Driving Regional Innovation: Supplemental Report for Innovation Intelligence

Introduction

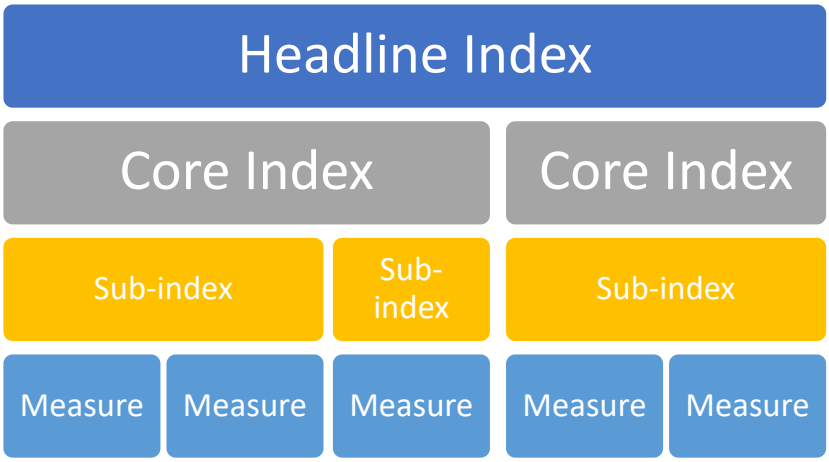
Five years after the release of the Innovation Index 2.0 (II2) in 2016, the Indiana Business Research Center (IBRC) is launching version three of the tool called **Innovation Intelligence** (II3). The new tool includes updated data, several new measures and a redesigned interface, which represents a full-scale upgrade of the popular tool. For the first time, we also provide some of the data behind the indexes on a time-series basis. This will help users chart progress on certain indicators over time and ensure the tool's data and insights can more easily be incorporated into economic development plans, such as Comprehensive Economic Development Strategy (CEDS).

This document serves as a supplement to the 2016 report *Driving Regional Innovation*, produced as part of II2. The first section is an overview of the structure of II3. The next section contains a summary of changes from II2—what measures we added and removed, new data sources and geographic coverage, etc.—along with the reasoning behind the changes. The final section contains the formulas for the measures.

Structure of Innovation Intelligence

Like the previous versions of the Innovation Index, the core of II3 is a collection of indexes that measure a region's innovation capacity and innovation outputs. The indexes are available at four geographic levels: counties, metropolitan statistical areas (MSAs), economic development districts (EDDs) and, new to this version, states. The II3 consists of a **headline index**, which combines all core and sub-indexes to reach an overall measurement of innovation capacity; **core indexes**, which are organized around broad topics related to innovation; and **sub-indexes**, which are more narrowly focused than core indexes. There are also a few "loner" measures

Figure 1: Innovation Intelligence Hierarchy



that aren't part of a sub-index but are part of a core index. This is largely unchanged from II2.[1] An example of the hierarchy is shown in *Figure 1*.

Summary of changes from II2

The II3 adds to and removes several measures from II2. *Table 1* lists the additions and deletions in II3.

Table 1: Summary of additions and deletions in II3

Change type	Measure Name	Core Index	Sub-index
Additions	Latent innovation	Employment & Productivity	Industry Profile
	Broadband infrastructure & adoption	Economic Wellbeing	Residential Internet Connectivity
	Broadband adoption barriers	Economic Wellbeing	Residential Internet Connectivity
Deletions	Business incubator spillovers	Human Capital & Knowledge Creation	Knowledge Creation & Technology Diffusion
	Density of residential fixed high-speed connections	Connectivity	Broadband Density & Penetration
	Average annual change in residential fixed high-speed connections	Connectivity	Broadband Density & Penetration
	Availability of capital from all banks	Business Profile	Proprietorship

Table 2 lists the general changes that have been made throughout the measures for consistency and relevancy.

Table 2: General changes to measures made throughout II3

Change from II2	Reason
10-year changes/averages were reduced to 5-year changes/averages	To use more recent data and for consistency

[1] There are some minor changes in the naming conventions of the indexes that we'll mention here for completeness. In the previous version of the Innovation Index, the "headline index" was called both the "Innovation Index" and the "headline index;" the "core indexes" were called "index categories;" and "sub-indexes" were called "core indexes." We made the changes for clarity and consistency.

3-year averages were increased to 5-year averages	To be more consistent with measures that cover a period greater than one year
Measures that were changes/averages from 2002 to the last year available were changed to 5-year changes/averages	To use more recent data and for consistency

Table 3 lists the measures in II3 that have been modified from the prior version of the index.

Table 3: Summary of modifications to individual measures in II3

Measure Name	Core Index	Sub-index	Change from II2
Traded sector births to deaths ratio	Business Dynamics	Establishment Dynamics	II3: the ratio of establishment births to deaths in high-tech, traded industries II2: called "Traded sector establishment dynamics" and incorporated expansions and contractions into the calculation
Change in establishment births to all establishment ratio	Business Dynamics	Establishment Formation	II3: five-year change II2: 10-year change of three-year averages
Jobs attributed to establishment expansions to contractions ratio	Business Dynamics	Establishment Formation	II3: jobs gained from est. expansions divided by jobs lost from est. contractions II2: est. expansions divided by est. contractions
Foreign direct investment (FDI) measures	Business Profile	Foreign Direct Investment Attractiveness	II3: measure names were changed to be clearer than in II2
Farm operators with internet access	Business Profile	Proprietorship	II3: measure name was changed II2: called "Online agriculture"
Proprietorship rate	Business Profile	Proprietorship	II3: five-year average

			II2: last year available (2014)
Government transfers to total personal income ratio	Economic Wellbeing	N/A	II3: name changed for clarity II2: called "Dependency ratio– measured by income sources"
Average gross domestic product (per worker)	Employment & Productivity	GDP	II3: five-year average II2: last year available (2014)
Industry cluster growth factor	Employment & Productivity	N/A	II3: changed methods for identifying regional growth clusters
Industry cluster strength	Employment & Productivity	N/A	II3: incorporated a measure of clusters in neighboring regions into calculation
Industry diversity	Employment & Productivity	N/A	II3: name changed, and measure uses NAICS industries II2: called "Cluster diversity" and uses Porter cluster definitions
Change in average patenting rate (per 1,000 workers)	Employment & Productivity	Patents	II3: Five-year change in two-year averages II2: Ten-year change in three-year averages
Average prime working-age (25-44) population growth	Human Capital & Knowledge Creation	N/A	II3: more precise name II2: called "Salad days population growth"
Average technology-based knowledge occupation clusters	Human Capital & Knowledge Creation	STEM Education & Occupations	II3: five-year average II2: last year available (2014)

Rationales for changes

This section contains the reasoning for the changes we've made in II3. Some measures have been changed because of data availability, while others have been changed to reflect emerging trends in innovation research.

Additions and Deletions

Latent innovation: Latent innovation, produced by Stephan Goetz and Yicheol Han at Penn State University, improves on conventional measures of innovation, like patents, R&D spending, and employment of STEM workers to measure unconventional or latent innovation in terms of spatial proximity to innovative industries and inter-industry transactions.[i] They use input-output (IO) tables to gauge the extent to which industries uniquely interact with and influence each other and contribute differently to latent innovation. They also include a measure of spatial colocation of industries, motivated by work showing that patent citations have clear spatial patterns and that industries in the same locations tend to collaborate with each other and exchange knowledge.[ii] To capture this, they measure the degree to which firms in different industries co-locate in the same county using a correlation coefficient. An advantage to their measure is that it shows that innovation is widespread across the United States; this isn't often the case when using a measure like patents, which tends to be highly concentrated in metro areas.

Full description of IBRC's algorithm replicating Goetz and Han:
We start with the 2012 national use table from IMPLAN, which shows the consumption of commodities by each industry (3- and 4-digit NAICS). This is a matrix that describes the sales of commodities from one industry to another.

1. We use the matrix to calculate the proportions of transactions to and from each industry. This results in two sets of proportions: set (1) describes the proportions of an industry's total *sales* that are made to each industry, and (2) describes the proportions of an industry's total *purchases* that are made from each industry.
2. Concurrently, we use the IBRC's "QCEW-complete" estimates of employment, which "fill in the holes" of the U.S. Bureau of Labor Statistic's QCEW data set, to calculate the pairwise correlation between employment in different industries by geography.
3. The correlation coefficients are used as weights on the proportions of transactions to and from industries. They have the effect of increasing the influence of transactions between industry pairs that are more connected and decreasing the influence between industry pairs that are less connected.
4. The two sets of weighted proportions are logged and summed up by industry; we refer to these as entropy scores.
5. We use the QCEW-complete data to calculate the share of employment in each industry in each of the geographies in the U.S. These shares are logged and summed up by industry to generate a ubiquity score, where higher values indicate the industry is more widespread across the U.S. and lower values indicate the industry is less widespread.
6. Next, for each industry, we add the two entropy scores together and divide by ubiquity; we refer to this as the "y-value."
7. To apply the y-value to each geography, we multiply it by the share of each industry in the geographies generated in step (5). We call this value the "zeta."
8. The zetas are summed up for each geography. Finally, we normalize this by calculating the z-score of the zeta. This is the latent innovation measure.

Broadband infrastructure and adoption and broadband adoption barriers: These measures come from the 2019 Digital Divide Index (DDI), produced by Roberto Gallardo at the Purdue Center for Regional Development at Purdue University.[iii] They replace the broadband-related measures in II2 from the FCC because they are more broadly encompassing of broadband infrastructure, access and adoption. Broadband infrastructure and adoption includes several variables from the Census ACS and FCC Form 477: the percent of 2019 population without access to 100/20 fixed broadband, median advertised download and upload speeds, percent of homes without internet access or not subscribing and percent of homes with no computing access. Broadband adoption barriers are the socioeconomic factors that may lead to lower broadband adoption and include variables from the ACS: percent of the population age 65+, percent of the population 25+ with less than a high school diploma, the poverty rate, and percent of the civilian non-institutionalized population with a disability.

Business incubator spillovers: We removed this measure because the source, the National Business Incubation Association (NBIA), no longer provides the data needed for the measure, and no alternative sources could be identified.

Density of residential fixed high-speed connections and **average annual change in residential fixed high-speed connections**: We replaced these measures with the DDI measures.

Availability of capital from all banks: We removed this measure because of inconsistent data availability.

State indexes: New in II3 is a state-level innovation index. Most measures and indexes available at the county, MSA and EDD level are also available at the state level. However, there are some measures that don't make sense to have at the state level because they are regionally-based, such as industry cluster strength and latent innovation. As a result, the Industry Cluster Performance and Industry Performance sub-indexes aren't available for states.

Modifications

Jobs attributed to establishment expansions to contractions ratio: We changed this from establishment expansions to contractions ratio because the source, Census Business Dynamics Statistics, no longer provides data for counts of establishment expansions and contractions. Instead, they provide counts of *jobs gained or lost* due to expansions or contractions. They functionally measure the same thing—whether firms are growing or shrinking—so this doesn't present an issue in II3.

Average prime working-age (25-44) population growth: We modified the name from "salad days (age 25-44) population growth" for clarity.

Technology-based knowledge occupation clusters: We changed this measure from the last year available to an average of the past five years to be more consistent with other measures in the STEM Education and Occupations sub-index.

Change in establishment births to all establishment ratio: We changed this measure from a 10-year change in three-year averages to a five-year change to be more straightforward and so it would reflect more recent establishment creation.

Traded sector establishment births to deaths ratio: In II2, this measure was called "Traded sector establishment dynamics" and incorporated traded sector establishment births and deaths, as well as contractions and expansions. Establishment contractions and expansions in traded industries are no longer reported by the Business Dynamics Statistics, so we removed these from the calculation.

Foreign direct investment (FDI) measures: We changed the names of these measures for clarity. "FDI employment index, national source" is now **FDI employment ratio, domestic source**; "FDI investment index, national source" is **FDI investment ratio, domestic source**; "FDI employment index, foreign source" is **FDI employment ratio, foreign source**; and "FDI investment index, foreign source" is **FDI investment ratio, foreign source**.

Farm operators with internet access: We changed the name from "online agriculture" for clarity.

Proprietorship rate: We changed this measure from the last year available, which was 2014 at the time of II2, to an average of the past five years of available data, 2015-2019.

Industry diversity: We changed the name from "cluster diversity" because the calculation is now based on NAICS industries, not industry clusters.

Change in average patenting rate (per 1,000 workers): We changed this to a four-year change in two-year averages to use more recent data and because of data availability issues. At the time of this writing, the most recent data available for this measure is 2019. So, the measure compares the patenting rate in 2013-2014 to the patenting rate in 2018-2019.

Industry cluster growth factor: We changed the methods for identifying "true" clusters, i.e., we made the criteria for determining whether a cluster exists in a region more stringent. The steps to identify true clusters are as follows:

1. Begin with *traded* 6-digit NAICS industries in each geography for the most recent year available, 2018.
2. Calculate the traded cluster location quotients (LQs) for each cluster by summing up the industries within each cluster in each geo, finding the percent of the geo's total traded employment that is in each cluster, and dividing this by the U.S. percentage.
3. Remove the largest industry from each cluster and recalculate the LQs.
4. Remove the second-largest industry from each cluster and recalculate the LQs.
5. "True" clusters are defined as having a traded cluster LQ greater than one after the two largest industries are removed from each cluster.

Steps (3) and (4) are the changes from II2. We added these steps because, in the previous iteration, many geos had clusters with high employment in the largest industries that were inflating the clusters' LQs. Since the concept of clusters is informed by agglomeration economies—or the benefits reaped due to co-location of firms in the same or related industries—if only a single or even two industries have significant employment, it's hard to say there's agglomeration in the cluster.

Industry cluster strength: We changed the methods for industry cluster strength to reflect the fact that smaller geographies like counties are embedded in regions with unique capacities and strengths and may specialize in many clusters. We use labor market areas (LMAs) as defined by the USDA Economic Research Service[iv] and refined by Fowler, et al (2016).[v] These LMAs have the advantage of including every county in the U.S. and are more recent than similar delineations of labor markets, such as economic areas defined by the U.S. Bureau of Economic Analysis, which were last revised in 2004. This measure is calculated as the average cluster LQ in all other geographies (counties, MSAs, and economic development districts) in the same labor market area.

Average gross domestic product (per worker): We changed average GDP from a one-year measure to an average of the past five years of data, 2015-2019, to be more consistent with other measures in the Employment & Productivity Core Index.

Government transfers to total personal income ratio: We changed this measure's name from "Dependency ratio—government transfers" for clarity.

Measure Formulas

This section contains the formulas for all measures in II3. *Tables 4* and *5* list abbreviations and acronyms we use throughout, and *Table 6* contains the formulas.

Table 4: Recurring abbreviations in measure formulas

Abbreviation	Description
g	Region
t	Year
lya	Last year available
emp	Employment
pop	Population
ttl	Total

Table 5: Recurring acronyms for data sources

Acronym	Description
ACS	American Community Survey, U.S. Census Bureau
BEA	U.S. Bureau of Economic Analysis

BIC	Broad Industry Category
CBP	County Business Patters
FSCPE	Federal-State Cooperative of Population Estimates, U.S. Census Bureau
NAICS	North American Industry Classification System
QCEW	Quarterly Census of Employment and Wages, U.S. Bureau of Labor Statistics

Table 6: Measure formulas

Measure Name	Formula
High School Attainment	$$edHS_g = \frac{pop18to24_{g,lya} - noHSatt_{g,lya}}{pop18to24_{g,lya}} * 100$$ *noHSatt: ACS 18-24 pop without a high school diploma*
Some College Attainment	$$edSC_g = \frac{somecol_{g,lya}}{pop25abv_{g,lya}} * 100$$ *pop25abv: ACS 25+ pop* *somecol: ACS 25+ pop with some college*
Associate Degree Attainment	$$edAD_g = \frac{assc_{g,lya}}{pop25abv_{g,lya}} * 100$$ *pop25abv: ACS 25+ pop* *assc: ACS 25+ pop with an associate degree*
Bachelor's Degree Attainment	$$edBach_g = \frac{bach_{g,lya}}{pop25abv_{g,lya}} * 100$$ *pop25abv: ACS 25+ pop* *bach: ACS 25+ pop with a bachelor's degree*
Graduate Degree Attainment	$$edGrad_g = \frac{grad_{g,lya}}{pop25abv_{g,lya}} * 100$$ *pop25abv: ACS 25+ pop* *grad: ACS 25+ pop with a graduate degree*
Patent Technology Diffusion	$$diff_p = \left(\frac{r_p - \bar{r}}{\bar{r}}\right) + \left(\frac{s_p - \bar{s}}{\bar{s}}\right)$$ $$diff_c = \frac{\sum_p diff_{p,c}}{ttl_{p,c}}$$ $$patdiff_g = \frac{\sum_{c=n}^{N} diff_c * patcount_{g,c}}{\sum_{c=n}^{N} patcount_{g,c}}$$ *r: the mean number of citations* *s: mean number of unique classes per citation* *Diffusion ranges from –2 to 143 (ii2)*

	p: individual patent *c: 12 categories assigned to each individual patent*
University-Based Knowledge Spillovers	$$Kspl_{c,t} = \sum_{n=1}^{N} [ln\ (1{,}000 \times RD_{n,t} + 1) \times e^{-(dst/100)}]$$ $$Kspl_c = \frac{\sum_{t=lya-2}^{lya} Kspl_{c,t}}{3}$$ *n: counties within 50 miles of county c* *dst: distance between county c and county n* *RD: total R&D spending in engineering, geosciences, life sciences, math and computer science, and physical science in thousands of dollars for all universities* For multi-county regions, Kspl is defined as: $$Kspl_g = \sum_{c=1}^{c=N} \left(\frac{emp_{g,c}}{emp_g}\right) \times Kspl_c$$ *c: county* *N: total counties in region g* *$emp_{g,c}$: employment of county c in region g* *emp_g: employment of region g*
Average STEM Degree Creation (per 1,000 Population)	$$STEM2pop_{g,t} = \frac{ttlSTEM_{g,t}}{pop_t} \times 1{,}000$$ $$avgSTEM2pop_g = \frac{\sum_{t=lya-4}^{lya} STEM2pop_{g,t}}{5}$$ *ttlSTEM: total number of graduates in STEM fields at all levels*
Average Technology-Based Knowledge Occupation Clusters	$$TCKempcl_g = \frac{TCKemp_{g,t}}{ttlemp_{g,t}}$$ $$avgTCKempcl_g = \frac{\sum_{t=lya-4}^{lya} TCKempcl_{g,t}}{5}$$ *ttlemp: total employment* *TCKemp: total employment in technology-based clusters (from Porter definitions).*

Average High-Tech Industry Employment Share	$$HTsh_{g,t} = \frac{HTemp_{g,t}}{ttlemp_{g,t}}$$ $$avgHTsh_g = \frac{\sum_{t=lya-4}^{lya} HTsh_t}{5}$$ *ttlemp: total employment* *HTemp: employment in high-tech industries: manufacturing (NAICS sectors 31-33); information (51); professional, scientific, and technical services (54); and management of companies and enterprises (55)*
Average Prime Working-Age (25-44) Population Growth	$$delta_{g,t} = \frac{pop25to44_{g,t} - pop25to44_{g,t-1}}{pop25to44_{g,t-1}}$$ $$pwagrowth_g = \frac{\sum_{t=lya-4}^{lya} delta_{g,lya}}{5}$$ *Pop25to44: ACS age 25 to 44 population*
Establishment Births to All Establishments Ratio	$$estBr_g = \frac{B_{g,lya}}{ttlest_{g,lya}}$$ *B: Establishment births* *ttlest: Establishment total at the beginning of year t*
Traded Sector Establishment Births to All Establishment Ratio	$$esttrBr_g = \frac{trB_{g,lya}}{ttltrest_{g,lya}}$$ *trB: Traded establishment births* *ttltrest: Traded total establishments*
Jobs Attributed to Estab. Births to Total Employment Ratio	$$jobBr_g = \frac{jobB_{g,lya}}{ttljob_{g,lya}}$$ *ttljob: Job total at the beginning of the last year available* *jobB: Jobs attributed to establishment births (B)*

Change in Establishment Births to All Establishment Ratio	$$estB_{g,lya} = \frac{B_{g,lya}}{ttlest_{g,lya}}$$ $$estB_{g,lya-4} = \frac{B_{g,lya-4}}{ttlest_{g,lya-4}}$$ $$estBd = \frac{estB_{g,lya} - estB_{g,lya-4}}{estB_{g,lya-4}}$$ *B: Establishment births* *D: Establishment deaths* *ttlest: Establishment total at the beginning of year t (D+X+C+ noΔ)‡*
Average Small Establishments (per 10,000 Workers)	$$Sestpw_{g,t} = \frac{Sest_{g,t}}{ttlemp_{g,t}/1000}$$ $$avgSest_g = \frac{\sum_{t=lya-4}^{lya} Sestpw_g}{5}$$ *Sest = CBP small establishments with less than 20 employees (for all industries)* *ttlemp = BEA total employment (for all industries)*
Average High-Tech, Early-in-Life-Cycle Establishment Ratio	$$SQ_{i,g,t} = \frac{Sest_{i,g,t}}{ttlest_{i,g,t}}$$ $$SQ_{i,US,t} = \frac{Sest_{i,US,t}}{ttlest_{i,US,t}}$$ $$P_{i,g} = \frac{ttlest_{i,g,t}}{ttlest_{g,t}}$$ $$ttlSestqt_g = \frac{SQ_{i,g,t}}{SQ_{i,US,t}} \times (P_{i,g,t})$$ $$ttlSestqt_{g,t} = \sum_{BIC=1}^{10} ttlSestqt_{i,g,t}$$ $$ttlSestqt_g = \frac{ttlSestqt_{g,lya} + ttlSestqt_{g,lya-4}}{2}$$

	Sest: Number of small establishments *ttlest = Total number of establishments* *i: high-tech BIC from Table 7 in the appendix*
Job Expansions to Contractions Ratio	$$jobX2C_g = \frac{X_{g,lya}}{C_{g,lya}}$$ *X: Job expansions* *C: Job contractions*
Establishment Births to Deaths Ratio	$$estB2D_g = \frac{B_{g,lya}}{D_{g,lya}}$$ *B: Establishment births* *D: Establishment deaths*
Traded Sector Births to Deaths Ratio	$$trestdyna_g = \frac{\mathrm{trB_{g,lya}}}{\mathrm{trD}_{g,\mathrm{lya}}}$$ *trB: Traded, high-tech, establishment births* *trD: Traded, high-tech, establishment deaths*
Average Annual Venture Capital (scaled by GDP)	$$avgVC\$_g = \frac{\sum_{t=lya-4}^{lya} VC\$_{g,t}}{5}$$ $$avgGDP_g = \frac{\sum_{t=lya-4}^{lya} GDP_g}{5}$$ $$VC2GDP_g = \frac{avgVC\$_g}{avgGDP_g}$$ *VC$: Venture capital, dollars* *GDP: Current-dollar GDP*
Average Annual Expansion Stage Venture Capital (scaled by GDP)	$$avgVCXstg_g = \frac{\sum_{t=lya-4}^{lya} VCXstg\$_{g,t}}{5}$$

	$$avgGDP_g = \frac{\sum_{t=lya-4}^{lya} GDP_g}{5}$$ $$VCX2GDP_g = \frac{VCXstg_g}{avgGDP_g}$$ *GDP: Current-dollar GDP* *VCXstg: Expansion stage funding (Company Investment Stage 2 at Round Date, value = Expansion).*
Average Annual High-Tech Industry Venture Capital (scaled by GDP)	$$avgVCHT_g = \frac{\sum_{t=lya-4}^{lya} VCHT_{g,t}}{5}$$ $$avgGDP_g = \frac{\sum_{t=lya-4}^{lya} GDP_{g,t}}{5}$$ $$VCHT2GDP_g = \frac{avgVCHT_g}{avgGDP_g}$$ *GDP: Current-dollar GDP* *VCHT: Funding for high-tech industries (NAICS: all 6-digit industries within the 4-digit high-tech industry set)*
Change in Average Venture Capital	$$avgVC\$_{g,lya} = \frac{\sum_{t=lya-2}^{lya} VC\$_{g,t}}{3}$$ $$avgVC\$_{g,lya-10} = \frac{\sum_{t=lya-12}^{lya-10} VC\$_{g,t}}{3}$$ $$VC\$d_g = \frac{VC\$_{g,lya-10} - VC\$_{g,lya}}{VC\$_{g,lya}}$$ *VC$: Venture capital, dollars*
Average Initial Public Offerings (scaled by GDP)	$$avgIPO_{g,lya} = \frac{\sum_{t=lya-4}^{lya} IPO_t}{5}$$ $$avgGDP_{g,lya} = \frac{\sum_{t=lya-4}^{lya} GDP_{g,t}}{5}$$

	$$IPO2GDP = \frac{avgIPO_{g,lya}}{avgGDP_{g,lya}}$$ *IPO: Total number of Initial Public Offerings* *GDP: Current-dollar GDP*
Average Annual Venture Capital Deals (scaled by GDP)	$$avgVCDeal_{g,lya} = \frac{\sum_{t=lya-4}^{lya} VCDeal_{g,t}}{5}$$ $$avgGDP_{g,lya} = \frac{\sum_{t=lya-4}^{lya} GDP_{g,t}}{5}$$ $$VCDeal2GDP_g = \frac{avgVCDeal_{g,lya}}{avgGDP_{g,lya}}$$ *VCDeal: Number of venture capital deals* *GDP: Current-dollar GDP*
Change in Average Venture Capital Deals	$$avgVCDeal_{g,lya} = \frac{\sum_{t=lya-2}^{lya} VCDeal_{g,t}}{3}$$ $$avgVCDeal_{g,lya-10} = \frac{\sum_{t=lya-12}^{lya-10} VCDeal_{g,t}}{3}$$ $$avgVCDeal = \frac{avgVCDeal_{lya} - avgVCDeal_{lya-10}}{avgVCDeal_{lya-10}}$$ *VCDeal: Number of venture capital deals*
FDI Employment Ratio, Foreign Source	$$FDIemp2labF_g = \frac{\sum_{t=lya-2}^{lya} FDIempF_{g,t}}{lab_{g,lya}} \times 1{,}000$$ $$FDIemp2labF_{US} = \frac{\sum_{t=lya-2}^{lya} FDIempF_{US,t}}{lab_{US,lya}} \times 1{,}000$$ $$FDIempF2US_g = \frac{FDIemp2labF_g}{FDIemp2labF_{US}} \times 100$$ *FDIempF: Foreign FDI employment announcements* *lab: ACS working-age population, defined as those between ages 18 and 66*

FDI Investment Ratio, Foreign Source	$$FDIinv2labF_g = \frac{\sum_{t=lya-2}^{lya} FDIinvF_{g,t}}{lab_{g,lya}} \times 1{,}000$$ $$FDIinv2labF_{US} = \frac{\sum_{t=lya-2}^{lya} FDIinvF_{US,t}}{lab_{g,lya}} \times 1{,}000$$ $$FDIinvF2US_g = \frac{FDIinv2labF_g}{FDIinv2labF_{US}} \times 100$$ *FDIinvF: Foreign FDI investment (in millions of $) announcements* *lab: ACS working-age population, defined as those between ages 18 and 66*
FDI Employment Ratio, Domestic Source	$$FDIemp2labUS_g = \frac{\sum_{t=lya-2}^{lya} FDIempUS_{g,t}}{lab_{g,lya}} \times 1{,}000$$ $$FDIemp2labUS_{US} = \frac{\sum_{t=lya-2}^{lya} FDIempUS_{US,t}}{\sum_{t=lya-2}^{lya} lab_{US,t}} \times 1{,}000$$ $$FDIempUS2US_g = \frac{FDIemp2labUS_g}{FDIemp2labUS_{US}} \times 100$$ *FDIempUS: U.S. FDI employment announcements* *lab: ACS working-age population, defined as those between ages 18 and 66*
FDI Investment Ratio, Domestic Source	$$FDIinv2labUS_g = \frac{\sum_{t=lya-2}^{lya} FDIinvUS_{g,t}}{lab_{g,lya}} \times 1{,}000$$ $$FDIinv2labUS_{US} = \frac{\sum_{t=lya-2}^{lya} FDIinvUS_{US,t}}{lab_{US,lya}} \times 1{,}000$$ $$FDIinvUS2US_g = \frac{FDIinvF2US_g}{FDIinvF2US_{US}} \times 100$$ *FDIinvUS: U.S. FDI investment announcements (in millions of $)* *lab: ACS working-age population, defined as those between ages 18 and 66*

Farm Operators with Internet Access	$$onlineagp_g = \frac{onlineag_{g,lya}}{ttlag_{g,lya}}$$ *onlineag: Number of farms operations with internet access* *ttlag: Total number of farm operations*
Proprietorship Rate	$$prpr_{g,t} = \frac{nfprp_{g,t}}{ttlemp_{g,t}}$$ $$avgprpr_g = \frac{\sum_{t=lya-4}^{lya} prpr_{g,t}}{5}$$ *nfprp = Number of nonfarm proprietors* *ttlemp = BEA total employment*
Change in Proprietorship Rate	$$prpr_{g,t} = \frac{nfprp_{g,t}}{ttlemp_{g,t}}$$ $$prprd_g = \frac{(prpr_{g,lya} - prpr_{g,lya-4})}{prpr_{g,lya-4}}$$ *Prpr: nonfarm proprietorship rate*
Proprietor Income to Total Wages and Salaries Ratio	$$prpinc2emp_g = \frac{prpinc_{g,lya}}{prpemp_{g,lya}}$$ $$WSinc2emp_g = \frac{WSinc_{g,lya}}{WSemp_{g,lya}}$$ $$prpinc2WS_g = \frac{prpin2emp_{g,lya}}{WSinc2emp_{g,lya}}$$ *prpinc: Proprietors' income* *prpemp: Number of proprietors* *WSinc: Total wages and salaries* *WSemp: Number of wage and salary employees*

Average Large Establishments (per 10,000 Workers)	$$Lestpw_{g,t} = \frac{Lest_{g,t}}{ttlemp_{g,t}/10{,}000}$$ $$avgLest_g = \frac{\sum_{t=lya-4}^{lya} Lestpw}{5}$$ *Lest: CBP large establishments with 500 or more employees* *Ttlemp: BEA total employment for year t*
Latent Innovation	$$p_{kj}^{in} = \frac{x_{kj}}{\sum_l x_{lj}}$$ $$p_{jk}^{out} = \frac{x_{jk}}{\sum_l x_{jl}}$$ $$e_j^{in} = \sum_k r_{kj}(-p_{kj}^{in} \log(p_{kj}^{in}))$$ $$e_j^{out} = \sum_k r_{jk}(-p_{jk}^{out} \log(p_{jk}^{out}))$$ $$p_{ij} = \frac{m_{ij}}{\sum_k m_{kj}}$$ $$u_j = -\sum_i p_{ij} \log(p_{ij})$$ $$y_j = (e_j^{in} + e_j^{out})/u_j$$ $$\zeta_i = \sum_j y_j * sm_{ij}$$ $$z_i = (\zeta_i - \bar{\zeta})/\sigma(\zeta)$$ *x_{ij}: amount of goods/services transacted from industry j to k* *$e_j^{in/out}$: entropy of purchases (in)/sales (out) of industry j* *r_{kj}: the correlation coefficient between industry j and k* *m_{ij}: employment in industry j in county i.* *u_j: ubiquity score (should be between 0 and 1). Higher ubiquity implies a lower level of latent innovation.* *sm_{ij}: the share of each industry j's employment in the county i.* *ζ: raw latent innovation score* *$\sigma(\zeta)$: the standard deviation of the raw latent innovation score* *z_i: standardized latent innovation score*

Industry Diversity	$$p_{i,g,t} = \frac{emp_{i,g}}{emp_g}$$ $$SEI_g = \sum_{i=1}^{N} [(p_{ig}) * \ln(p_{i,g})] / \ln(N)$$ $$diversity_g = \frac{SEI_g}{SEI_{US}}$$ *i: industry* *g: region (i.e. county, MSA, etc)* *N: number of industries present in region*
Industry Cluster Growth Factor	First iteration: $$cluster\ growth_g = \frac{\sum_{d=1}^{N}(emp_{g,d,t} - emp_{g,d,t-10})}{emp_{g,d,t-10}}$$ Remove the largest industry from each cluster and repeat. Remove the second-largest industry from each cluster and repeat. *t: year* *d: dominant cluster*
Industry Cluster Strength	$$nemp_g = emp_{lma} - emp_g$$ $$nemp_{g,c} = emp_{lma,c} - emp_{g,c}$$ $$LQ_{g,c} = \frac{nemp_{g,c}/emp_g}{nemp_{USc}/emp_{US}}$$ $$Neighbor\ Cluster\ Strength_g = \frac{\sum_{c=1}^{C} LQ_{n,c}}{C}$$ *c: cluster* *lma: Labor Market Area* *C: number of clusters in region g*
Average Gross Domestic Product (per Worker)	$$GDP2emp_g = \frac{GDP_{g,t}}{ttlemp_{g,t}}$$ $$avgGDP2emp_g = \frac{\sum_{t=lya-4}^{lya} GDP2emp_{g,t}}{5}$$

	GDP: IBRC current-dollar GDP by county *Ttlemp: BEA total employment in region*
Change in Gross Domestic Product (per Worker)	$$GDPemp_{g,t} = \frac{GDP_{g,t}}{ttlemp_{g,t}}$$ $$GDPempd_{g,t} = \frac{GDP2emp_{g,lya} - GDP2emp_{g,lya-5}}{GDP2emp_{g,lya-5}}$$ *GDP2emp: ratio of GDP to employment*
Change in Average Patenting Rate	$$patr_{g,lya} = \frac{ttlpat_{g,t}}{ttlemp_{g,t}/1000}$$ $$avgpatr_{g,lya} = \frac{\sum_{t=lya-1}^{lya} patr_{g,t}}{2}$$ $$avgpatr_{g,lya-4} = \frac{\sum_{t=lya-5}^{lya-4} patr_{g,t}}{2}$$ $$patrd_g = \frac{avgpatr_{g,lya} - avgpatr_{g,lya-4}}{avgpatr_{g,lya-4}}$$ *ttlpat: Number of patents* *ttlemp: total employment*
Patent Diversity	$$SEIpat_{g,t} = \frac{\sum_{c=1}^{N} p_{g,t,c} * \ln(p_{g,t,c})}{-\ln(12)}$$ $$avgSEIpat_g = \frac{\sum_{t=lya-4}^{lya} SEIpat_{g,t}}{5}$$ $$SEIpat_{US,t} = \frac{\sum_{c=1}^{N} p_{US,t,c} * \ln(p_{US,t,c})}{-\ln(12)}$$ $$avgSEIpat_{US} = \frac{\sum_{t=lya-4}^{lya} SEIpat_{US,t}}{5}$$ $$patdv_g = \frac{avgSEIpat_g}{avgSEIpat_{US}}$$

	12: total number of IBRC patent technology categories *p: Proportion of total patents that are part of the IBRC technology category (pat_ibrc/ttlpat)*
Job Growth to Population Growth Ratio	$$empd_g = \frac{ttlemp_{g,lya} - ttlemp_{g,lya-4}}{ttlemp_{g,lya-4}}$$ $$popd_g = \frac{pop_{g,lya} - pop_{g,lya-4}}{pop_{g,lya-4}}$$ $$emp2popratio_g = \frac{empd_g}{popd_g}$$ $$popdhc_g = pop_{g,lya} - pop_{g,lya-4}$$ $$avgpop_g = \frac{pop_{g,lya} + pop_{g,lya-4}}{2}$$ $$job2pop_g = \frac{emp2popratio_g * popdhc_g}{avgpop_g}$$ *ttlemp: QCEW total employment* *pop: FSCPE Population*
Change in Share of High-Tech Industry Employment	$$hts_{g,t} = \frac{HTemp_{g,t}}{ttlemp_{g,t}}$$ $$HTempd_g = \frac{hts_{g,lya} - hts_{g,lya-4}}{hts_{g,lya-4}}$$ *HTemp: High-tech employment* *ttlemp:QCEW total employment*
Broadband Infrastructure and Adoption	$$INFA = NBBND * 0.5 + NIA * 0.3 + NCD * 0.3 - DNS * 0.05 - UPS * 0.05$$ *NBBND: % of pop w/o fixed 100/20 internet access (z-score)* *NIA: % of pop w/o internet access (z-score)* *NCD: % of population w/o a computing device (z-score)* *DNS: Median download speeds advertised (z-score)* *UPS: Median upload speeds advertised (z-score)*

Broadband Adoption Barriers	$$SE = AGE65 + POV + LTHS + DIS$$ *AGE65: % of pop ages 65+ (z-score)* *POV: poverty rate (z-score)* *LTHS: % of 25+ population without high school diploma (z-score)* *DIS: % of non-institutionalized population with any disability (z-score)*
Growth in Wage/Salary Earnings per Worker (Average Annual)	$$WS2emp_{g,t} = \frac{WS_{g,t}}{WSemp_{g,t}}$$ $$WS2emp_g = \frac{WS2emp_{g,lya} - WS2emp_{g,lya-4}}{WS2emp_{g,lya-4}}$$ *WS: BEA wage and salary earnings* *WSemp: BEA wage and salary employees*
Change in Proprietors' Income per Proprietor (Average Annual)	$$prpinc2emp_{g,t} = \frac{prpinc_{g,t}}{prpemp_{g,t}}$$ $$prpinc2emp_g = \frac{prpinc2emp_{g,lya} - prpinc2emp_{g,lya-4}}{prpinc2emp_{g,lya-4}}$$ *prpinc: BEA nonfarm proprietors' income* *prpemp: BEA nonfarm proprietors' employment*
Per Capita Personal Income Growth	$$pcInc_{g,t} = \frac{inc_{g,t}}{pop_{g,t}}$$ $$pcInc_g = \frac{pcInc_{g,lya} - pcInc_{g,lya-4}}{pcInc_{g,lya-4}}$$ *inc: BEA personal income*
Income Inequality (Mean to Median Ratio)	$$HHincdist_g = \frac{HHincmean_{g,lya}}{HHincmdn_{g,lya}}$$ *HHincmean = Mean household income* *HHincmdn = Median household income*

Average Poverty Rate	$$povr_{g,t} = \frac{pov_{g,t}}{popUniv_{g,t}}$$ $$avgpovr_{g,lya} = \frac{\sum_{t=lya-4}^{lya} povr_t}{5}$$ $$abvpovr_g = (1 - povr_{g,lya})$$ *pov: Number of impoverished persons* *popUniv: Population estimate for the poverty universe* *abvpovr: The "positive" side of a poverty rate, that is, the rate of those* ***above*** *poverty*
Average Unemployment Rate	$$unempr_{g,t} = \frac{unemp_{g,lya}}{ttlemp_{g,lya}}$$ $$unempr_{g,t} = \frac{\sum_{t=lya-4}^{lya} unempr_{g,t}}{5}$$ $$empr_g = (1 - unempr_g)$$ *unemp: Number of unemployed persons* *ttlemp: BLS number of persons in labor force* *empr: The "positive" side of an unemployment rate, that is, the rate of those* ***employed***
Government Transfers to Total Personal Income Ratio	$$HHdpnd_g = \frac{HHtransrec_{g,lya}}{HHearnings_{g,lya} + HHincDIR_{g,lya} + HHtransrec_{g,lya}}$$ *HHearnings = Net earnings* *HHtransrec = Personal current transfer receipts* *HHincDIR = Personal dividend, interest, and rent income*

Average Net Migration	$$netmigr_{g,t} = \frac{netmig_{g,t}}{pop_{g,t}}$$ $$avgnetmigr_g = \frac{\sum_{t=lya-4}^{lya} netmigr_{g,t}}{5}$$ *netmig: Net domestic migration for year t to region g*

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Appendix

Table 7: High-Tech Industries by Four-Digit NAICS Definitions with Their Broad Industry Category

Broad Industry Category (BIC)	NAICS	Industry
Chemical Manufacturing	3251	Basic Chemical Manufacturing
	3252	Resin, Synthetic Rubber, and Artificial Synthetic Fibers and Filaments
	3254	Pharmaceutical and Medicine Manufacturing
	3255	Paint, Coating, and Adhesive Manufacturing
	3259	Other Chemical Product and Preparation Manufacturing
Machinery and Equipment	3332	Industrial Machinery Manufacturing
	3333	Commercial and Service Industry Machinery Manufacturing
	3336	Engine, Turbine, and Power Transmission Equipment Manufacturing
	3339	Other General Purpose Machinery Manufacturing
Computer and Communication Manufacturing	3341	Computer and Peripheral Equipment Manufacturing
	3342	Communications Equipment Manufacturing
	3343	Audio and Video Equipment Manufacturing
Electrical and Optical Manufacturing	3344	Semiconductor and Other Electronic Component Manufacturing
	3345	Navigational, Measuring, Electro Medical, and Control Instruments
	3346	Manufacturing and Reproducing Magnetic and Optical Media
	3353	Electrical Equipment Manufacturing
Aerospace Product and Parts Manufacturing	3364	Aerospace Product and Parts Manufacturing
Communications	5112	Software Publishers
	5171	Wired Telecommunications Carriers

	5172	Wireless Telecommunications Carriers (Except Satellite)
	5174	Satellite Telecommunications
	5179	Other Telecommunications (Including Resellers in 07 & 12)
Data and Internet	5182	Data Processing, Hosting, and Related Services
	5191	Internet Publishing and Broadcasting and Web Search Portals
Architectural, Engineering, and Related Services	5413	Architectural, Engineering, and Related Services
Scientific and Technical Services	5415	Computer Systems Design and Related Services
	5416	Management, Scientific, and Technical Consulting Services
	5417	Scientific Research and Development Services
Management of Companies and Enterprises	5511	Management of Companies and Enterprises