Initial Applications of Fuzzy Set Procedures for Estimation of Export Base Employment*

Roy W. Thomsen, Thomas R. Harris and G. Cornelis van Kooten

University of Nevada Reno

Abstract: Current export base methods that calculate basic and non-basic employment are too restrictive because they fail to account for uncertainty involved in the process. This paper shows the assignment of industries as either basic *or* non-basic by the location quotient procedure does not consistently represent the data for Nevada counties. Using fuzzy set procedures and membership functions in conjunction with the location quotient allow more flexibility in terms of matching the data for each industry in the region of interest. Using fuzzy set procedures we determine the proportion of employment that is basic and non-basic in nine non-governmental industries.

Key Words: Fuzzy set, export base theory, location quotient, regional development, membership, basic and non-basic employment.

*Prepared for presentation at the Western Agricultural Economics Association 2002 Annual Meetings, July 31, 2002, Long Beach, CA.

Industries that supply markets outside the region are crucial to the local economy (Watkins 2001). Export or basic industries, also known as the economic base, bring money into the local economy, and in fact growth, decline or stagnation of a local economy rests upon the basic sectors (Harris 2001). Since the export base model relies on the division of a region's employment into basic and non-basic categories, the identification of industries as basic and non-basic is a key concern.

Current methods rely on crisp procedures to categorize industries as basic (exporters) or non-basic (importers) to estimate basic employment. However, the actual import and export data for the state of Nevada and its seventeen counties do not support the use of the simplistic location quotient procedure to determine basic and non-basic industries both because many industries are not homogeneous and because exports do not often exceed imports at a location quotient value of one. The fuzzy set approach allows industries' membership to be assigned on a continuous rather than a discrete basis: rather than defining a group as an importer or an exporter, a membership value from zero to one is assigned, with one representing full membership in a particular group and zero representing non-membership (van Kooten et al. 2001, p.498). Thus industries can be designated partial importers and partial exporters. More accurate designation of basic and non-basic industries will give a better estimate of export base employment in a local economy.

The objective of this paper is to estimate export base employment for the seventeen counties of the state of Nevada through the application of fuzzy sets and location quotients. We begin with a brief description of the most common methods for identifying export and non-export industries, covering particularly the location quotient method. We then give some background in fuzzy sets before applying the methodology to estimating export base employment in Nevada county industries. Our results and a brief discussion conclude the paper.

Three common methods

The most widely used methods for identifying basic industries are the assignment procedure, direct interview, and minimum requirements. The first two are not based on a mathematical formula, but depend on expert advice and the researcher's subjective assessment of the local economy. The minimum requirements method is similar to the location quotient (described in detail below) but compares employment in the region of interest to the smallest sized region in the class, instead of to the nation as a whole (Harris 2001).

The assignment procedure is the least complex and hence least expensive method, dividing sectoral employment between basic and non-basic categories based on the researcher's simple designation rather than on a theoretical rationale. Although in some cases this designation may be made based on input from focus groups, often the researcher is called upon to render a subjective judgment. In many cases experienced researchers have solid evidence and analysis behind their decisions, but nonetheless the chance of errors is large and the generated result is of limited use in analyzing the effects of change over time (Schaffer 2001).

The direct interview method uses a questionnaire or personal interviews to get industry information. Not only is this time-consuming and costly, particularly in larger regions (Harris 2001), but it may contain errors as well, since sensitive issues including revenues, employment, and markets may not be accurately represented. Further, this approach yields data for only one year, leading to an average instead of a marginal multiplier (Schaffer 2001).

The minimum requirements approach compares a region's employment structure to the smallest sized region rather than to the state or nation, assigning all employment greater than the group minimum to basic employment (Harris 2001) per the following formula

$$ENB_{ir} = (\frac{E_{ir}}{E_r} - \frac{E_{im}}{E_m}) \cdot E_r$$

where E_m is the region with the smallest $\frac{E_{ir}}{E_r}$ ratio in the class.

The previous methods may be relatively simple, but can be time consuming, expensive, and/ or overly subjective. The next approach, the location quotient, is probably the most popular and efficient of those currently in use, but is not without its flaws.

Location quotient method and results

The location quotient compares a local economy to a larger state or national economy of which the locality is a part (Guihathakurta 2002). In this study Nevada counties are the local economies and the State of Nevada is the reference economy. The location quotient attempts to identify specializations in the local economy (FSU 2001), as well as identify export and non-export industries in the local economy. A location quotient is calculated by comparing the ratio of employment in the industry at the local level to employment in the industry at the state or national level (UALR 2001), as shown:

$$LQ_{ir} = \frac{(E_{ir} / E_r)}{(E_{in} / E_n)}$$

where LQ_{ir} = location quotient for industry *i* in region *r*, E_{ir} = employment in industry *i* in region *r*, E_r = total employment in region *r*, E_{in} = employment in industry *i* in Nevada and E_n = total employment in Nevada.

Basic and non-basic employment can be estimated using the location quotient. $LQ_{ir} > 1$ implies the basic needs of the local economy are met and there is excess employment, while $LQ_{ir} < 1$ implies that all employment in industry *i* is used to meet the needs of the region. Industries with location quotients greater than one are divided into basic and non-basic employment as follows:

$$EB_{ir} = (1 - \frac{1}{LQ_{ir}}) \cdot E_{ir}$$

Non-basic employment for industries with location quotients greater than one is calculated as:

$$ENB_{ir} = E_{ir} - EB_{ir}$$

where ENB_{ir} = non-basic employment in industry *i* in region *r*, E_{ir} = total employment in industry *i* in region *r* and EB_{ir} = basic employment in industry *i* in region *r*. If $LQ_{ir} < 1$ it is assumed basic employment does not exist in the industry:

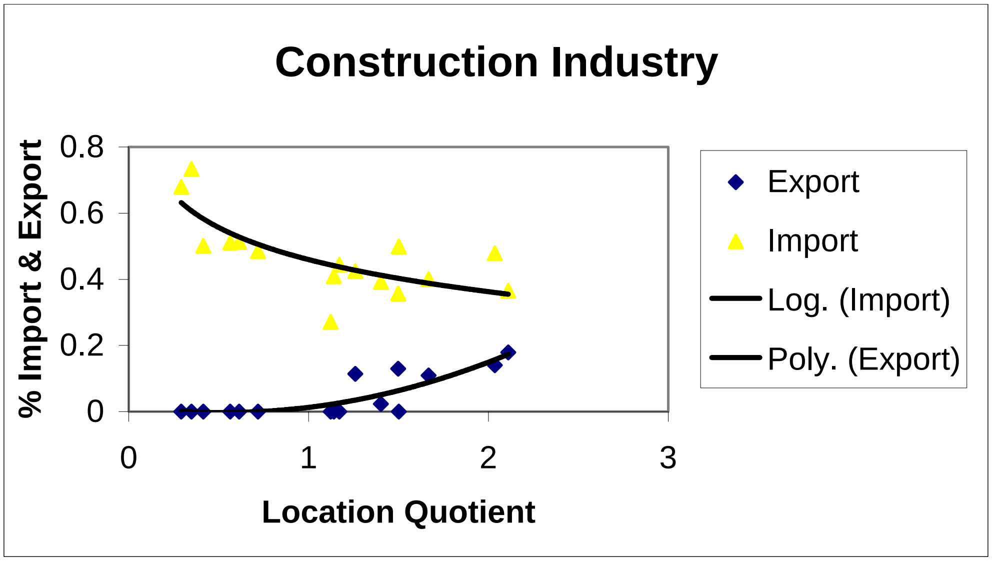
$$ENB_{ir} = E_{ir}$$

We calculated the location quotients for nine industries in the 17 counties in Nevada and compared them to percent imports and exports derived from Implan data. State, local and Federal government are assigned to basic industries, because they have no reference economies in which to compute location quotients, and therefore are not included in this study. Imports and exports include domestic and foreign.

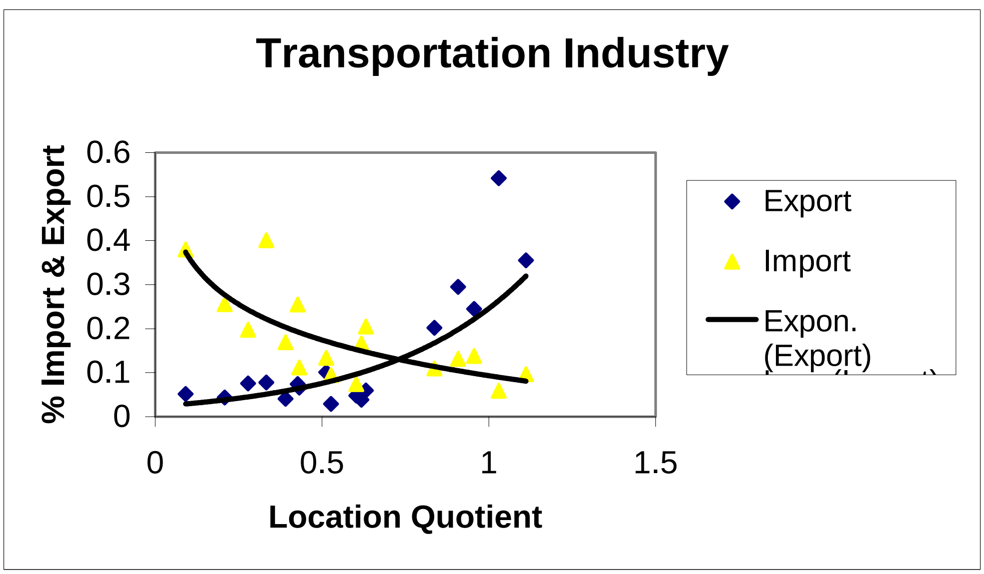
The following graph shows the location quotient on the horizontal axis and percent imports and exports on the vertical axis for the construction industry[1]. If an industry is an exporter, exports should exceed imports at $LQ_{ir} > 1$. The graph clearly shows exports do not

[1] Trend lines fitted using Excel. % Import = $-0.14Ln(LQ_{ir}) + 0.4596$, $R^2 = .58$. % Export = $0.070LQ_{ir}^2 – 0.0739LQ_{ir} + 0.0165$, $R^2 = .72$.

exceed imports at $LQ_{ir} > 1$ for the construction industry. In fact, exports do not exceed imports until approximately $LQ_{ir} > 2.5$, far beyond the conventional value of 1.



Another example is the transportation industry[2], in which exports exceed imports at a location quotient of only 0 .75. Very few counties have an $LQ_{ir} > 1$ in the transportation



[2] % Import = -0.1171Ln(LQ_{ir}) + 0.0931, R^2 = 0.58. % Export = $0.0234e^{2.3537(LQir)}$, R^2 = 0.64.

industry, which means only two counties would have basic employment. Inconsistent results, in terms of the location quotient being a predictor for a county being an exporter or importer, were attained for the remainder of the industries[3] as well, indicating room for improvement.

Some or all of the following limitations could cause inaccuracy in the location quotient method. First, there are times when one or more of the location quotients computed for an economy simply do not make sense. For example, the agriculture industry exports at least 80 percent at almost all location quotient values. In that case the industry must be analyzed on an individual basis. Second, it must be recognized that every industry typically has some basic and non-basic employment (Hood 2001). It is often difficult to define appropriate boundaries that accurately define a region. In the "real world" boundaries between industries, regions and employment are often difficult to draw and it is beneficial to use a combination of tools (FSU 2001). The last, and perhaps largest source of inaccuracy is the assumption that no cross-hauling exists between local economies. The fuzzy set procedure does not make this assumption, as it allows for an industry to be a partial importer and partial exporter.

Fuzzy sets and membership

Lofti Zadeh first published a paper on fuzzy sets in 1965 to address the issue of the vagueness of natural language. He proposed that the meaning of natural language is a matter of degree, or what is currently referred to as 'membership' (Nguyen and Walker 1997, p.2). Most development in fuzzy set theory in the past 20 years has been in the academic realm, except for its commercial use in Japan and England since the mid 1970s (Zimmerman 1996, p.1).

Fuzzy sets are a departure from two-valued sets and standard logic, using a 'soft' system of variables and a continuous range of truth-values between 0 and 1 (Bonde 2000). Fuzzy sets are also different from probability theory, the main distinction being the difference between the

[3] Graphs of selected industries in Appendix A.

notions of probability and a degree of membership (Kantrowitz 1993). A certain membership value does not represent the probability of an event happening. For example, a membership value for industry *i* of 0.8 in the set 'importer' does not imply that industry *i* has an 80 percent probability of being an importer.

"Fuzzy sets deal with the type of uncertainty which arises when the boundaries of a class of objects are not sharply defined" (Nguyen and Walker 1997, p.11). Therefore, fuzzy set theory lends itself well to the problem of estimating basic and non-basic employment, where boundaries between local economies and what it means to be an exporter or importer is not clear. The rest of this section compares standard subset notation to fuzzy set notation and outlines the three steps of fuzzy set application.

The following fuzzy set and ordinary subset notation is taken directly from Nguyen and Walker (1997). An ordinary subset *A* of a set *U* is determined by its indicator function χ_{A} defined by

$$\chi_{\mathrm{A}}(x) = \begin{cases} 1 \text{ if } x \in A \\ 0 \text{ if } x \notin A \end{cases}$$

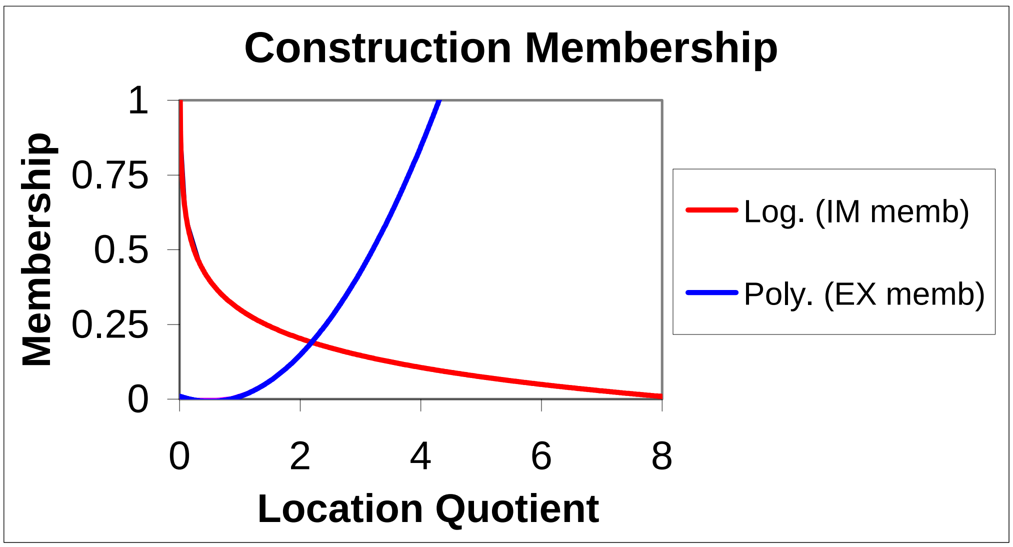
The indicator function is a subset *A* of a set *U* specifies whether or not an element is in *A*. It either is or it is not, and therefore can be very restrictive (p.5).

A fuzzy subset of a set *U* is a function $U \rightarrow [0,1]$. For a fuzzy set $A = U \rightarrow [0,1]$, the value *A(u)* is called the **degree of membership** of *u* in the fuzzy set *A*. *A(u)* is not, however, meant to be a likelihood value or probability. An example of a fuzzy membership function for construction sector exports is:

$$A(u) = E(LQ_{ir}) = \begin{cases} -0.14Ln(LQ_{ir}) + 0.3 & \text{if } LQ_{ir} \leq 4.2 \\ 1 & \text{if } LQ_{ir} > 4.2 \end{cases}$$

E(LQ_{ir})

$E(LQ_{ir})$ is the degree of membership of industry *i* in region *r* in the fuzzy set exporter, or *E*, based on the location quotient LQ_{ir}. The following is a graphical representation of the above membership function for the construction industry. It shows us that at $LQ_{ir} \geq 4$ the construction industry has full membership as an exporter. At $LQ_{ir} = 2$ the construction industry has 0.22 membership as an exporter and 0.22 membership as an importer. Membership values do not have to equal to one, because again, they are not probabilities.



Piecewise linear functions are common practice in modeling membership functions (Nguyen and Walker 1997, p. 5-6). However, they can also be non-linear and non-linear piece-wise functions, depending on the fit of the data for particular industries. More graphical representations of membership functions are in Appendix B.

We used three steps to apply fuzzy set reasoning to solve our current problem. The three steps can be used as a general guideline to perform fuzzy set reasoning. They are:

1) Fuzzification of the terms that appear in the conditions of rules.

2) Inference from fuzzy rules.

3) Defuzzification of the fuzzy terms that appear in the conclusion of the rules (ATTAR 1999).

The first step, fuzzification, is the transformation of an objective term into a fuzzy concept to allow a fuzzy condition in a rule to be interpreted. In the present study, this is when a functional form is given to the import and export data, and location quotients are assigned membership values. The second step is inference, determining basic and non-basic membership for given location quotients. In most industries, as the location quotient increases membership in the set ‘basic industry’ increases and membership in the set ‘non-basic industry’ decreases. The third step is deffuzification, the translation of fuzzy concepts back into objective terms so they can be used in practice. This involves calculating the proportion of basic and non-basic employment in a given industry and region. Fuzzy sets allow industries to have both basic and non-basic employment, which is an advantage over the four methods discussed above.

Methodology

We collected data from Implan[4] to calculate percentages of imports and exports using 1998, 1 digit REIS industry classification. Percent exports were computed by dividing total county imports by total county output for each industry. Similarly, percent exports were computed as foreign and domestic exports divided by total county output for each industry. We calculated location quotients using State of Nevada employment data as the reference economy.

First we plotted location quotients against import and export percentages. We then fit and normalized trend lines between [0,1] to derive the membership functions, matching the data

[4] Imports and total output are from the *Industry Output/Outlay Summary* report, and export foreign and domestic imports are from the *Institution Industry Demand* report. Employment data is from the *Output, Value Added and Employment* report.

as closely as possible for each industry. It is important to derive different membership functions for each industry because they are so heterogeneous.

Finally, we computed basic and non-basic employment proportions for each industry. The proportion value *P* is simply multiplied by total employment in each industry to get basic and non-basic employment. The proportion value *P* is computed as follows,

$$P_{NB}(I,E) = \frac{I(LQ_{ir})}{I(LQ_{ir}) + E(LQ_{ir})},$$

$$P_B(I,E) = 1 - P_{NB}(I,E).$$

Where $P_{NB}(I,E)$ = non-basic employment proportion for a given LQ_{ir}, $P_B(I,E)$ = basic employment proportion for a given LQ_{ir}, $I(LQ_{ir})$ = import membership function and $E(LQ_{ir})$ = export membership function.

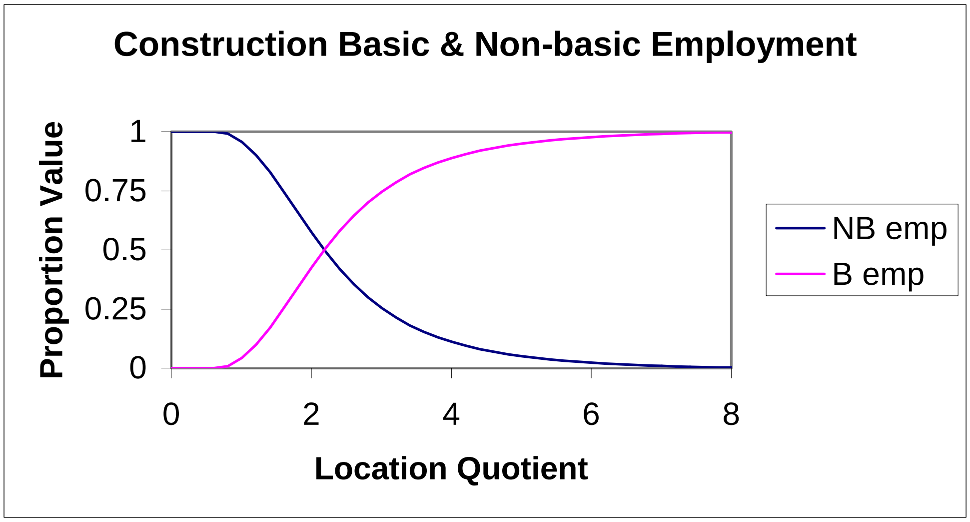
The proportion values are simply multiplied by the total employment in industry *i* in region *r* to get basic and non-basic employment.

$$EB_{ir} = P_B(I,E) \cdot E_{ir}$$

$$ENB_{ir} = P_{NB}(I,E) \cdot E_{ir}$$

The proportion values can then be plotted against the location quotient to get a visual representation of the functional form for basic and non-basic employment. The following graph shows basic and non-basic employment for the construction industry[5]

[5] More basic and non-basic industry employment graphs can be found in Appendix C.



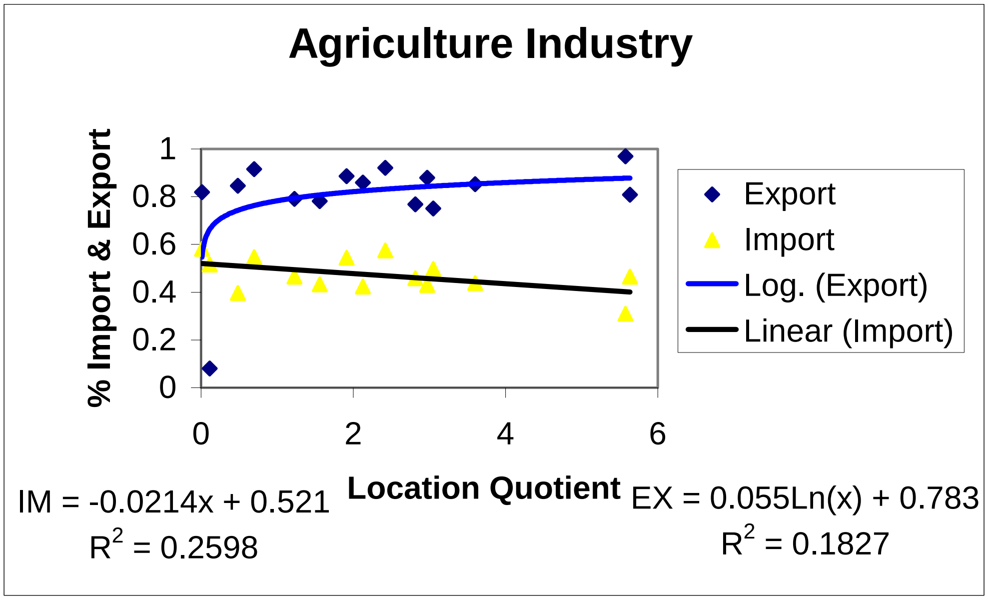
As shown by the graph, basic and non-basic employment proportions must always sum to one. For the construction industry basic and non-basic employment is equal at a location quotient of approximately 2. All employment is non-basic up to a location quotient of approximately 0.75 and all employment is basic beyond a location quotient of about 8.

Results and Discussion

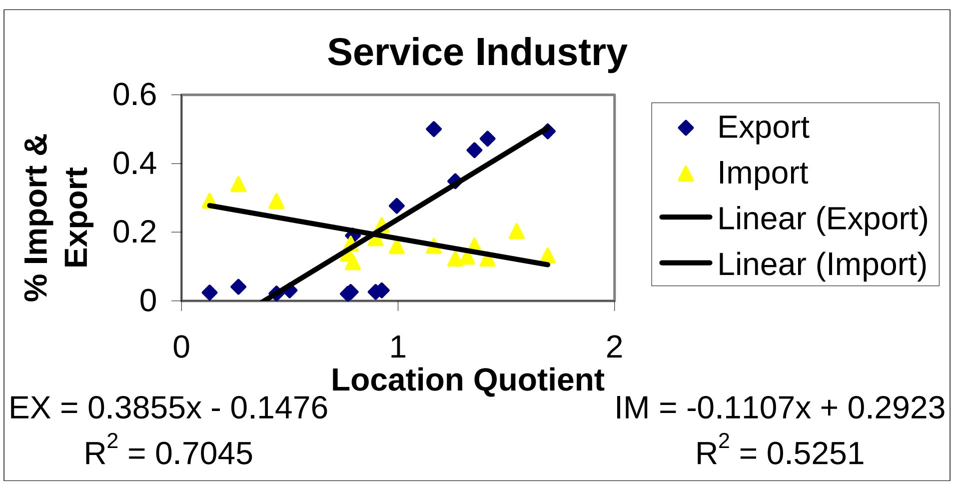
As shown above for the construction and transportation industries, and in Appendix A, the rule that industries with $LQ_{ir} > 1$ are exporters is not sufficient given the sample of Nevada counties, with only a few exceptions. The reason the data may not fit using the location quotient procedure is because of the flawed assumption of no cross-hauling between regions. A clear example is the agriculture industry, in which ranchers in Washoe County may import hay from Douglas county and at the same time export hay to Lyon County. Another problem is that boundaries between regions can be hard to determine in practice, which is another cause for uncertainty. An economic region may cover more than one county, or even state, like Lake Tahoe. The last problem when using the location quotient method is that industries are assigned as either basic *or* non-basic industries, when in reality all contain some employment in both.

Because of the uncertain nature of estimating basic and non-basic employment, the application of fuzzy set theory is a possible alternative or complement to conventional methods. Using fuzzy set procedures and membership functions in conjunction with the location quotient to derive basic and non-basic employment permits more flexibility in terms of matching the data for each industry in the region of interest. The fuzzy set procedure allows an industry to be a member in both the set 'importer' and the set 'exporter,' which is a departure from crisp logic sets. Our application of fuzzy sets to export base employment theory in the State of Nevada gives positive initial results and will hopefully be grounds for further research using this method.

Appendix A: Graphs of location quotient versus percent imports and exports

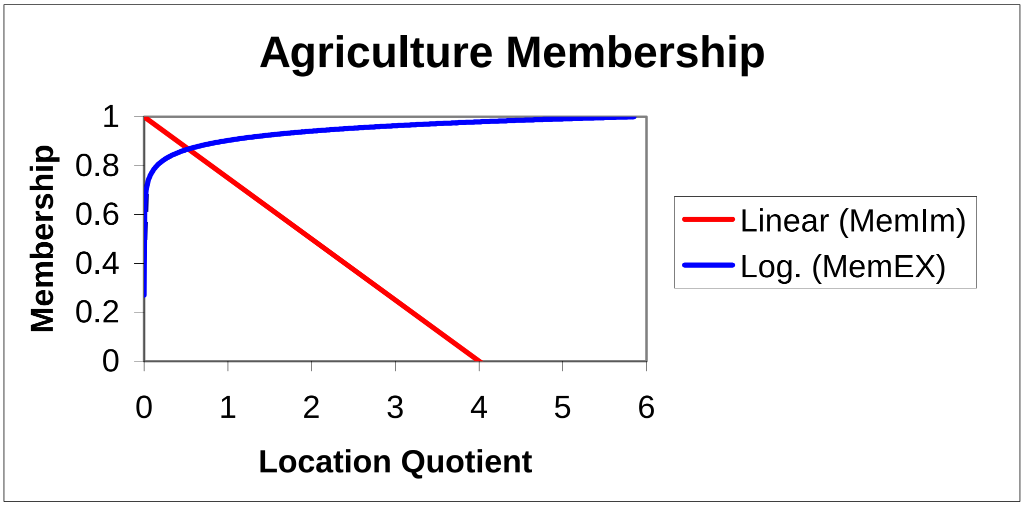


Exports exceed imports at a location quotient of approximately 0.5 for the agriculture industry. At LQ_{ir} >1 agriculture exports are greater than 80 percent. Therefore, the location quotient procedure would not accurately estimate basic and non-basic employment for the agriculture industry in Nevada.

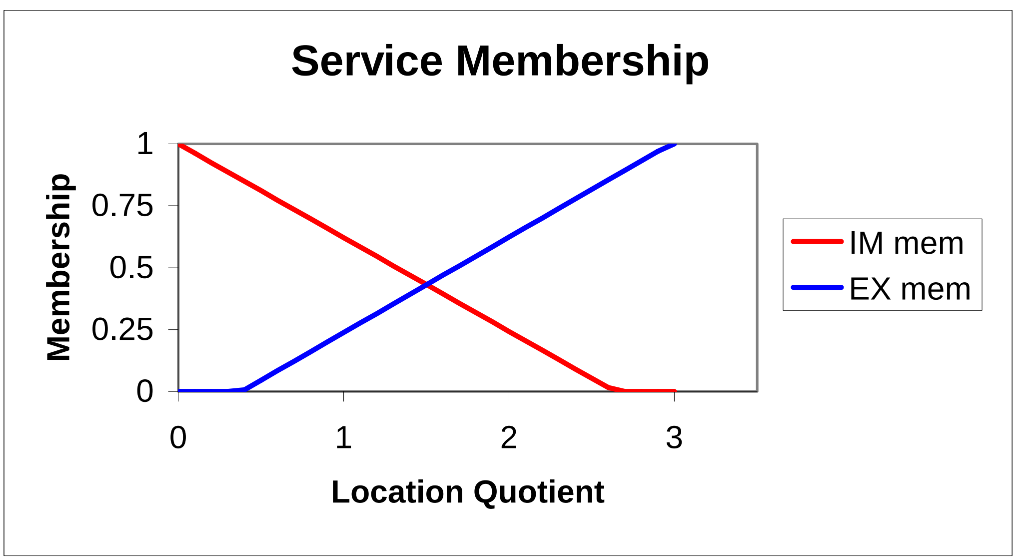


The service industry behaves well when using the location quotient method, but it is one of the few exceptions to our results for Nevada counties.

Appendix B: Graphs of membership functions for selected industries

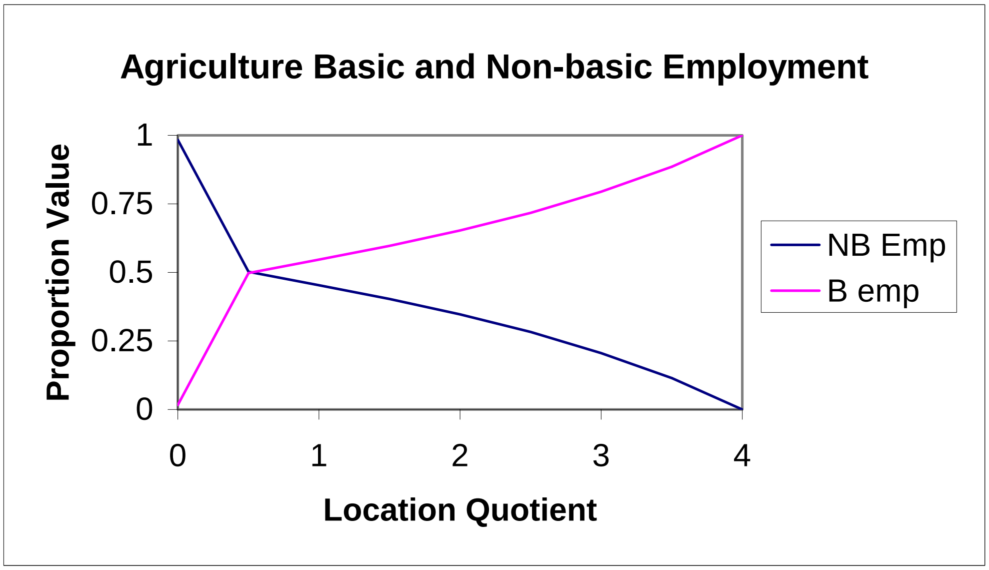


The agriculture industry membership graph is similar to its graph in Appendix A with location quotients plotted against percent imports and exports. This does not mean membership values can be interpreted in terms of probabilities however. For example, at an $LQ_{ir} = 2$ the agriculture industry has membership in the set 'importer' of 0.52.

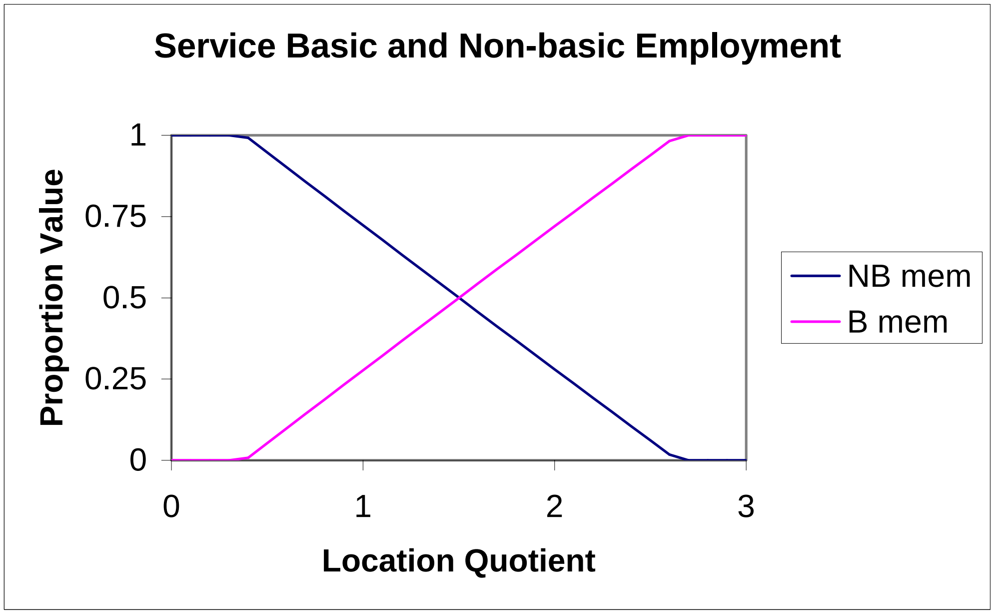


The service industry is the most simple functional form, linear piece-wise, and is easy to determine membership in 'exporter' and 'importer' from a given location quotient.

Appendix C: Graph of basic and non-basic employment for selected industries



Basic employment increases sharply for $LQ_{ir} < 0.5$ and then increases at less of a slope for $LQ_{ir} > 0.5$. The opposite is true for non-basic employment, because it is simply $1 - EB_{ir}$.



In contrast to the agriculture industry basic employment, service industry basic employment is increasing at a constant rate where $0.4 < LQ_{ir} < 2.7$. Basic employment equals non-basic employment at a location quotient of approximately 1.5.

References

Bonde, Allen. “Fuzzy Logic Basics.” 2000. GTE Government Systems Corp. 14 Dec. 2001. <http://www.austinlinks.com/Fuzzy/basics.html>.

“Fuzzy Logic.” 1999. Attar Software Limited. 14 Dec. 2001. <http://www.attar.com/pages/fuzzy.htm>.

Guihathakurta, Subhro. “The Concept of the Economic Base.” 2000 Arizona State University. 17 July 2002. <http://www.public.asu.edu/~subhro/pup622/econanal/>.

Harris, Thomas. “Re: Class notes.” University of Nevada Reno. 4 Sep. 2001.

Hood, Ron. “Economic Analysis: A ‘Location Quotient’ Primer.” 2001 Azplan Site. 13 Dec. 2001. <http://www.azplansite.com/location.htm>.

“Implications of Location Quotients.” 2001 UALR Institute for Economic Advancement: University of Arkansas at Little Rock. 14 Dec. 2001.

Kantrowitz, Mark. “What is Fuzzy Logic?” 1993. 14 Dec. 2001. <http://www.cs.cmu.edu/Web/Groups/AI/html/faqs/ai/fuzzy/part1/faq.html>.

“Location Quotient Technique.” Florida State University Department of Urban and Regional Methods III: Forecasting. 14 Dec. 2001. <http://garnet.acns.fsu.edu/~tchapin/urp5261/topics/econbase/lq.htm>.

Minnesota IMPLAN Group, Inc. *IMPLAN Professional Version 2.0*. Stillwater, MN: 2000.

Nguyen, T. Hung, and Elbert A. Walker. *A First Course in Fuzzy Logic*. New York: CRC Press, 1997.

Schaffer, William A. "Regional Impact Models." 1999 Georgia Institute of Technology. 14 Dec. 2001. <http://www.rri.wvu.edu/WebBook/Schaffer/chap02.html>.

van Kooten, Cornelis G., Emina Krcmar and Erwin H. Bulte. "Preference Valuation in Non-Market Uncertainty: A Fuzzy Approach." *Amer. J. Agr. Econ.* 83 (2001): 487–500.

Watkins, Thayer. "The Economic Base Model." San Jose State University Economics Department. 14 Dec. 2001. <http://www.sjsu.edu/faculty/watkins/base.htm>.

Zimmerman, H. J. "Recent Developments in Fuzzy Logic and Intelligent Technologies." In *Fuzzy Logic*. (pp. 1-4) edited by J. F. Baldwin. West Sussex: John Wiley & Sons Ltd, 1996.