THE SHANNON-WEAVER INDEX OF ECONOMIC DIVERSITY

An Overview and Descriptive Analysis

Description of the Shannon-Weaver Index

In order for an economy to withstand supply and demand shocks, it must either maintain its competitive advantage or have enough variety of industries to reemploy displaced workers (Malizia and Ke, 1993). While economic specialization takes advantage of economies of scale (Skyes, 1950) and competitive advantage (Diamond and Simon, 1990), the performance of an area dominated by one sector is likely to be closely tied to the performance of that sector, which can become a liability for the area if the core industry suffers a national or regional downturn (Fitchen, 1995). Economic diversity is thought to enhance economic performance by 1) shielding a region from the adverse effects of idiosyncratic economic shocks and 2) increasing the proportion of intermediate and final demand that can be supplied locally, thereby slowing the leakage of money out of the local economy.

Without denying the value of specialization and competitive advantage, the focus of this article is on economic diversity and one measure of economic diversity in particular: the Shannon-Weaver (S-W) Index. The S-W Index is an entropy method that measures the economic diversity of a region against a uniform distribution of employment where the norm is equal employment in all industries. In other words, it is a measure of the extent to which the employment of a region is evenly distributed among its industries. It ranges in value from zero to one, with zero indicating minimum diversity and a value of one indicating maximum diversity. A value of zero (complete specialization) occurs when the economic activity of a region is concentrated in only one industry. A value of one (perfect diversity) occurs when all industries are present in the region, with employment spread equally among them.

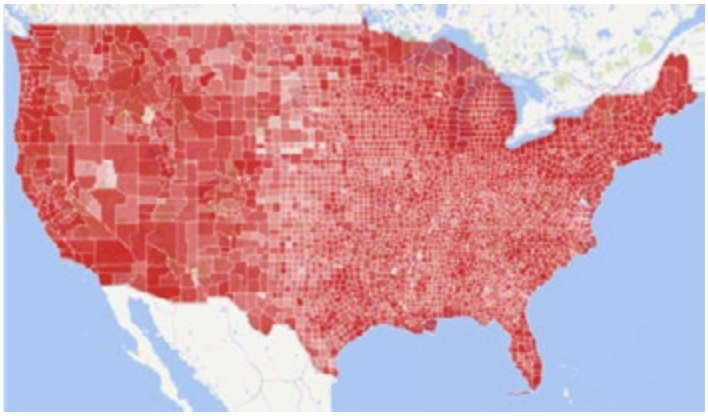
The S-W Index has been calculated and displayed by the IMPLAN data and software system for economic impact analysis since their 1999 data set. In IMPLAN, the S-W Index for a region is calculated as follows:

$$\text{S-W} = \frac{\sum i \left[(Ei/E) * (\text{Log}(Ei/E)/\text{Log}(2))\right]}{[\text{Log}(1/N)/\log(2)]}$$

where E_i is employment in industry i, E is total employment in the region, and N is the number of possible industries. Although the equation is here written with logarithms of base 2, the base of the logarithm used when calculating the S-W Index can be chosen freely, though comparing S-W values across time or place requires that they are all calculated with the same log bases. Shannon and Weaver (1948) discuss logarithm bases 2, 10 and *e*, and these have since become the most popular bases in applications that use the S-W Index.

The S-W Index can be very useful for graphing trends across time or mapping differences across geographies, such as in Figure 1.

Figure 1. Shannon-Weaver Indices of Continental U.S. Counties, 2014



Limitations of the Shannon-Weaver Index

Keep in mind, however, that the S-W Index does not account for the fact that many of the industries in a region may be closely related and would therefore provide little protection were one of the other closely-related industries to suffer a major decline. For example, a given region would receive the same S-W Index if its 1,000 employees were spread in either of the two hypothetical patterns shown in Table 1. While both cases have 1,000 employees and five industries, with employment spread evenly amongst the five industries, it should be apparent that Case 1 represents a much more diverse economy than Case 2. This subtle difference between the two cases is not reflected in the S-W Index, which would give the same value to both cases. Wagner and Deller (1993) discuss this issue and propose an alternative measure of economic diversity.

One might expect that aggregating closely-related sectors together (e.g., aggregating all the sectors in Case 2 in Table 1 in a single "Auto industry") would improve the S-W Index by treating like sectors as a single sector, rather than as distinct sectors. Yet the S-W Index as currently calculated actually increases when the employment data are aggregated into a smaller number of related sectors. This occurs for two reasons: when a region's employment data are aggregated into fewer sectors, a) there are fewer sectors with zero employment and b) the employment appears to be more evenly spread amongst those aggregated sectors – i.e., the aggregated sector smooths out the variation between the individual industries within the aggregated industry.

Related to this issue of sector aggregation is the issue of comparing S-W indices over time. Because the IMPLAN sectoring scheme changes periodically (in reflection of the BEA's

Table 1. Two Sample Industry Mixes Resulting in the same S-W Index Values.

Case 1		Case 2	
Industry	**Employment**	**Industry**	**Employment**
Grain farming	250	Automobile manufacturing	250
Petroleum refining	250	Light truck and utility vehicle manufacturing	250
Motor vehicle parts manufacturing	250	Motor vehicle body manufacturing	250
Wholesale trade	250	Motor vehicle parts manufacturing	250
Legal services	250	All other transportation equipment manufacturing	250

Benchmark I-O tables, which are released roughly every five years), the number of sectors will change, which will influence the S-W Index calculation, rendering year-to-year comparisons imperfect when comparing across years with different sectoring schemes. One solution is to use the time series version of the IMPLAN data, which currently span from 2001 to 2014 and are all in the 536 sectoring scheme. This time series data set also addresses the issue of consistency pointed out by the State of Hawaii's Department of Business, Economic Development and Tourism (2008).

While the S-W Index displayed in IMPLAN Pro and IMPLAN Online use Employment as the factor of choice, it is certainly possible to use other factors, such as Employee Compensation, as the factor of choice to give an alternate view and additional insight into the region's economic diversity. This could be useful if the industries in a given region vary widely in their levels of Employee Compensation, in which case even if employment were perfectly evenly spread amongst all industries, the Employee Compensation would not be.

In the case of bedroom community counties (i.e., counties in which most residents commute to another county to work), a relatively low S-W Index may represent less of a concern since for these counties, it is the economic strength of the county in which its residents work which is of most importance (see the example of Lancaster County, PA below).

Note that IMPLAN currently measures S-W Index based on total employment, which includes both wage and salary workers and proprietors. It may be instructive to investigate the changes in S-W Index when just wage and salary employees are considered. This may be an important factor given the proprietor data are residence based, while wage and salary employment data are place of work based.

Descriptive Analysis

In 2016, IMPLAN Group completed the development of a time-series set of IMPLAN data spanning from 2001 to 2014[1]. Keeping in mind the fact that a high S-W Index is not necessarily an explicit goal of a given region nor a guarantee of economic "health" of a region, in this section, we briefly discuss the U.S. states and counties that had the largest changes in S-W Index over this period of time, as well as the states and counties with the current maximum and minimum S-W Indices.

States

Not surprisingly, Washington, D.C. remained the "state" with the lowest S-W Index throughout the time period, and even declined (from 0.65130 to 0.61029). Excluding Washington, D.C., the state with the lowest S-W Index currently is Hawaii at 0.71016, followed by Nevada at 0.71699. Interestingly, Nevada began the period as the state with the lowest S-W Index but also has the distinction of being the state whose S-W Index increased the most over the 14 years.

Massachusetts experienced the largest drop over the time period, ending the period with a S-W Index of 0.74896. While total employment in the state increased by nearly 300,000, the state lost 6 industries. In 2001, the top 15 industries made up 42.4% of total employment, while in 2014 they made up 45.3% of total employment. In terms of employment, the following sectors remained in the top 10 throughout the period: Local government education, Wholesale trade, Hospitals, Full-service restaurants, Real estate, Junior colleges, and Retail food and beverage stores. All other food and drinking places, Local government non-education, State government non-education moved lower down the list, being supplanted by Other financial investment

1 The years 2001-2013 were re-estimated using IMPLAN's most current and best practices, as well as revised and more current raw data, and are based on IMPLAN's current 536 sectoring scheme. More detail about this data set can be found on the IMPLAN website, implan.com.

activities, Individual and family services, and Scientific research and development services.

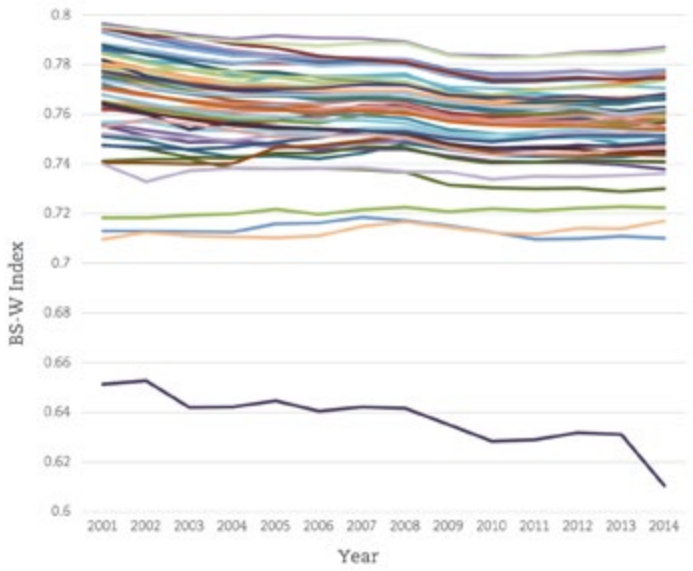
The state with the largest S-W Index is Indiana, with 0.78712, making it one of just three states whose S-W Index is larger than the nation's, the other two being Ohio and Wisconsin. It is interesting to note the geographic proximity of these three states. It is also interesting to note that these three states do not have the largest number of industries – this distinction belongs to the nation, followed by California and Texas – thus showcasing the role of employment concentrations in the S-W calculations.

State-level economic diversity trended downward over the time period, with the max S-W Index falling from 0.79646 to 0.78712 and the minimum S-W Index holding steady at 0.71, excluding Washington D.C. State-level economic diversity also appears to be converging, with the range between the lowest and highest S-W Indices falling from 0.087 to 0.077 (see Figure 2).

Counties

Despite becoming more specialized between 2001 (0.78119) and 2014 (0.76778), Lancaster County, PA had the highest S-W Index in 2014. In 2001, Lancaster County had 372 industries and 283,000 employees, compared to 363 industries and 308,933 employees in 2014. In 2014, the top employer in Lancaster County was Wholesale trade, with 15,824 employees. The next four largest employers (Local government education, Nursing and community care facilities, Full-service restaurants, and Real estate) were all more than half the size of the top employer, a much less steep drop off than in the case of Chattahoochee County, in addition to having more than three times the number of industries.

Figure 2: State-level Shannon-Weaver Indices, 2001-2014



In 2014, the county with the lowest S-W Index (0.16405) was Chattahoochee County, GA. The largest employer in Chattahoochee County, GA is the Federal Military sector, with just under 18,000 employees. This is intuitive given the presence of Fort Benning in the county. The next highest employer (Scientific research and development services) is a third that size, with just 680 employees. Furthermore, this sector is highly connected to the Federal Military sector, representing the Federal Military sector's 10th-largest non-payroll local expenditure. While this county is very specialized, its S-W Index has increased from 0.13098 in 2001. In 2014, there were a total of 100 industries and 21,614 employees in Chattahoochee County, compared to 87 industries and 18,499 employees in 2001.

Between 2001 and 2014, the county with the largest increase in S-W Index was Glades County, FL, rising from 0.37061 to 0.60431. Interestingly, while Glades County gained 17 industries in this time period, (rising from 103 industries to 120), it lost nearly half of its employee base (falling from 6,086 to 3,247). Thus, in this case the increase in the number industries and the more even distribution of employment across those industries overcame the loss in total employment in terms of S-W Index. As an interesting corollary, Glade County's population increased in this same time period (rising from 10.750 to 13,635), suggesting that a higher percentage of its residents are either not in the labor market (retirees, for example) or are commuting out of the county to work elsewhere. Indeed, with

Philadelphia within an hour's drive from the center of Lancaster County, it is very likely that a good portion of this county's residents work in neighboring Philadelphia County.

Between 2001 and 2014, the county with the largest decrease in S-W Index was Martin County, IN, falling from 0.54567 to 0.43685. This is a very interesting case, since both the number of industries and total employment increased in this time frame (rising from 121 to 127 and from 6,677 to 8.381, respectively). Thus, in this case, the less-even distribution of employment across the industries outweighed the increase in the number of industries and the total employment level in the county. Indeed, in both years the top employer was Federal Non-Military, but in 2001 this represented 24 percent of the county's total employment, while in 2014 this represented 46 percent of the county's total employment. Much of this employment likely exists to support, among other things, the Naval Surface Warfare Center in the county.

Conclusions and Suggestions for Further Research

Due to the limitations of the S-W Index as well as to the fact that there are times and places where a certain degree of specialization is appropriate, the S-W Index should not be used in isolation to claim a particular region's overall economic health or prospects for future economic growth. Nonetheless, it can serve as a useful tool when considered alongside other metrics, both economic and non-economic.

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