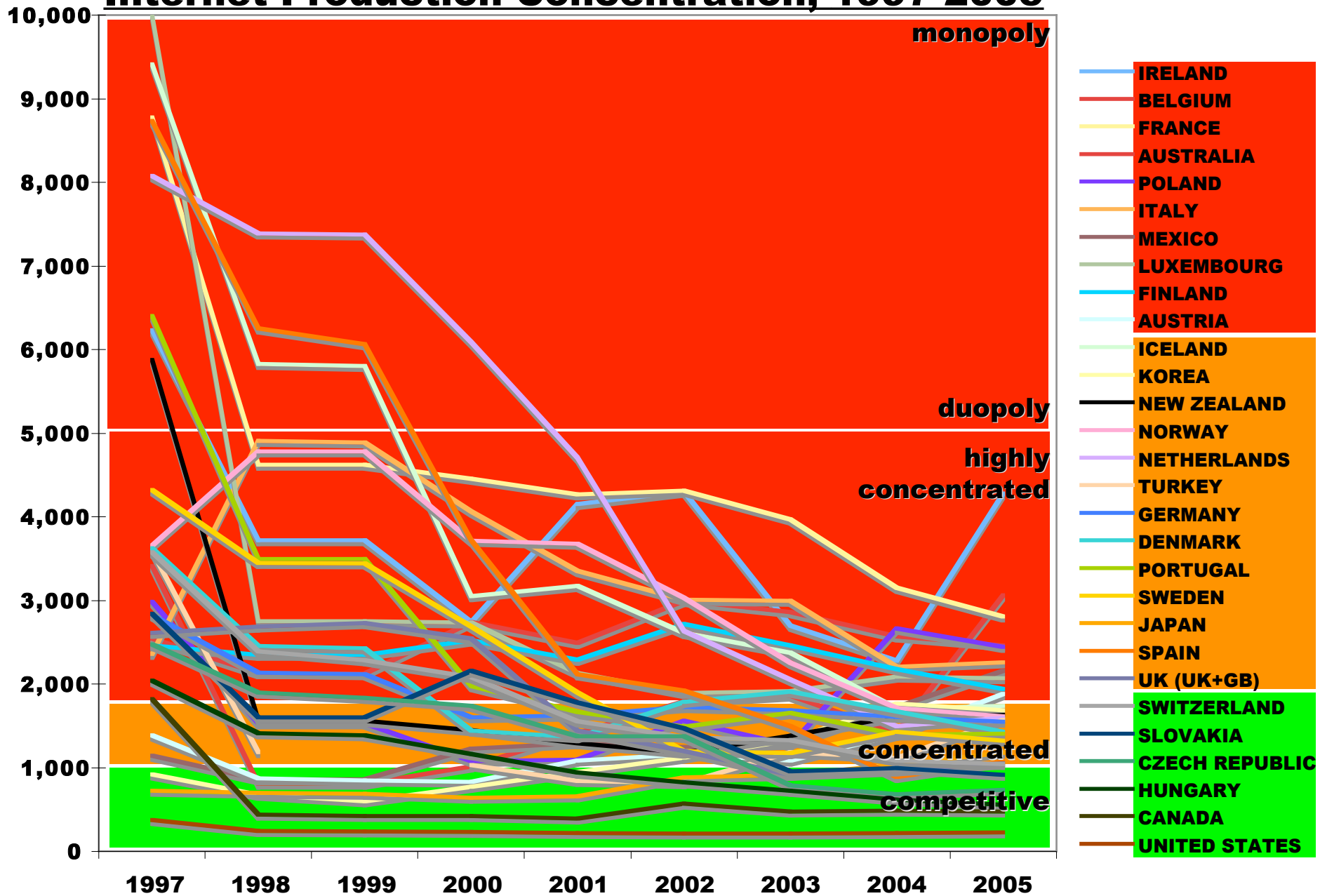
<b>Market Structure &amp; Interpretation</b>	<b>Current HHI</b>	<b>Dynamic Change</b>
Conditions/environments that are less likely to have anti-competitive effects.	<1000 1000-1800 >1800	Any <100 <50
Conditions that “may raise significant competitive concerns.”	1000-1800 >1800	>100 50 – 100
Conditions that “exist in already highly concentrated markets” and are “more likely to raise significant competitive concerns.”	>1800	>100

# methodology I:

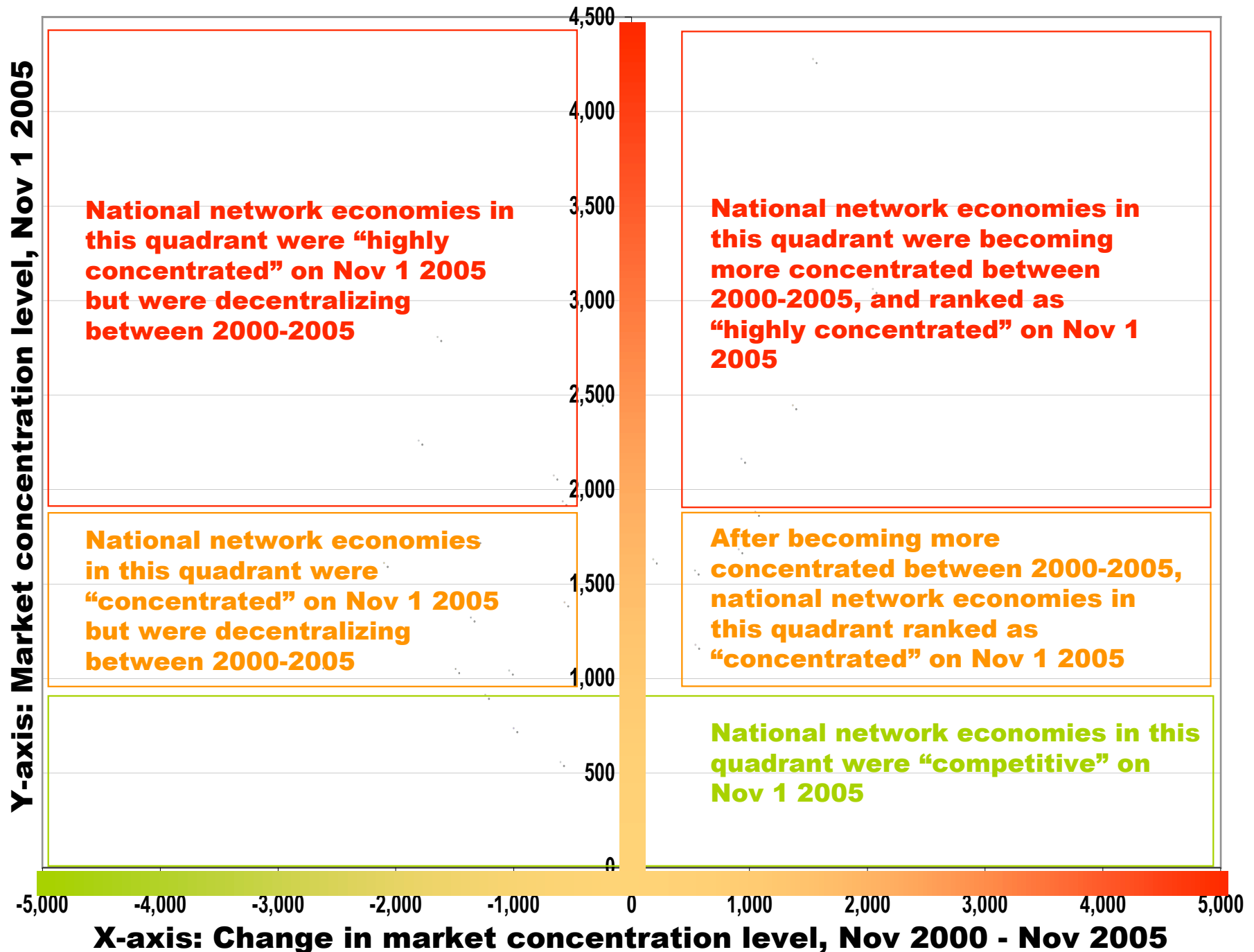
## The Herfindahl-Hirschman Index (HHI)

- Firms == routed Autonomous System Numbers (ASNs) grouped by whois country code of ASN(s) allocation
- Industry == “national Internet production” == sum of unique public IP addresses originated by ASNs with country code of ASN(s) allocation
- Market share == ratio of individual:total unique IP address originated by ASNs grouped by country code of ASN(s) allocation
- National HHI == sum of squared (public IP originated by ASN) grouped by country code of ASN(s) allocation
- Data taken from Univ. Oregon Route Views Project, first RIB capture for each November 1, 1997-2005

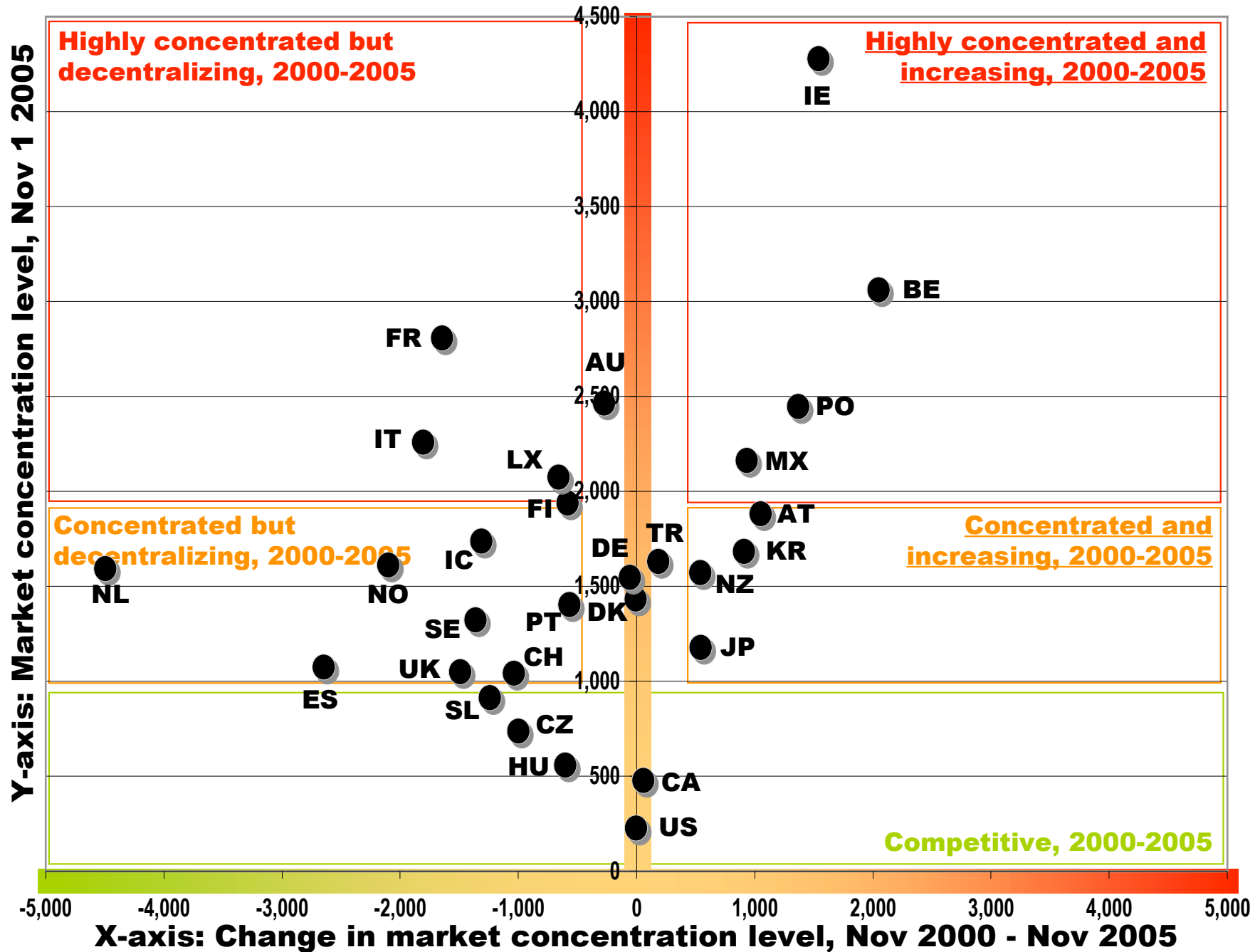
# Evolving OECD Market Structures: Internet Production Concentration, 1997-2005



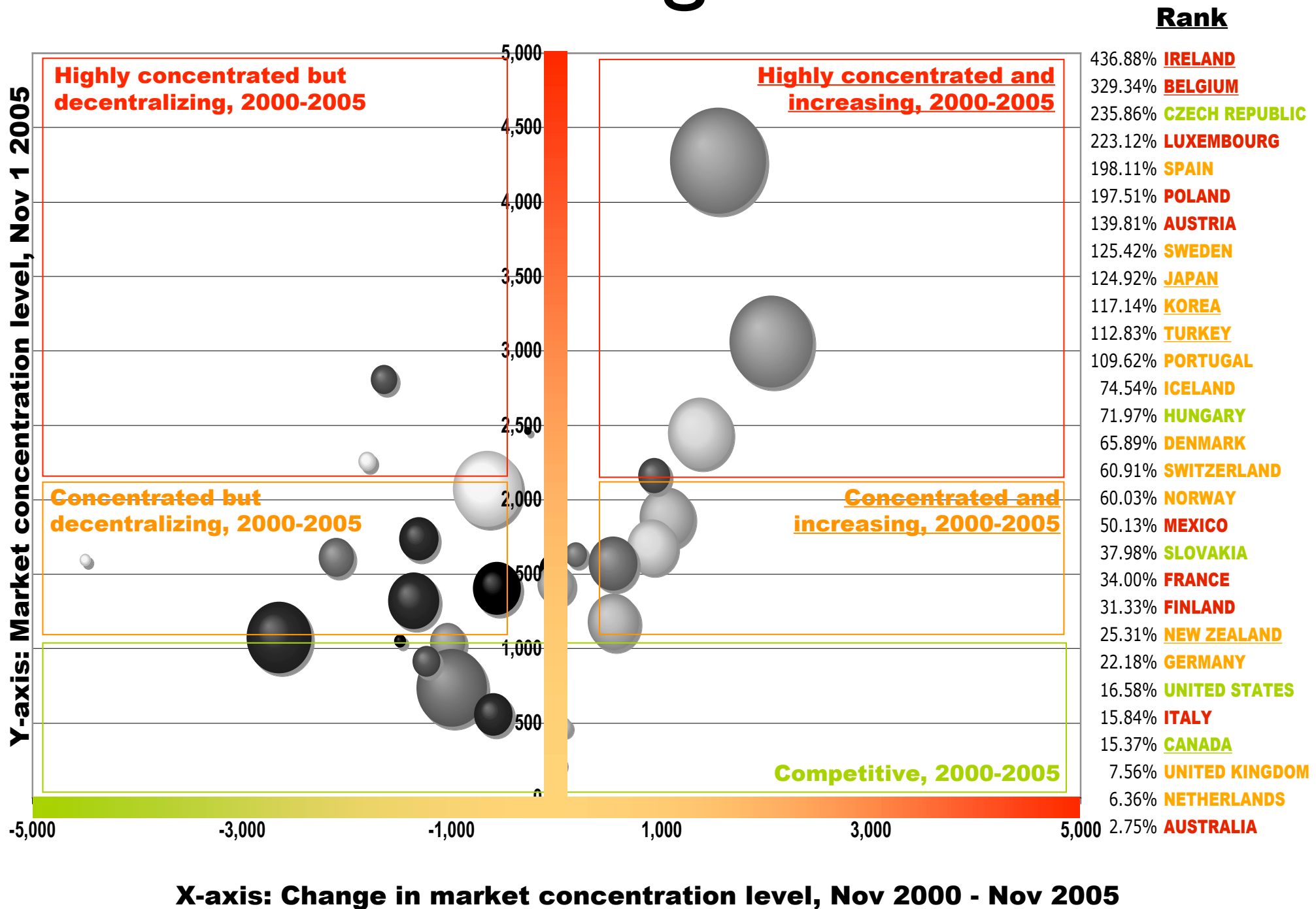
# Production Concentration



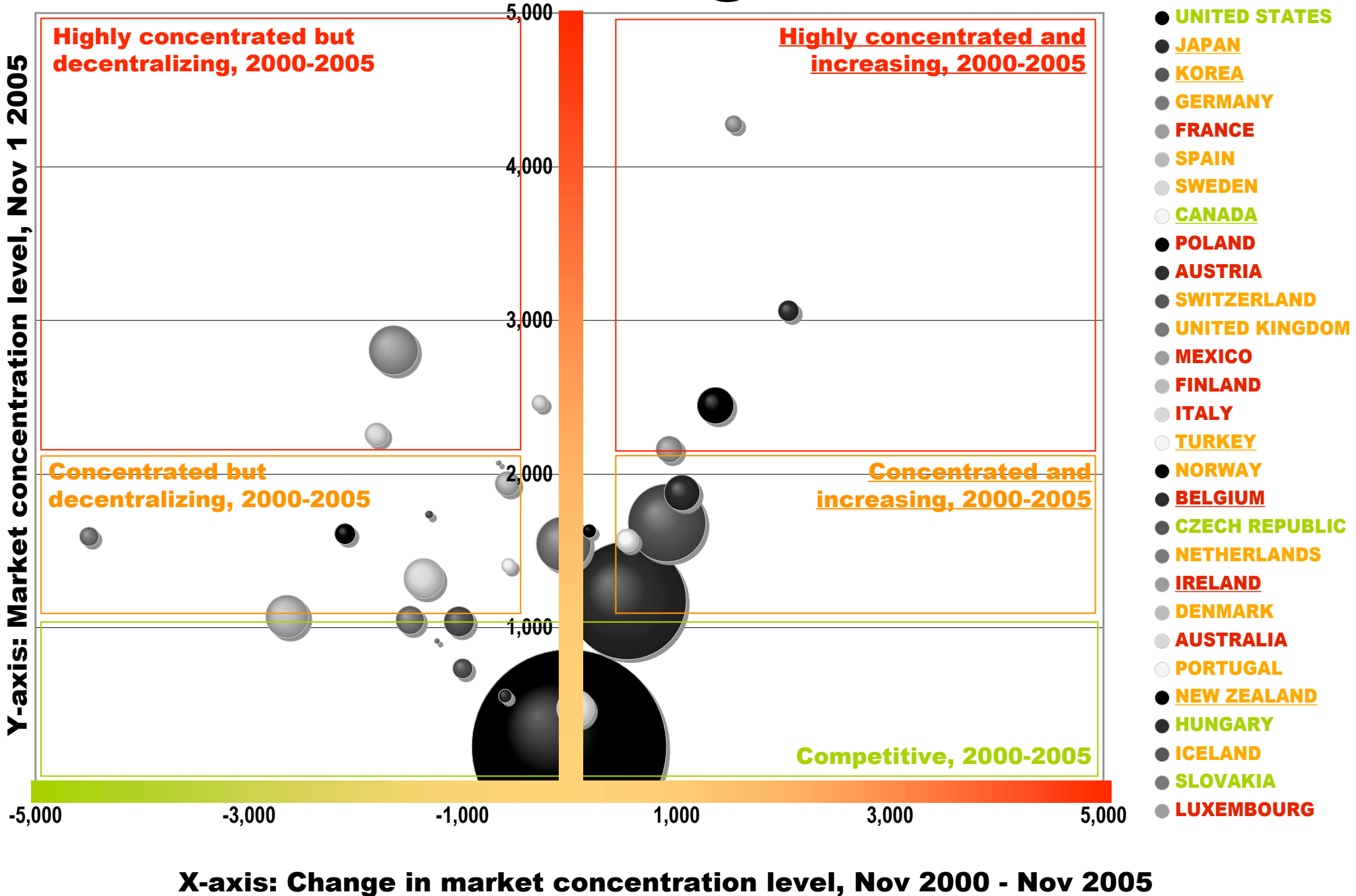
# Production Concentration



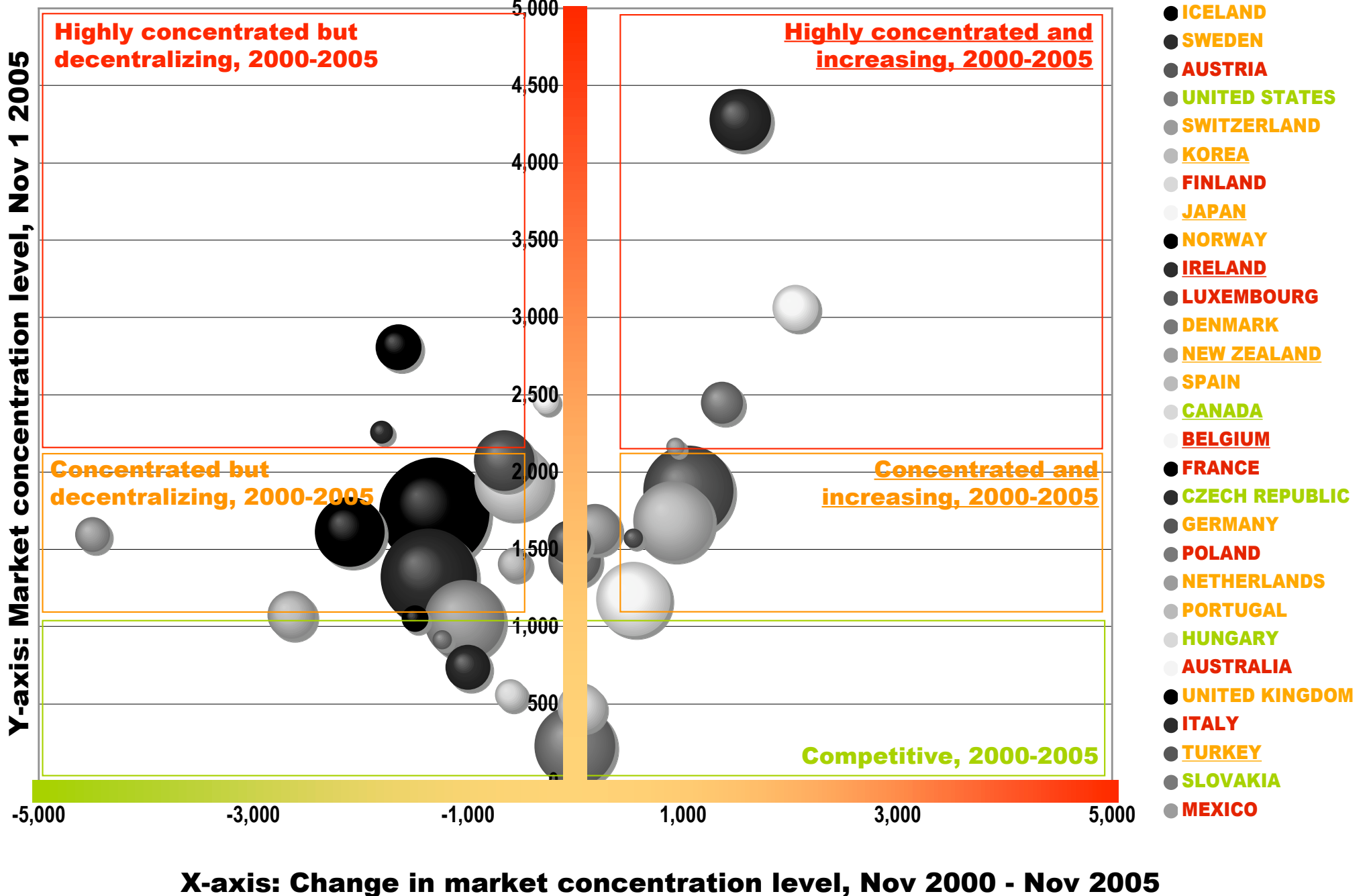
# relative growth



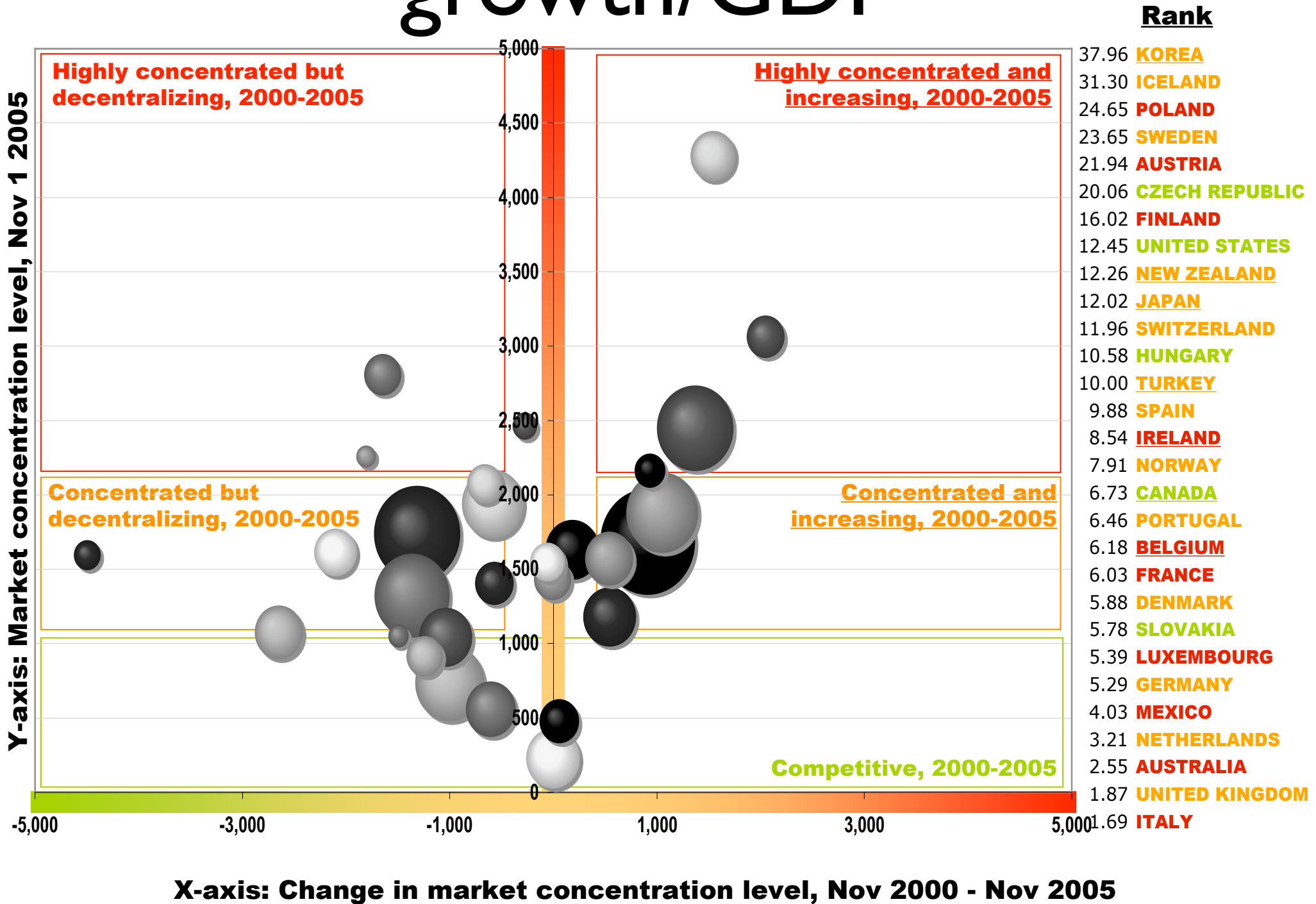
# absolute growth



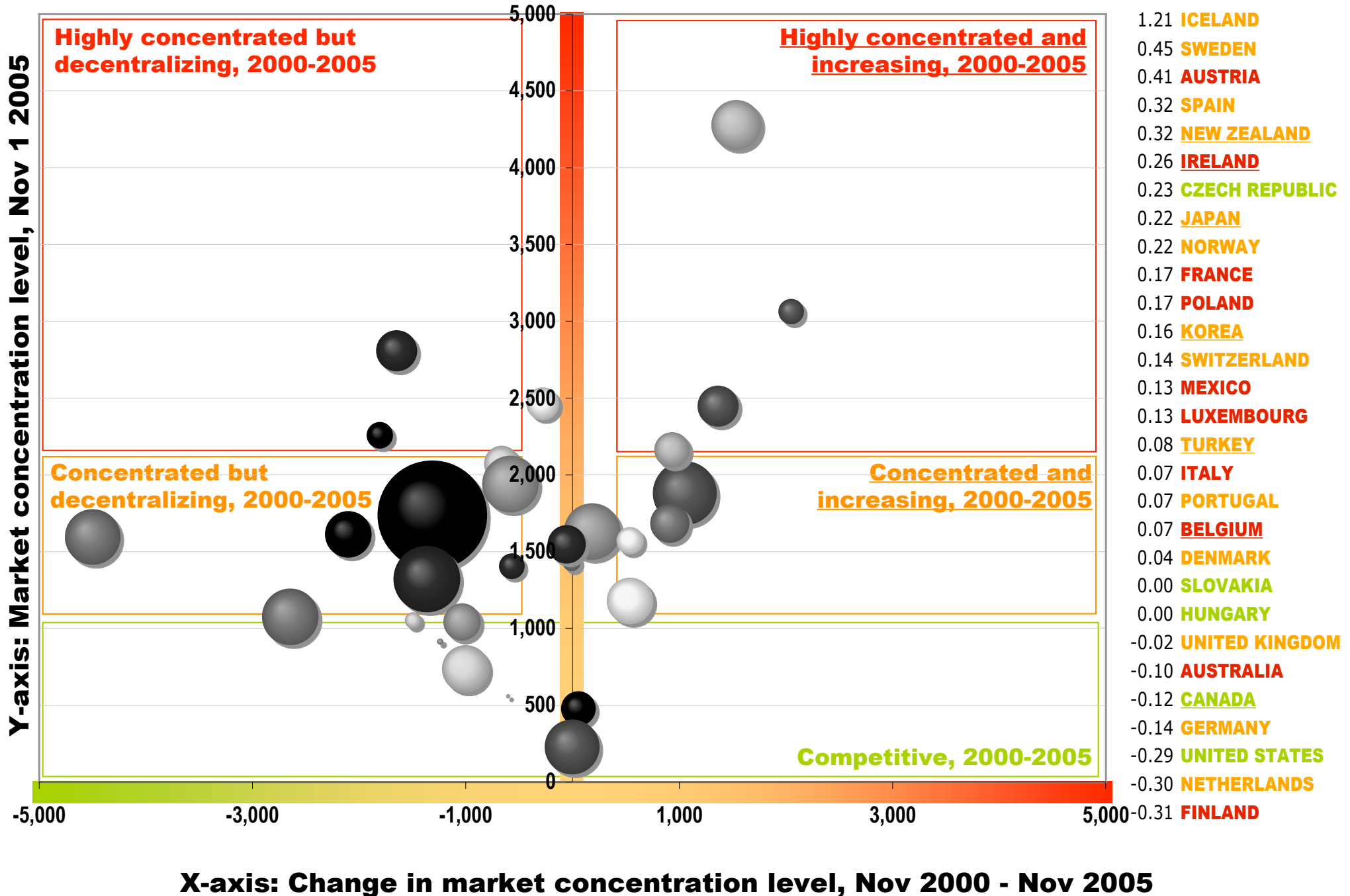
# growth per capita



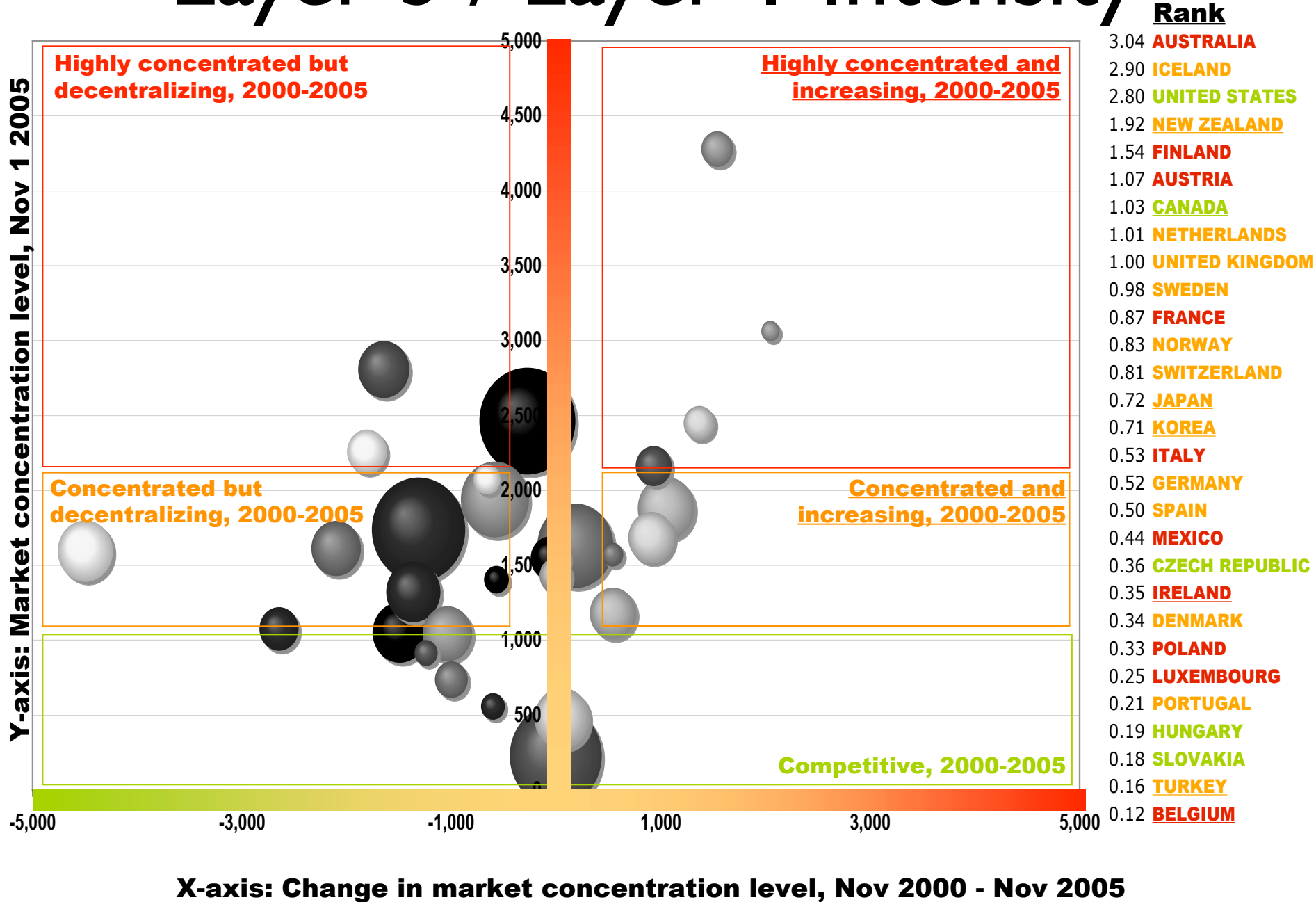
# growth/GDP



# Layer 3 / Layer I Intensity change



# Layer 3 / Layer I Intensity



# preliminary observations

Average national Internet production growth between 2000-2005

Overall Internet production on 1 Nov 2005, plus growth since the launch of Southern Cross

Group share of overall OECD Internet production in 2000 and 2005

<b>Concentrated</b>	<b>79.34%</b>	<b>290,775,181</b>	<b>104,981,957</b>	<b>56.50%</b>	<b>16.93%</b>	<b>21.26%</b>
Concentrating	118.29%	128,342,830	70,580,382	122.19%	5.26%	9.38%
Diffusing	80.32%	98,330,863	22,143,547	29.06%	6.94%	7.19%
Stationary	37.79%	64,101,488	12,258,028	23.64%	4.72%	4.69%

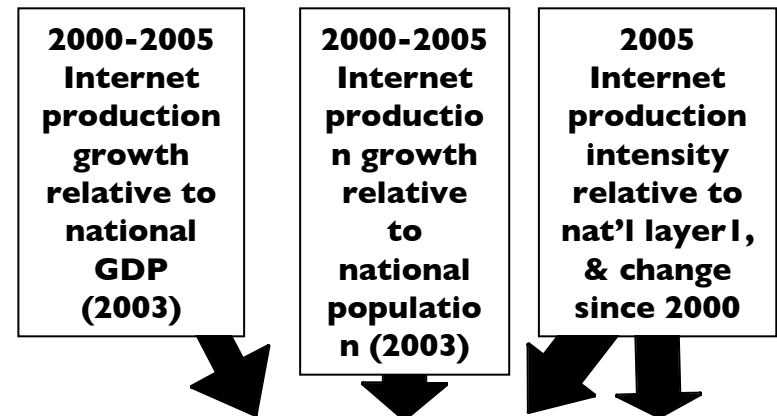
<b>Highly Concentrated</b>	<b>146.07%</b>	<b>121,313,020</b>	<b>28,181,331</b>	<b>30.26%</b>	<b>8.49%</b>	<b>8.87%</b>
Concentrating	230.73%	25,671,332	14,278,451	125.33%	1.04%	1.88%
Diffusing	76.07%	57,818,688	12,890,136	28.69%	2.94%	4.23%
Stationary	2.75%	37,823,000	1,012,744	2.75%	3.35%	2.77%

- OECD's "highly concentrated" markets, though growing are either barely pacing, or in some cases shrinking relative to overall OECD Internet growth.

# preliminary observations

- Among the OECD's stable "competitive" national network economies\* (HHI 1,000 or less), GDP and telecoms infrastructure tend to drive twice as much Internet production growth over time

\*Includes US, CA, HU, & CZ



<b>Competitive</b>	<b>0.17</b>	<b>11.12</b>	<b>0.91</b>	<b>-0.04</b>
Concentrating	na	na	na	na
Diffusing	0.08	12.14	0.24	-0.14
Stationary	0.30	9.59	1.91	0.12

<b>Concentrated</b>	<b>0.28</b>	<b>12.83</b>	<b>0.90</b>	<b>0.20</b>
Concentrating	0.28	19.99	0.53	0.15
Diffusing	0.32	12.03	1.03	0.26
Stationary	0.16	7.81	0.93	0.07

<b>Highly Concentrated</b>	<b>0.20</b>	<b>9.70</b>	<b>0.85</b>	<b>0.10</b>
Concentrating	0.22	13.07	0.46	0.21
Diffusing	0.21	7.28	0.80	0.02
Stationary	0.05	2.55	3.04	-0.10

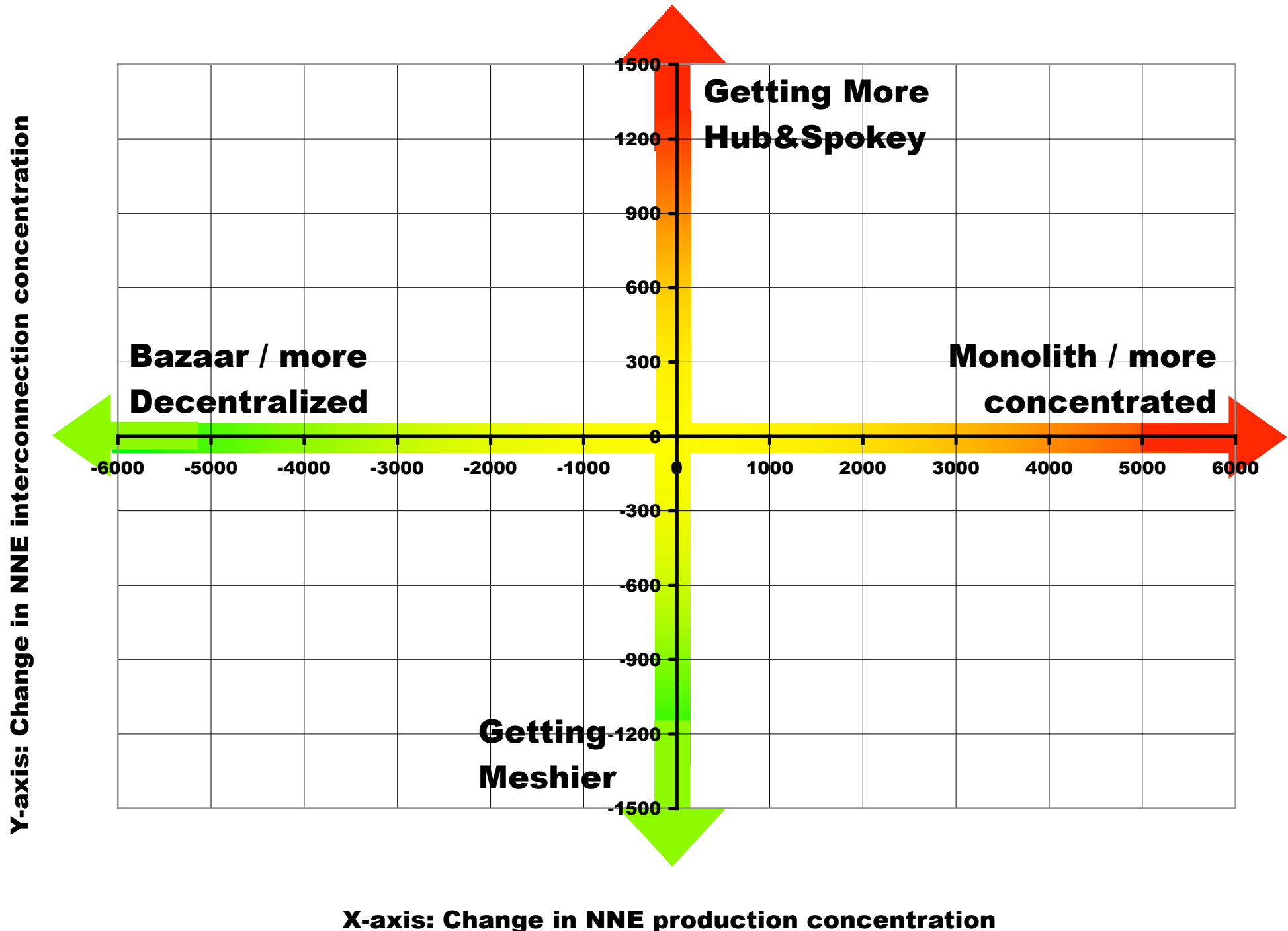
*Really need Bayesian analysis to evaluate results (coming soon)*

# methodology 1.1:

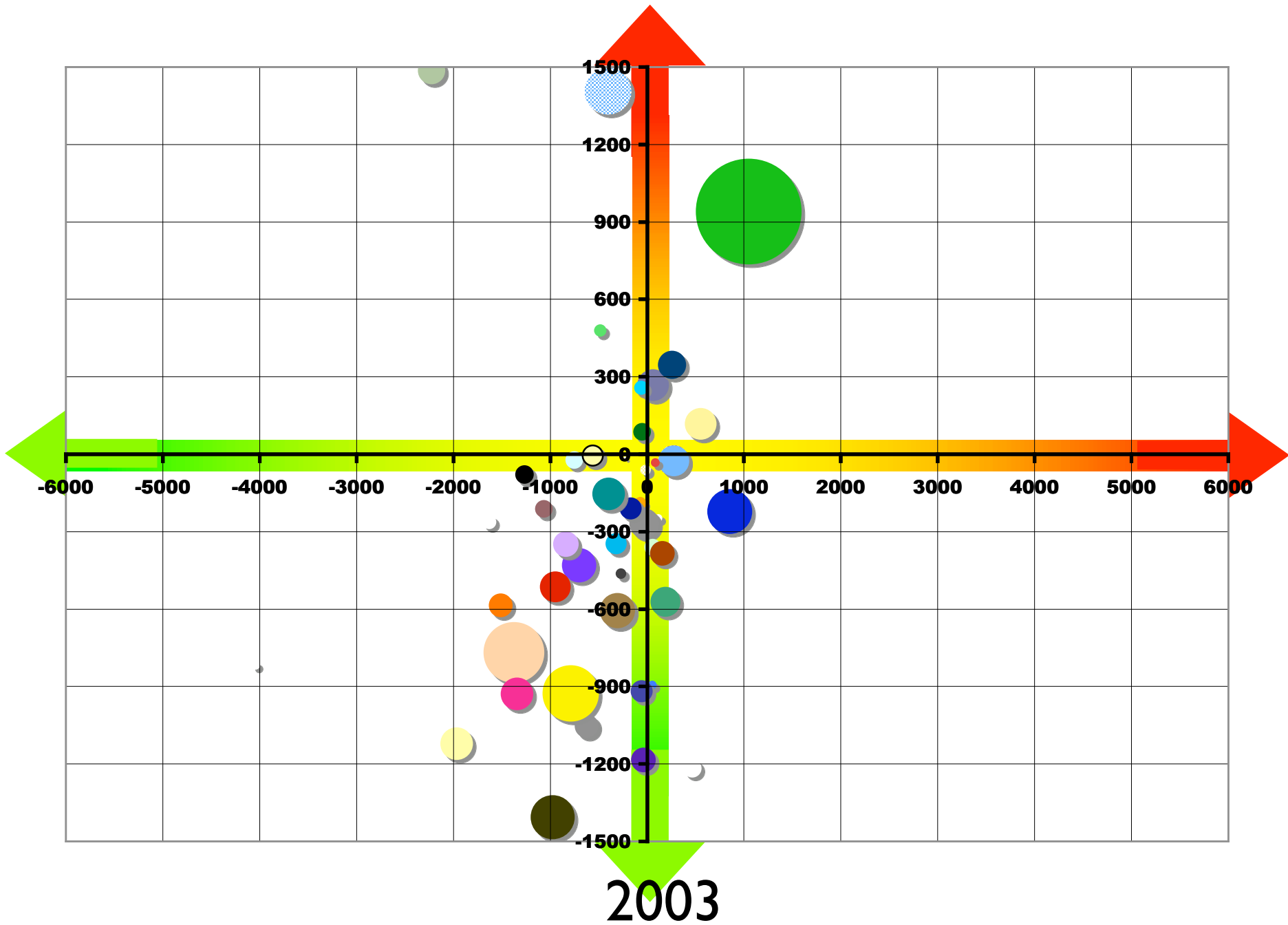
## production + interconnection

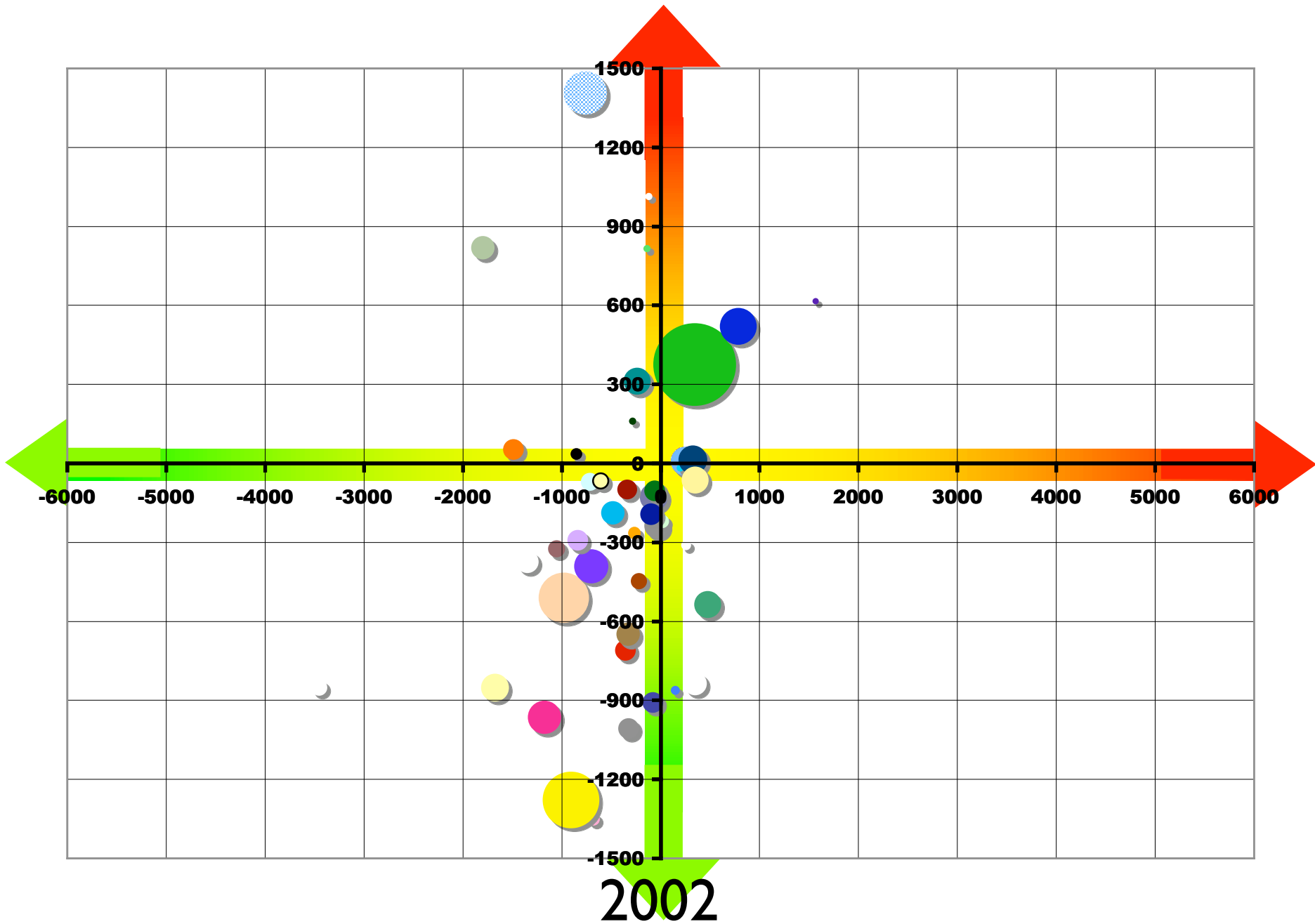
- HHI for internet production as before
- Interconnection as second dimension == sum of [AS degree (adjacencies) minus one] for ASNs with country code of ASN(s) allocation
- Subtracting one degree per AS to eliminate measurement error caused by singlehomers -- which currently constitute 15-60% of **every** NNE
- Market share == ratio of individual:total AS adjacencies grouped by country code of ASN(s) allocation
- National HHI == sum of squared (ASN adjacency shares) grouped by country code of ASN(s) allocation
- Adjacencies (AS degrees) generated with straightenRV

# Framework

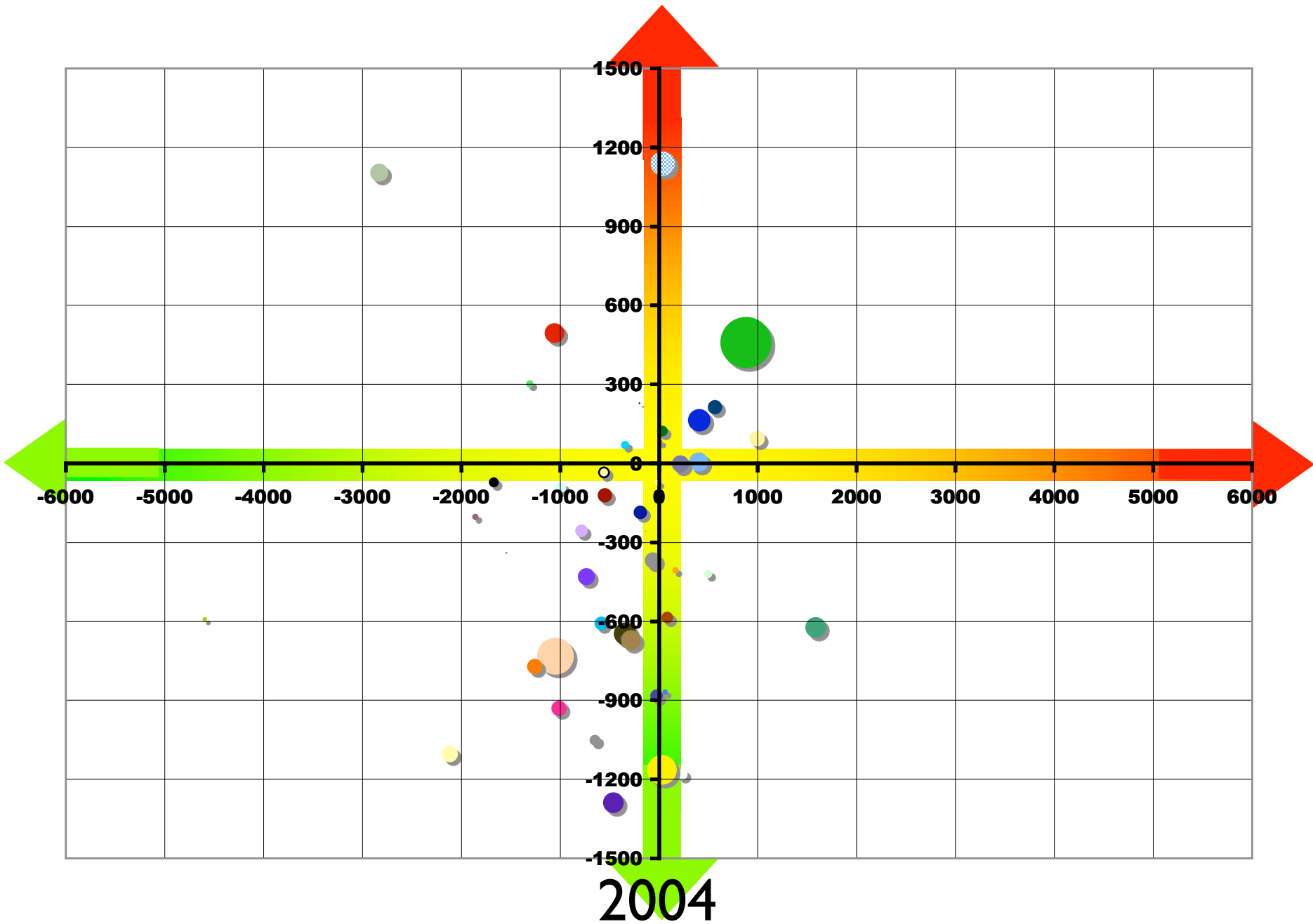




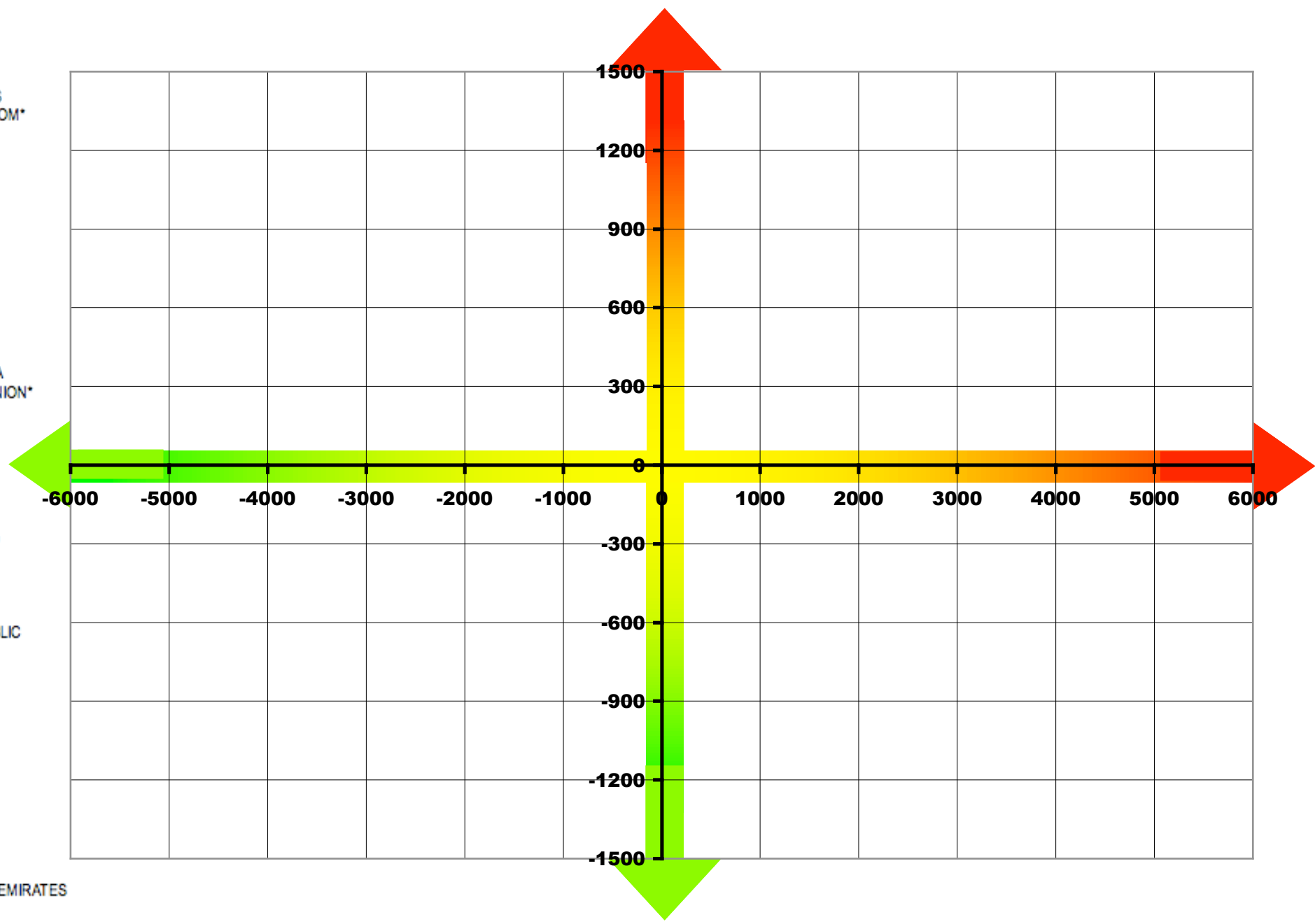








- UNITED STATES
- JAPAN
- CHINA
- JAPAN
- GERMANY
- CANADA
- AUSTRALIA
- NETHERLANDS
- UNITED KINGDOM\*
- BRAZIL
- FRANCE
- ITALY
- SPAIN
- SWEDEN
- HONG KONG
- FINLAND
- RUSSIA
- SWITZERLAND
- AUSTRIA
- MEXICO
- INDIA
- POLAND
- SOUTH AFRICA
- EUROPEAN UNION\*
- NORWAY
- TAIWAN
- MALAYSIA
- KOREA
- TURKEY
- CHILE
- THAILAND
- NEW ZEALAND
- ARGENTINA
- SINGAPORE
- ISRAEL
- DENMARK
- CZECH REPUBLIC
- ROMANIA
- BELGIUM
- VENEZUELA
- INDONESIA
- PORTUGAL
- HUNGARY
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- PHILIPPINES
- UKRAINE
- IRELAND
- BULGARIA
- EGYPT
- COSTA RICA
- UNITED ARAB EMIRATES

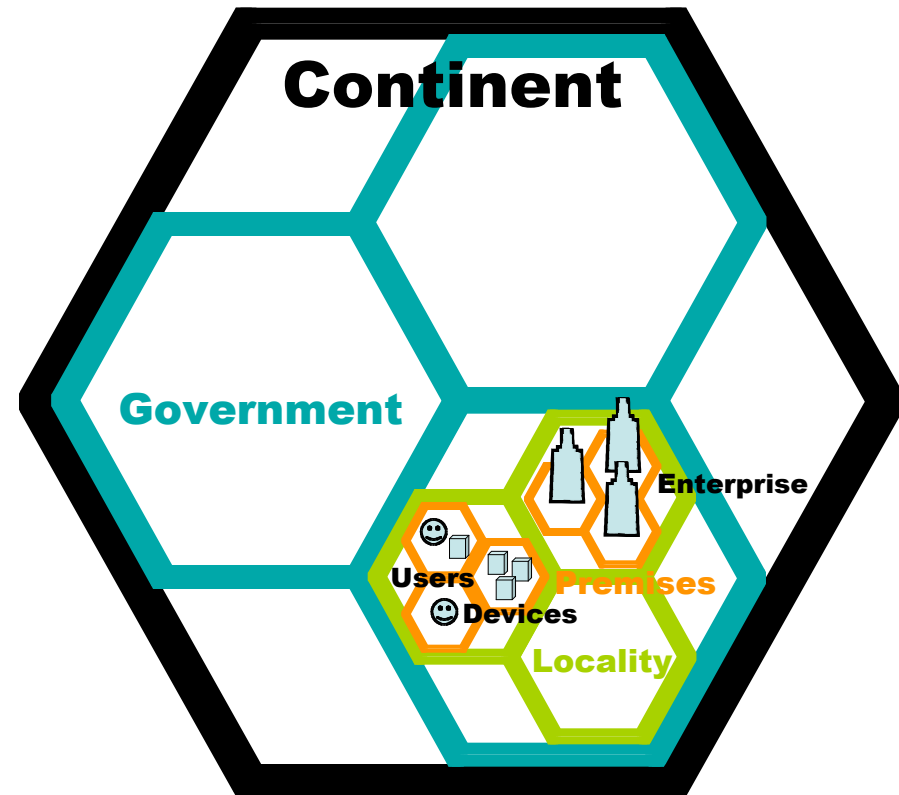
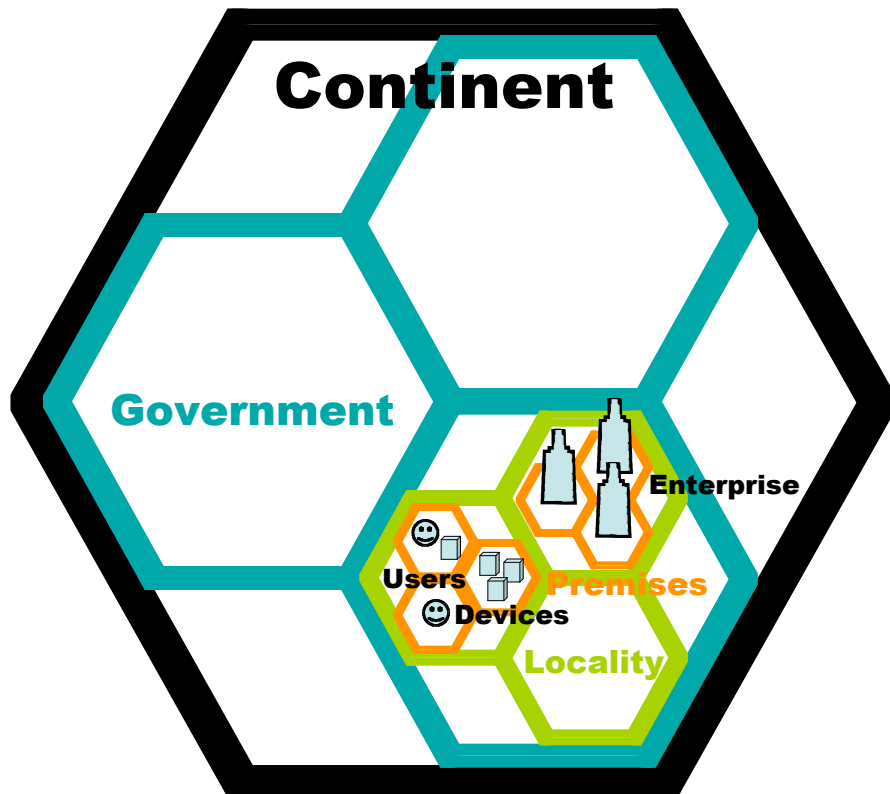


# future work (next week)

- International adjacencies as third dimension
- Identify multi-AS ARDs and recalculate market shares
- Examine NNE market structure as consequence of other factors:
  - Fully loaded local cost (availability, regulatory treatment, price) of gross infrastructure inputs, esp. access segments and international segments
  - Fractal treatment of “locality”...

# future work

Measuring local effects of variable treatment of intervening critical inputs



intercontinental  
international  
enterprise-enterprise  
enterprise-residential  
residential-residential

# toward an empirical network macro-economics..?

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