Driving Regional Innovation: Supplemental Report for Innovation Intelligence

February 2024

Introduction

In 2021, five years after the release of the Innovation Index 2.0 (II2), the Indiana Business Research Center (IBRC) launched version three of the tool called **Innovation Intelligence** (II3). In early 2024, the IBRC updated II3 with more recent data, while keeping the core functionality of the tool unchanged.

The tool introduced in 2021 included—and still includes—updated data, several new measures, and a redesigned interface, which represented a full-scale upgrade of the popular II2 tool. For the first time, we also made time series of much of the measure data that underlies the indexes available for public. This has helped users chart progress on certain indicators over time and ensured the tool's data and insights can more easily be incorporated into economic development plans like the Comprehensive Economic Development Strategy (CEDS).

This document serves as a supplement to the 2016 report *Driving Regional Innovation*, produced as part of the II2, and is laid out as follows. The first section is an overview of the structure of II3. The second section contains the data sources and years for each of the measures in 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 II, the core of II3 is a collection of indexes that measure a region's innovation capacity and innovation outputs. The II3 consists of a **headline index**, which combines all other core and sub-indexes to reach an overall measurement of innovation

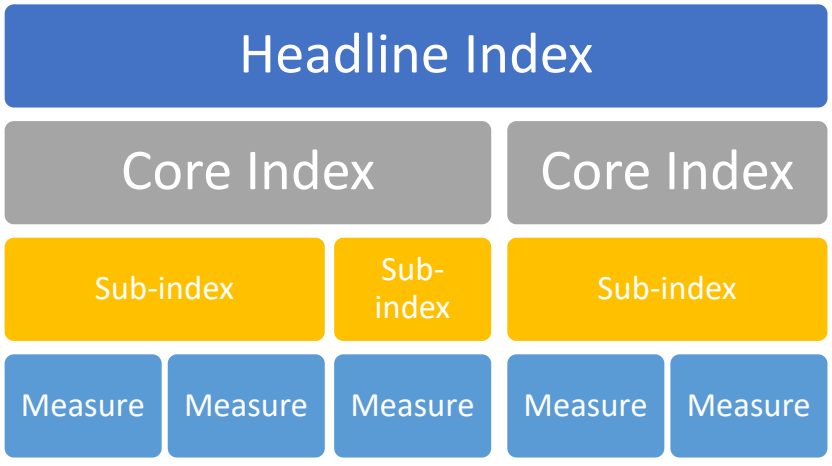

Figure 1: Partial hierarchy of Innovation Intelligence Headline Index

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 that aren't part of a sub-index but are part of one of the five core indexes. This is largely unchanged from the II2. A partial example of the hierarchy is shown in *Figure 1*.

Measure descriptions, years and data sources

The table below lists the name of each measure in the II3 organized by core index, along with a short description, the years of the underlying data and source information.

Measure Name	Description	Year(s)	Source
Human Capital and Knowledge Creation			
High school attainment	The percent of the population age 18 to 24 with a high school diploma.	2021	ACS
Some college attainment	The percent of the population age 25 and older with some college, but no degree.	2021	ACS
Associate degree attainment	The percent of the population age 25 and older with an associate degree.	2021	ACS
Bachelor's degree attainment	The percent of the population age 25 and older with a bachelor's degree.	2021	ACS
Graduate degree attainment	The percent of the population age 25 and older with a graduate, professional or other post-bachelor's degree.	2021	ACS
Patent technology diffusion	An original calculation that measures the degree to which a technology spreads and is adopted. It is based on a region's volume of patents and the technology classes of those patents.	2017-2021	U.S. Patent and Trademark Office and IBRC
University-based knowledge spillovers	The amount of university R&D spending in engineering, geosciences, life sciences, math and computer science, and physical science weighted by the exponential of the negative distance between the university and the county selected at universities at least 50 miles from the selected region. To avoid dealing with very small numbers, we divide the distance by 100 miles before taking the exponential.	2016-2020	Haversien Distance Matrix; National Science Foundation
Technology-based knowledge occupation clusters	The percent of total employment that is in occupations which apply high-level technology (e.g., scientists and engineers).	2019-2021	BLS Occupational Employment Statistics and IBRC
Average high-tech industry employment share	The percentage of total employment that is in high-tech industries.	2017-2021	BLS Census of Employment and Wages and IBRC

Average prime working-age population growth	The five-year-average annual growth rate for the population age 25 to 44.	2017-2021	U.S. Census Bureau
Business Dynamics			
Establishment births to all establishments ratio	The ratio of new businesses to all businesses.	2016-2020	U.S. Census Bureau
Traded sector establishment births to all establishments ratio	The ratio of new businesses that serve "export" markets, (i.e., sell to outside of the region rather than serving the local population) relative to all establishments.	2016-2020	U.S. Census Bureau
Jobs attributed to establishment births to total employment ratio	The percentage of total employment that was created by new businesses.	2016-2020	U.S. Census Bureau
Change in establishment birhts to all establishment ratio	The five-year change in the ratio of establishment births to all establishments.	2016-2020	U.S. Census Bureau
Average small establishments (per 10,000 workers)	The five-year average number of small establishments (those with less than 20 employees) per 10,000 workers.	2016-2020	U.S. Census Bureau and Bureau of Economic Analysis
Average high-tech, early-in-life-sycle establishment ratio	The five-year average ratio of small, high-tech firms in a region to the national proportion.	2016-2020	U.S. Census Bureau and BIC
Job expansions to contractions ratio	The ratio of employment gains from expanding and entering establishment to employment losses from contracting and exiting establishments.	2016-2020	U.S. Census Bureau
Establishment births to deaths ratio	The ratio of establishment births to establishment deaths, signaling the degree to which new businesses are replacing businesses that are dying.	2016-2020	U.S. Census Bureau
Traded sector births and expansions to deaths and contractions ratio	This ratio measures whether the businesses that serve distant markets (instead of local markets) are, on balance, growing or declining. It is calculated as the sum of births and expansions divided by the sum of deaths and contractions.	2016-2020	U.S. Census Bureau
Business Profile			
Average annual venture capital (scaled by GDP)	The five-year average of venture capital funding in the region divided by the region's five-year average GDP.	2017-2021	Thomson ONE and IBRC

Average annual expansion stage venture capital (scaled by GDP)	The five-year average expansion-stage funding in the region divided by the region's five-year average GDP.	2017-2021	Thomson ONE and IBRC
Average annual high-tech industry venture capital (scaled by GDP)	The five-year average of venture capital funding in the region for firms in high-tech industries divided by the region's five-year average GDP.	2017-2021	Thomson ONE and IBRC
Change in average venture capital	The ten-year change in the three-year-average of venture capital dollars in a region.	2012-2021	Thomson ONE
Average initial public offerings (scaled by GDP)	The five-year average number of IPOs in a region divided by the region's five-year average GDP.	2017-2021	Thomson ONE and IBRC
Average annual venture capital deals (scaled by GDP)	The five-year average total number of venture capital deals in a region divided by the region's five-year average GDP.	2017-2021	Thomson ONE and IBRC
Change in average venture capital deals	The ten-year change in the three-year average of venture capital deals.	2012-2021	Thomson ONE
FDI employment ratio, foreign source	The ratio of the most recent three years of employment created by new, foreign-sourced greenfield investment to the most recent year's working-age population (ages 18 to 66).	2018-2020	fDi Markets and ACS
FDI investment ratio, foreign source	The ratio of the most recent three years of investments by new, foreign-sourced greenfield investment to the most recent year's working-age population (ages 18 to 66).	2018-2020	fDi Markets and ACS
FDI employment ratio, domestic source	The ratio of the most recent three years of employment created by new, US-based incoming greenfield investment to the the most recent year's working-age population (ages 18 to 66).	2018-2020	fDi Markets and ACS
FDI investment ratio, domestic source	The ratio of the most recent three-years of dollars of greenfield investment by new, US-sourced FDI to the most recent year's working-age population (ages 18 to 66).	2018-2020	fDi Markets and ACS
Farm operators with internet access	The percentage of farms that use the internet to conduct business.	2017	U.S. Census Bureau
Proprietorship rate	The number of nonfarm proprietors divided by the total number of workers.	2017-2021	U.S. Bureau of Economic Analysis
Change in proprietorship rate	The number of nonfarm proprietors divided by the total number of workers.	2017-2021	U.S. Bureau of Economic Analysis

Proprietor income to total wages and salaries ratio	The ratio of total proprietor income to total wage and salary income in a region	2017-2021	U.S. Bureau of Economic Analysis
Average large establishments (per 10,000 workers)	The five-year average number of large establishments (those with 500 employees or more) per 10,000 workers.	2016-2020	U.S. Census Bureau and Bureau of Economic Analysis
Employment and Productivity			
Latent innovation	Estimates the complexity and uniqueness of an industry in a region. Operating principle is that being unique and complex are indicators of specialization and innovation. Uses the Latent Innovation Index measure created by Goetz and Han.	2021	BLS Census of Employment and Wages, IBRC, Goetz and Han (2020)
Industry diversity	Estimates the degree to which a region depends upon multiple industries – a balanced portfolio of industries, not just a few. Provides an indicator of the tradeoff between specialization and diversification, with the latter providing metric for resilience and mitigating risk. Calculates the Shannon Evenness Index for all industries in a region divided by the SEI for the US.	2021	BLS Census of Employment and Wages and IBRC
Industry cluster growth factor	Estimates the contribution of clusters to regional employment growth. The "factor" is the contribution to total growth, for example, 3 clusters – auto, business services and medical devices – contributed 1% growth rate to the overall growth rate of 4%, or 25% of employment growth is attributed to regional growth clusters. The percent of employment growth in a region that can be attributed to strong clusters. A regional growth cluster (RGC) is defined as having growing employment, and being a significant and increasing share of the regional economy. The greater the percentage, the greater the role that RGCs had in job growth.	2021	BLS Census of Employment and Wages and IBRC

Industry cluster strength	Estimates the degree to which a broader and larger region (labor market area) may specialize in a cluster. Smaller regions – geographic boundaries like counties – are embedded in larger geographic units of analysis like MSAs or labor market area. This is calculated as the average cluster LQ in all other counties/msa's in a county's/msa's labor market area.	2021	BLS Census of Employment and Wages and IBRC
Average gross domestic product (per worker)	The five-year average current-dollar GDP per worker.	2017-2021	U.S. Bureau of Economic Analysis and IBRC
Change in gross domestic product (per worker)	The five-year change in current-dollar GDP per worker.	2017-2021	U.S. Bureau of Economic Analysis and IBRC
Change in average patenting rate	The ten-year change in three-year average patents per 1,000 workers.	2012-2021	U.S. Patent and Trademark Office and IBRC
Patent diversity	A comparison of the diversity of patent making in the region against the U.S. patent diversity score for the latest three years of available data. If the score is above 1, the region is more diverse than the U.S. as a whole.	2019-2021	U.S. Patent and Trademark Office and IBRC
Job growth to population grown ratio	The ratio of the five-year change in employment to the five-year change in population.	2017-2021	U.S. Census Bureau of Bureau of Economic Analysis
Change in share of high-tech industry employment	The five-year change in the percentage of total employment from high-tech industries.	2017-2021	BLS Census of Employment and Wages and IBRC
Economic Well-Being			
Broadband infrastructure and adoption	Group of five variables related to broadband infrastructure and adoption: (1) percentage of total population without access to fixed broadband of at least 100 Mbps download and 20 Mbps upload; (2) percent of homes without a computing device (desktops, laptops, smartphones, tablets, etc.); (3) percent of homes with no internet access (have no internet subscription, including cellular data plans or dial-up); (4) median maximum advertised download speeds; and (5) median maximum advertised upload speeds.	2021	Purdue University Center for Regional Development

Broadband adoption barriers	Group of five variables known to impact technology adoption: (1) percent population ages 65 and over; (2) percent population 25 and over with less than high school; (3) individual poverty rate; (4) percent of noninstitutionalized civilian population with a disability: and (5) a brand new digital inequality or internet income ratio measure (IIR). In other words, these variables indirectly measure adoption since they are potential predictors of lagging technology adoption or reinforcing existing inequalities that also affect adoption.	2021	Purdue University Center for Regional Development
Change in annual wage and salary earnings per worker	The five-year change in annual wage and salary earnings per worker.	2017-2021	U.S. Bureau of Economic Analysis
Change in proprietor income (per proprietor)	The five-year change in proprietor income per proprietor.	2017-2021	U.S. Bureau of Economic Analysis
Per capita personal income growth	The five-year change in per capita personal income.	2017-2021	U.S. Bureau of Economic Analysis
Income inequality (mean to median income ratio)	The ratio of regional average income divided by regional median income.	2021	ACS
Average poverty rate	The five-year average percentage of a region's population that live below the poverty line. The inverse of the poverty rate is used because a high poverty rate is a negative outcome.	2021	ACS
Average unemployment rate	The five-year average of regional unemployment calculated as the number of unemployed divided by the number in the labor force. The inverse is used because high unemployment is considered a negative outcome.	2017-2021	U.S. Bureau of Labor Statistics
Government transfers to total personal income ratio	The ratio of total personal transfer receipts to total personal income.	2021	U.S. Bureau of Economic Analysis
Average net migration	The five-year average of net domestic migration divided by the total population.	2017-2021	ACS

Table 1: Measure descriptions, years and data sources:

Summary of changes from II2

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

Measure Name	Core Index	Sub-index	A/D

Latent innovation	Employment & Productivity	Industry Profile	Addition
Broadband infrastructure & adoption	Economic Wellbeing	Residential Internet Connectivity	Addition
Broadband adoption barriers	Economic Wellbeing	Residential Internet Connectivity	Addition
Business incubator spillovers	Human Capital & Knowledge Creation	Knowledge Creation & Technology Diffusion	Deletion
Density of residential fixed high-speed connections	Connectivity	Broadband Density & Penetration	Deletion
Average annual change in residential fixed high-speed connections	Connectivity	Broadband Density & Penetration	Deletion
Availability of capital from all banks	Business Profile	Proprietorship	Deletion

Table 2: Summary of additions and deletions in II3

Table 2 lists the measures in II3 that have been modified from the II2.

Measure Name	Core Index	Sub-index	Change from II2
Traded sector establishment births to deaths ratio	Business Dynamics	Establishment Dynamics	II3: the ratio of establishment births to deaths in 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-age worker (25-44) population growth	Human Capital & Knowledge Creation	N/A	II3: more precise name and slight change to calculation II2: called "Salad days population growth"
Technology-based knowledge occupation clusters	Human Capital & Knowledge Creation	STEM Education & Occupations	II3: five-year average II2: one-year (2014)

Table 3: Summary of modifications to individual measures in II3

Table 3 lists the general changes that have been made throughout the measures for consistency and relevancy.

Change from II2	Reason
10-year changes/averages were reduced to 5-year changes/averages	To use more recent data and for 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 4: Summary of general changes made throughout II3

Rationales for changes

This section provides the reasoning for the changes we've made in the 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 are located in the same county using a correlation coefficient. An advantage to their measure is that it shows that innovation is widespread across the U.S.; this isn't often the case when using a measure like patents, which tend 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 BLS QCEW, 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 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 Digital Divide Index (DDI), produced by Roberto Gallardo at the Purdue Center for Regional Development at Purdue University,[iii] 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 by the DDI measures.

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

State indexes: New in the 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, such as the cluster-based measures (m40201 and m40202), industry diversity (m40192) and latent innovation (m40191).

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 the II3.

Average prime-age worker (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 & 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 the 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 the 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* six-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 Bureau of Economic Analysis, which was 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 the II3. The first table has a list of recurring abbreviations that occur throughout, and the second table contains the formulas. Measures that have been added or modified from II2 are italicized.

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

Table 5: Recurring abbreviations in 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 w/o 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	$edSC_g = \frac{grad_{g,lya}}{pop25abv_{g,lya}} * 100$ *pop25abv: ACS 25+ pop* *grad: ACS 25+ pop 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* *ttl: total*
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 non-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	$$delta_{g,t} = \frac{pop25to45_{g,t} - pop25to45_{g,t-1}}{pop25to45_{g,t-1}}$$ $$pwagrowth_g = \frac{\sum_{t=lya-4}^{lya} delta_{g,lya}}{5}$$ *Pop25to45: 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 broad industry category (BIC) from Table 9*
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)	$$avgVC\$_g = \frac{\sum_{t=lya-4}^{lya} VC\$_{g,t}}{105}$$ $$avgGDP_g = \frac{\sum_{t=lya-4}^{lya} GDP_g}{5}$$ $$VC2GDP_g = \frac{avgVC\$_g}{avgGDP_g}$$

	VC$: Venture capital, dollars *GDP: Current dollar GDP*
Average Annual Expansion Stage Venture Capital (scaled by GDP)	$$avgVCXstg_g = \frac{\sum_{t=lya-4}^{lya} VCXstg\$_{g,t}}{5}$$ $$avgGDP_g = \frac{\sum_{t=lya-4}^{lya} GDP_g}{5}$$ $$VCX2GDP_g = \frac{VCXstg_g}{avgGDP_g}$$ *avgGDP: 10-yr average 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)	$$avgVCHT_g = \frac{\sum_{t=lya-4}^{lya} VCHT_{g,t}}{5}$$ $$avgGDP_g = \frac{\sum_{t=lya-4}^{lya} GDP_{g,t}}{5}$$ $$VCHT2GDP_g = \frac{avgVCHT_g}{avgGDP_g}$$ *VCHT: Funding for high-tech industries (NAICS: all six-digit industries within the four-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*
Change in Average Venture Capital Deals	$$avgVCDeal_{g,lya} = \frac{\sum_{t=lya-2}^{lya} VCDeal_{g,t}}{3}$$ $$avgVCDeal_{g,lya-10} = \frac{\sum_{t=lya-12}^{lya-10} VCDeal_{g,t}}{3}$$ $$avgVCDeal = \frac{avgVCDeal_{lya-10} - avgVCDeal_{lya}}{avgVCDeal_{lya}}$$ *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 (in millions of $) announcements* *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: non-farm 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.* *z_i: county-specific latent innovation score.* *sm_{ij}: the share of each industry j's employment in the county i.*
Industry Diversity	$$p_{i,g,t} = \frac{emp_{i,g}}{emp_g}$$ $$SEI_g = \sum_{i=1}^{N} \left[(p_{ig}) * \ln(p_{i,g}) \right] / \ln(N)$$ $$diversity_g = \frac{SEI_g}{SEI_{US}}$$ *i: industry* *g: region (i.e. county, MSA, etc)* *N: number of industries present in region*
Industry Cluster Growth Factor	$$cluster\ growth_g = \frac{\sum_{d=1}^{N} (emp_{g,d,t} - emp_{g,d,t-10})}{emp_{g,t}}$$ *t: year* *d: dominant cluster* *g: region*
Industry Cluster Strength	$$nemp_g = emp_{lma} - emp_g$$ $$nemp_{g,c} = emp_{lma,c} - emp_{g,c}$$ $$LQ_{g,c} = \frac{nemp_{g,c}/emp_g}{nemp_{USc}/emp_{US}}$$ $$Neighbor\ Cluster\ Strength_g = \frac{\sum_{c=1}^{C} LQ_{n,c}}{C}$$ *g: region* *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	$$patr_{g,lya} = \frac{ttlpat_{g,t}}{ttlemp_{g,t}/1000}$$ $$avgpatr_{g,lya} = \frac{\sum_{t=lya-1}^{lya} patr_{g,t}}{2}$$ $$avgpatr_{g,lya-4} = \frac{\sum_{t=lya-6}^{lya-4} patr_{g,t}}{2}$$ $$patrd_g = \frac{avgpatr_{g,lya-14} - avgpatr_{g,lya}}{avgpatr_{g,lya}}$$ ttlpat: Number of patents ttlemp: total employment
Patent Diversity	$$SEIpat_{g,t} = \frac{\sum_{c=1}^{N} p_{g,t,c} * \ln(p_{g,t,c})}{-\ln(12)}$$ $$avgSEIpat_g = \frac{\sum_{t=lya-4}^{lya} SEIpat_{g,t}}{5}$$ $$SEIpat_{US,t} = \frac{\sum_{c=1}^{N} p_{US,t,c} * \ln(p_{US,t,c})}{-\ln(12)}$$

	$$avgSEIpat_{US} = \frac{\sum_{t=lya-4}^{lya} SEIpat_{US,t}}{5}$$ $$patdv_g = \frac{avgSEIpat_g}{5avgSEIpat_{US}}$$ *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: BEA 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: IBRC 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	$$pcInc_{g,t} = \frac{inc_{g,t}}{pop_{g,t}}$$ $$pcInc_{g} = \frac{pcInc_{g,lya} - pcInc_{g,lya-4}}{pcIng_{g,lya-4}}$$

	p: Proportion of total patents that are part of the IBRC technology category (pat_ibrc/ttlpat)
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* *pop: ACS Population for year t*

Table 6: Measure formulas

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