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Firm size diversity, functional richness, and resilience

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ABSTRACT. This paper applies recent advances in ecology to our understanding of firm development, sustainability, and economic development. The ecological literature indicates that the greater the functional richness of species in a system, the greater its resilience – that is, its ability to persist in the face of substantial changes in the environment. This paper focuses on the effects of functional richness across firm size on the ability of industries to survive in the face of economic change. Our results indicate that industries with a richness of industrial functions are more resilient to employment volatility.

1. Introduction

A firm is a production function for transforming inputs (e.g. labor, capital) into output (Jensen and Meckling, 1976). Within any industry, there are processes that shape the distribution of firm sizes. For instance, economies

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of scale, capital and labor intensity, target markets, tariffs, and niche all have effects on the size and number of firms within an industry. It may be beneficial for competitors in an industry to be different sizes (Fujita *et al.*, 1999). Firms of different sizes can pursue different business strategies, because their interests do not overlap. Combined, the business strategies of firms create and sustain economic growth.

The processes driving firm growth appear to vary with firm size and location. Among large firms, growth rates tend to stabilize with increasing firm size, which leads to firm persistence and opportunity for long-term growth (Buzzelli, 2001). This positive feedback loop allows large firms to capture more resources, which means that the largest firms in an industry rarely relinquish their dominance (Buzzelli, 2001). Large firms enjoy reputation effects that help to maintain their status in financial markets and the public consciousness (Sleuwaegen and Goedhuys, 2002), and can capitalize on production economies of scale more effectively than smaller firms (Mittelstaedt *et al.*, 2003). Larger firms have lower growth rates, but are more likely to survive (Sutton, 1997). For instance, more than half of the 50 largest manufacturing companies in the US had been in the top 50 firms 20 years earlier (Buzzelli, 2001). Conversely, smaller firms likely cannot afford the investments necessary to compete with larger firms, and thus exploit niches that are better suited to their capabilities. Small firms sometimes usurp the dominant firms, though the odds are against them, as their growth rates are variable leading to mixed success in challenges to larger, older dominant firms (Buzzelli, 2001). Similar patterns for sustainability are found in nature, where large and small species follow different strategies for survival. In the economic and business literature, scholars have tended to focus on organizational and environmental conditions for sustainability.

Firm size, organization and sustainability

Large dynamic economic systems appear to diversify into a heterogeneous mix of economic activities leading to smaller fluctuations in their growth trajectories (Lee *et al.*, 1998). However, the degree of diversification of these dynamic economies is much smaller than what would be expected if diversification increased in a linear fashion with the size of the economy (Lee *et al.*, 1998). Descriptions of firm dynamics have typically centered on models characterizing industry as converging towards a steady-state condition (Sutton, 1997). However, firm sizes do not converge to a pattern of stable size differences over time (Geroski *et al.*, 2003). This characterization of firm dynamics is an over-simplification, as empirical evidence emphasizes that entries and exits occur throughout the course of the life of an industry (Sutton, 1997). Firm dynamics are characterized by pulses of flux, interspersed with momentary stasis; firms move more or less randomly, changing their size and rank on a regular basis (Geroski *et al.*, 2003). The evolution of firm size distributions is likely driven by two opposing forces: a supply and demand process that concentrates a firm size distribution, and a diffusion process that characterizes search and learning behavior and bounded rationality on the size distribution of firms (Hashemi, 2003). Thus, the existence of an optimum firm size or an equilibrium pattern of size differences between firms is unlikely (Geroski *et al*., 2003).

Geroski *et al*. (2003) state that firms rarely innovate in the UK, with only a few firms producing a steady stream of innovations. They speculate that if innovation drives growth, then unpredictable, irregular innovative activity may lead to random growth rates. Freel (2000), in contrast to a study of large firms (Geroski and Machin, 1992), found that small, innovating firms had higher growth rates than non-innovating firms in the same size class. This is important, as most small firms view their primary competition as other small firms occupying similar market niches (Freel, 2000). Further, the probability of survival and the size of extant firms varies significantly within an industry, suggesting scale-specific niche effects (Dunne *et al*., 1988).

Freeman (1986) analyzed the 100 largest firms in the UK, and found concavity in Pareto plots. This finding was attributed to the existence of contiguous size classes in the firm size distributions. Freeman (1986) claimed that the nonlinear firm size distribution could be explained if the Gibrat assumption of proportionate effect is weakened. Instead of growth independent of size, the proportionality of expected growth to realized size holds for all the units in a size class. In essence, the growth of firms is autocorrelated in size classes. This phenomenon is likely the consequence of abrupt changes in scale, rather than a result of the gradual transition of firm location in the firm hierarchy (Freeman, 1986).

Size affects how firms cope with changes in their environments. As firms increase in size, they become more formalized, and task differentiation and specialization increase (Hodge and Anthony, 1991). Daft (1986) asserts that large firms develop more operating rules, and rely more heavily on written communication. Small firms, conversely, tend to operate without formal rules or procedures, and decisions tend to be collective (Mintzberg, 1979). It is possible that large firms are better suited to fulfill the tasks and responsibilities necessary to take advantage of market opportunities, because the organizational structures necessary for running a large firm may allow a firm to tap into commerce. This speculation has been supported by empirical research. Johnson *et al*. (1999) found evidence of nonlinearities in the growth-size relationship for small services firms in the UK. They argued that the nonlinearities reflected the short-term constraints small firms faced in adjusting to shocks. They speculated that firm growth beyond a very small size might require a discrete jump to a significantly larger operation. A possible explanation for this finding was that at a small scale an owner of a services firm might find himself badly stretched, especially since customer service is likely a focus of his business. This problem can be overcome, by adding staff, but that requires a formal management structure, which in turn implies a significantly greater scale of operation to support the business. Mittelstaedt *et al*. (2003) characterized size as the determining variable in whether a firm has the capacity to engage in export commerce. Focusing on manufacturing firms in South Carolina, it was discovered that firms with fewer than 20 employees were too small to sustain viable exporting activities (Mittelstaedt *et al*., 2003). Below 20 employees, it appears that firms cannot afford the fixed costs associated with exporting (Mittelstaedt *et al*., 2003). This is particularly relevant, because nearly 67 per cent of all manufacturing firms in the US have fewer than 20 employees (US Bureau of the Census, 2000). However, it does appear that firms with 20–100 employees are large enough to access the market in export commerce (Mittelstaedt *et al.*, 2003). Klette and Griliches (2000), building upon the empirical work of other researchers, modeled firm growth and concluded that research and development investment and innovation drive firm growth. Pagano and Schivardi (2003) found that large firm size spurs productivity, because it allows firms to increase their returns via research and development, which in turn means that size is a cause of growth for firms.

These factors affect how industries expand or contract in response to changes in their environments. Axtell (2001) tested the entire distribution of tax-paying firms in the US, and found that the distribution satisfied Zipf's law, likely as a result of a variation of Gibrat's law (Kesten process). Gibrat (1957) found that during industry expansion firm numbers rose slowly, with growth occurring primarily in incumbent firms. When an industry contracted, Gibrat (1957) found that firm numbers fell dramatically, with many small firms going extinct. Dunne *et al*. (1989) reported that for firms with a single manufacturing facility, no benefit was enjoyed from incumbency with respect to growth rate: growth rates decreased with increased firm size and age. In contrast, for multi-facility firms, a benefit from incumbency was realized: growth rates stabilized with increased firm size and age. Troske (1996) compared firm entry and exit in manufacturing and non-manufacturing industries, and found that firm exit was characterized by declining growth rates and firm size prior to exit from a market. Ghosal (2003) suggested that periods of uncertainty about profits, in conjunction with higher sunk costs, have a strong negative impact on the survival of small firms and impede entry of new firms, while having virtually no effect upon large firms. Despite constant perturbations in firm dynamics within an industry, the entry and exit of firms has little effect on the largest firms in an industry (Sutton, 1997).

Factors of geography

While firms within an industry may choose different strategies for survival according to their size, proximity to firms in other industries is important as well. Specialization in cities is dependent upon economic interactions within a given sector, while diversity in cities is driven by economic interactions across sectors (Duranton and Puga, 2000). New plants and innovative activities are typically created in larger, diversified cities (Duranton and Puga, 2000). Obviously, there are other forces at work, as diverse cities would dominate and specialized cities would disappear, but that is not the case (Duranton and Puga, 2000). This trend also holds at the firm level, as R&D and trial plants are overwhelmingly located in major metropolitan areas (Duranton and Puga, 2000). Glaeser *et al*. (1992) reported that local competition and urban variety encouraged growth in industries. Industries grew more slowly in cities in which they were more heavily overrepresented (Glaeser *et al*., 1992). Glaeser *et al*. (1992) suggest that diversity and competition help and specialization hurts employment growth.

The location of a firm in a landscape likely plays a role in its development. In the Ivory Coast, a region with a better supply route enjoyed more growth than other areas (Sleuwaegen and Goedhuys, 2002). Industries agglomerate in areas that have natural cost advantages (Ellison and Glaeser, 1999). For example, the wine industry must be located in regions favorable to growing grapes (Ellison and Glaeser, 1999). Ellison and Glaeser (1999) concluded that since a firm's location decisions are sensitive to cost, natural advantages account for much of the observed geographic concentration of industries. Geographic concentration of industries is the result of a dynamic process driven by new plants, plant extinctions, and expansions and contractions in existing plants (Dumais *et al*., 2002). The geographic concentration of manufacturing firms in the US has declined, despite randomness in the growth process, which implies a reversion in state-industry growth (Dumais *et al*., 2002). Kenworthy (1999) argues that the homogenization (i.e., convergence) of economic integration is limited, because market competition permits space for variation and institutions mediate the impact of market forces. Further tests of the convergence and convergence club hypotheses have been performed using economic data from other scales, including US states (Barro and Salai-i-Martin, 1992) and US counties, and conclusions about trends in inequality indices are mixed. Sohn (2004) found little evidence that stronger economic linkage results in and/or from a more concentrated location of similar industries, while finding that economic linkage for dissimilar industries was reflected in the spatial distribution of industries.

It has generally been accepted that greater business diversity is a desirable condition for a community, because it is unlikely that different types of businesses will have the same seasonal and cyclical fluctuations (McLaughlin, 1930). Empirical support for this notion is mixed, as different measures of 'diversity' have been used. Rodgers (1957) found that specialization is not necessarily a sign of economic instability, if the specialized industry is sound and has prospects for the future, while others have found that increased specialization leads to increased cyclical economic instability (Conroy, 1975; Wundt, 1992). Additionally, Brewer and Moomaw (1985) found that industrial diversification increases with city size, and Izraeli and Murphy (2003) found a link between industrial diversity and reduced unemployment. Dissart (2003) reported that more regional economic diversity results in more economic stability. This conclusion was based upon a review of published literature on the subject of economic diversity and stability. Further, a bigger economy is likely more diverse, which in turn is more stable, as more diversity leads to decreased unemployment rates (Dissart, 2003). Zhang (1994) reported that interacting spatial economies are either stable or unstable, with an economic system maintaining stability when population growth is not strongly affected by economic conditions or is slowly adapted to equilibrium. An increase in the population growth rate results in destabilization of and the emergence of endogenous oscillations in the system (Zhang, 1994).

Resilience and economic systems

Organizational dynamics are characterized by long periods of relative stability punctuated by brief periods of change that involve a shift to a new state (Perrings, 1998). This evolutionary process has been modeled as a Markov process, in which phase transition probabilities are dependent upon the strength of attractors of distinct equilibria (Aoki, 1996; Perrings, 1998). To illustrate this concept, Perrings (1998) provided the example of an economy in which a high proportion of assets are aggregated in flood-prone coastal zones. The value of those assets induces more investment in flood and coastal protection, which encourages more development in this coastal zone (Perrings, 1998). Perrings (1998) claims that the result of this pattern of development is a decline in the resilience of the system to major perturbations (e.g., storms), while its capacity to withstand minor perturbations increases. Additionally, technological discontinuities (e.g., new technologies or new methods of production) can also drive firm diversity, as that change can cause a re-organization of a system after a critical threshold has been reached (Carroll, 1993; Rosser *et al.*, 2003). These findings suggest that there exists a third way to understand firm growth and economic development, namely the resilience of economic systems. The sustainability of an industry will depend on the coping strategies of firms, and on the diversity of firms in an environment, but may well depend on diversity of size within an industry, where firms of different sizes adapt to achieve sustainability, a necessary requirement for economic development. This approach is consistent with findings in ecological resilience research.

Resilience and capacity for adaptive response in coupled social–economic–ecological systems depend crucially upon the nature and structure of the linkages between human and natural components. Resilience is the ability of a complex system to maintain its structural and functional capacity after a disturbance to the system (Perrings, 1998). Ecological, economic, and social systems are constantly subjected to perturbations, yet these complex systems often display considerable resilience, evidenced by an ability to recover and persist (Holling, 1973; Peterson *et al.*, 1998, Peterson, 2000). The response of complex systems to perturbation is often adaptive, allowing for greater resilience in response to future disruptions. If the resilience of a system is exceeded, the result may be collapse and subsequent reorganization of the system. In the long term, this may also be adaptive, but often entails substantial short-term societal costs (Holling, 1986, 1996). For instance, the responses of production to large negative shocks, such as oil price fluctuations, are characterized by nonlinear processes (Terasvirta and Anderson, 1992).

Carpenter *et al.* (2001) further examine resilience, defining it as 'the magnitude of disturbance that can be tolerated before a socioecological system moves to a different region of state space controlled by a different set of processes'. In ecosystems, spatial features of vegetation structure indicate regions of self-similarity separated by distinct breaks in landscapes of abandoned farmlands (Krummel *et al.*, 1987), in the Everglades (Gunderson and Snyder, 1994) and urban landscapes (Hostetler, 1999). Analyses of temporal data sets reveal that many abiotic processes tend to follow scaling laws (hence are scale invariant over wider ranges), whereas biotic time series data reflect the discontinuities present in animal body mass investigations (Havlicek and Carpenter, 2001). By definition, structural patterns that promote resilience are the most likely to persist over time and be replicated across space.

Firm size diversity, functional richness and resilience
Within the context of functional richness, previous findings on industrial sustainability suggest the following. First, firms of varying scales exist simultaneously, fulfilling different needs within their 'environment'. Second, regional factors affect the propensity of firms to succeed. Firm size diversity within industries is one such regional factor that should be considered. Applied in this context, the concept of resilience as deriving from functional diversity within scales and reinforcement across scales (Peterson *et al.*, 1998) suggests that the most resilient industries will be those with functions spread across the range of firm size.

Industries expand, contract, and adapt by adding or shedding employees within a manufacturing class. More resilient industries should show less volatility in employment trends than less resilient industries. We would expect lower variance in the employment trend for more resilient manufacturing industries, as this measure suggests decreased volatility in firm dynamics. In this study, functional richness is estimated within firm size classes, and we test the hypothesis that resilience is greater where there is diversity in firm size and type, in the context of the volatility of three-year employment trends.

2. Methods

A dataset of manufacturing firms in a defined geographic locale was used to test the relationship between functional richness and resilience. The 2000–2001 South Carolina Industrial Directory (South Carolina Department of Commerce, 2000) was used to identify firms in South Carolina. Firm information of location, Standard Industrial Classification (SIC) code, number of employees, and years of operation was gathered. The SIC code system was established by the Bureau of Census to classify firms according to production. Analogous to genus-species classifications, 2-, 3-, and 4-digit classifications reflect increasing levels of diversification within common categories. Of the 5,207 South Carolina manufacturing firms reported in the most recent Census of Economics (US Bureau of the Census, 2000), 3,997 (76.8%) are listed in the South Carolina Industrial Directory. Industrial categories were included in the study if the firms in that SIC classification had the largest number of employees or the greatest diversity of firms within an industrial classification. A total of 1,055 firms were included in analyses, representing 14 3-digit sub-categories and 93 4-digit sub-sub-categories (table 1). Each of these 14 datasets was analyzed using Bayesian Classification and Regression Tree models (BCART) to characterize the firm size distributions.

Classification and Regression Tree (CART) models are a relatively new, computationally intensive tool for dividing data into homogenous groups based on the values of candidate predictor variables (Breiman *et al.*, 1984). The CART algorithm recursively partitions the data into a succession of increasingly homogenous nodes, based on values or categories of a set of predictor variables. The algorithm begins by defining the deviance of the

Table 1. *Three-digit Standard Industrial Code firm classifications (US Bureau of Census 2000). Functional groups are 4-digit sub-categories within each 3-digit category. Average functional richness refers to the average number of functional groups represented within each size class within an industry*

SIC Code	*Manufacturing industry*	*Number of firms*	*Number of size classes*	*Number of functional groups*	*Average functional richness*
225	Knitting mills	34	5	8	4.2
232	Men's and boy's furnishings and work clothing	30	6	5	2.5
243	Millwork, veneer, plywood	83	9	5	3.11
251	Household furniture	45	8	5	3.3
267	Converted paper and paperboard products	37	7	7	3.57
308	Plastic products, misc.	174	12	9	4
329	Abrasive, asbestos and miscellaneous	40	6	5	2.67
344	Fabricated structural metal products	184	11	7	5.36
353	Construction, mining and materials handling	29	6	7	3
354	Metalworking machinery and equipment	114	10	8	4.3
355	Special industry machinery	119	10	6	2.6
356	General industrial machinery and equipment	68	7	9	4.86
371	Motor vehicle and motor vehicle parts	79	9	5	2.44
382	Laboratory apparatus and analytical, optical	19	5	7	2.8

first node (all of the data) as

$$D(\mu) = \sum (y_i - \mu)^2$$

where y_i are the observations within the node and μ is the node mean. Then each candidate predictor variable is examined to find a point that splits the response variable into two new nodes, a left and right, where

$$D(\mu_L) = \sum (y_i - \mu_L)^2 \quad \text{and}$$
$$D(\mu_R) = \sum (y_i - \mu_R)^2$$

are the respective deviances of the left and right nodes. The split that maximizes the deviance reduction

$$\Delta D(\mu) = D(\mu) - \{D(\mu_L) + D(\mu_R)\}$$

is chosen, and the process begins again at the left and right nodes. The resultant model can be depicted as a branching tree where the terminal nodes define groups of maximum homogeneity. However, a limitation of the conventional CART approach is that the conditional recursive partitioning algorithm will likely result in a tree that is not globally optimal. A Bayesian implementation of the CART algorithm addresses this limitation by performing a stochastic search over the space of all possible trees, based on prior probabilities of a split occurring at any given node (Chipman *et al*., 1998). The Bayesian algorithm is particularly effective at detecting discontinuities in datasets (Bremner and Taplin, 2004).

Within an SIC code, we calculated the functional richness within size classes. Functional richness is a measure of the diversity of firms, and was calculated by simply counting the number of different types of firms, based on SIC codes, in each size class. Functional richness, observed variance, coefficient of variation and standard deviation of three-year employment trend, number of size classes, and number of firms were then analyzed via a Pearson Correlation matrix. These variables were characterized from the Harris Info Datasource, a national database of 406,000 manufacturing firms. This database provides national industrial benchmarks, and includes data for firms within SIC classifications. National samples of employment and three-year employment trends were used to calculate average three-year employment trends for the 14 industrial sectors (Harris InfoSource, 2002). Our goals were to determine if: (1) firm size distributions are distributed continuously or discontinuously, and (2) functional richness is related to resilience as measured by employment volatility.

3. Results

All 14 of the SIC industrial sectors analyzed displayed significant discontinuities in the firm size distribution. The number of size classes ranged from 5 (knitting mills; laboratory apparatus and analytical optical) to 12 (plastic products, misc.) (table 1). There were five to nine functional groups within each SIC classification (table 1). Mean functional richness within size classes ranged from 2.44 (motor vehicle and motor vehicle parts) to 5.36 (fabricated structural metal products) (table 1).

Table 2. *Pearson correlation matrix assessing the relationships between functional richness, number of functional groups, employment variance, number of size classes and number of firms*

	Functional richness	*Number of functional groups*	*Employment variance*	*Number of size classes*	*Number of firms*
Functional richness	1				
Number of functional groups	0.716	1			
Employment variance	−0.457	−0.401	1		
Number of size classes	0.333	0.150	−0.331	1	
Number of firms	0.519	0.320	−0.457	0.937	1

There were no violations of normality in the Pearson correlations. There were positive correlations between the functional richness within a size class and the total number of functional groups within an industry ($r = 0.716$, $p = 0.004$, $df = 12$), between functional richness within a size class and the number of firms ($r = 0.518$, $p = 0.058$, $df = 12$). There was a negative correlation between functional richness within a size class and variation in employment trends ($r = -0.457$, $p = 0.101$, $df = 12$) (table 2). Each of these findings is consistent with expectations. The redundancy of function across size classes will increase as the number of firms increases if, as Sutton (1997) and Geroski *et al.* (2003) argue, industries do not converge toward a steady state condition. This is particularly true as product category diversification increases. Functional richness will likely increase as the number of firms increases as well, indicating larger numbers of entrants to fill particular market niches. Functional richness across size classes indicates lower entry barriers for firms, so we would expect the greatest number of firms in industries with the greatest richness. The positive correlation between functional richness and number of size classes may indicate greater firm size diversification, or may be an artifact of the strong (and understandable) correlation between the number of firms in an industry and the number of size classes. Taken together, these results suggest that as opportunities for product diversification increase in an industry, so does the functional richness across firm size.

What does this tell us about resilience? As functional richness increases across firm size, industries become more resilient (table 2). Firms are able to absorb exogenous shocks more easily than if a single steady state existed for firms. Stability within employment, measured by the standard deviation and coefficient of variation of the three-year employment trend within each industry, characterizes employment volatility within industrial sectors. Stable three-year employment trends indicate strong industrial

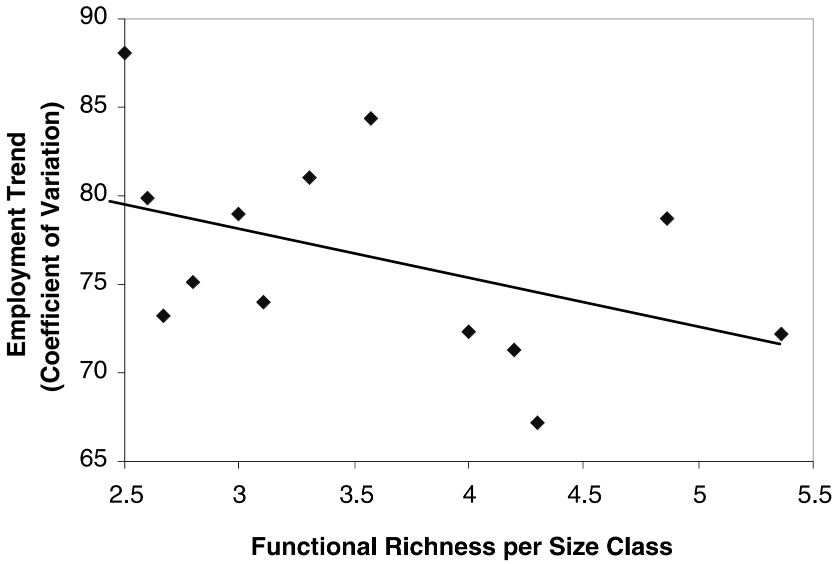

Figure 1. *Relationship between functional richness and employment trend (coefficient of variation), with a best fit trendline*

resilience, while large differences in employment patterns within and between industries is indicative of lower stability. SIC classifications with greater richness of function within size classes are characterized by a lower coefficient of variations in their employment trends, indicating greater volatility in less functionally rich industries (figure 1).

4. Discussion

Holling (1992) proposed that complex systems can be viewed as a dynamic hierarchy, structured by a few dominant processes operating at distinct spatiotemporal scales. Through a process of entrainment these dominant processes create discontinuities in features of the system, such as animal body mass or city size (Rosser, 2000). The creation of these structural discontinuities can be viewed as a form of self-organization, the emergence of a pattern from the internal dynamics of the system, rather than an imposed, top–down process.

This analysis demonstrates that firms are clustered in size classes within industrial sectors. Each of the SIC industrial sectors differed with respect to the amount of clustering, firm diversity, and richness of diversity across size classes. Resilience is the ability of a system to withstand shocks and remain within a basin of attraction (Holling, 1973). The functional richness within a size class is an aspect of resilience (Allen *et al*., 2005). In characterizing the resilience of a system, we have followed the cross-scale resilience model of Peterson *et al*. (1998). The model proposes that the determination of discontinuities and the quantification of function of firms within and across size classes provide a measure of the resilience of a system (Allen *et al*., 2005). We characterize the cross-scale resilience model proposed by Peterson *et al*. (1998) combined with the coefficient of variation of the employment trend for the data, as a plausible measure of resilience within an industrial sector. Our results indicate that manufacturing industries with greater functional richness spread across size classes suffer from less volatility in employment. The ability of small and large firms to adapt to variability in their 'environment' without adding or shedding members suggests that economic stability is enhanced when firms of different sizes emerge or are encouraged to emerge within industries.

Ecological, economic and social systems are coupled, and interactions between these systems are increasing in intensity (e.g., the magnitude of material and energy flows) and scale (i.e., the spatial extent of interaction). As human and natural systems become increasingly entangled, it makes less sense to think of them as separate, and more sense to regard them as overlapping components within a single system (O'Neill *et al*., 1986). Peterson *et al*. (1998) proposed that ecological resilience stems from diverse, overlapping function within a scale, and by reinforcement of function at different scales. The diversity of species is important for the resilience of an ecosystem, because species that are redundant in one set of environmental conditions may be critically important in other conditions (Brock *et al*., 2002). The distribution of functional diversity within scales and functional redundancy across scales, allows ecosystems to re-organize and maintain function following a broad range of environmental perturbations (e.g., fire, hurricanes, invasive species; Peterson *et al*., 1998). The loss of species that maintain ecosystem function reduces the ability of ecosystems to re-organize and maintain ecosystem function (Peterson *et al*., 1998), even though the loss may not immediately manifest itself in system disruption. Species that cannot compete on small spatial and short temporal scales persist over regional and longer time scales via their ability to more effectively utilize niches at these scales than their competitors (Levin, 2000).

Forys and Allen (2002) explored the cross-scale resilience model proposed by Peterson *et al*. (1998), and found that despite dramatic change in species composition, functional group richness did not change within scales and there was no significant loss of function across scales. The function of firms, interpreted here as analogous to species, may overlap but differ due to competition with similarly sized firms, which may increase the diversity of firms operating at a particular scale within a particular manufacturing industry (Forys and Allen, 2002). Across scales, there is overlap in function because firms are less likely to face competition from firms operating on different spatial and temporal scales.

Policies promoting economic diversity have to incorporate temporal scale effects upon growth, in that short-term policies focus upon promoting growth, while long-term policies focus upon promoting stability with growth (Wagner, 2000). Wagner (2000) states that diversity is a static concept that examines the size, specializations, and linkages between industries, while diversification is a process that increases diversity over time. We offer a dynamic perspective that suggests that growth and resilience stem from structures that allow various stable states and diversity in function within an industry at a regional scale.

Ecological resilience provides a new view for developing economic systems. Industry factor and environmental factor paradigms share a focus on the success or failure of individual firms. Ecological resilience views economic growth and firm volatility as systems effects, not firm effects. Perhaps economic development policy should encourage the development of firms of many sizes within an industry, rather than a 'right size' approach. This recommendation should be taken with caution, as there is evidence in complex systems that greater connectedness and interaction can lead to instability, with the effect being amplified by a larger number of agents (May, 1972). This implies that in a system with great diversity, if the interactions between the agents are too tightly coupled, the system could be on the verge of instability.

Whether or not the results of this analysis apply at smaller or larger scales is not the subject of this paper, but could be the focus of future research. There is anecdotal evidence that diversity may not contribute to resilience at smaller scales (e.g., diverse St Louis declining; concentrated Las Vegas ascending). Additionally, the interpretation of these results based on our characterization of the SIC levels may limit the applicability of the research, and some caution should be taken in broadly applying our results. However, our approach does provide a plausible method for assessing and operationalizing the measure of resilience in economic systems.

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Appendix. **Breakdown of functional groups within Standard Industrial Classification codes**

3-digit SIC	*4-digit SIC*	*Count*	*Average employment*	*Std. Dev.*
225		**25**	**181.40**	**247.26**
	2251	5	242.00	231.05
	2252	1	325.00	.
	2253	8	70.13	49.37
	2254	2	260.50	303.35
	2257	9	87.44	149.80
	2258	6	51.67	62.39
	2259	3	125.00	165.14
232		**34**	**74.03**	**106.48**
	2321	12	86.67	95.06
	2322	1	195.00	.
	2323	1	8.00	.
	2325	1	25.00	.
	2326	2	33.50	14.85
	2329	13	92.15	125.46
243		**175**	**24.15**	**37.13**
	2431	36	28.14	24.83
	2434	17	19.94	20.37
	2435	12	92.83	88.33
	2436	3	124.00	132.53
	2439	16	52.44	60.14
251		**57**	**56.25**	**129.17**
	2511	19	107.95	187.10
	2512	9	39.67	51.78
	2514	1	3.00	.
	2515	12	41.25	55.63
	2519	4	8.75	10.90
267		**52**	**158.27**	**336.67**
	2671	2	3.50	0.71
	2672	9	109.67	154.66
	2673	8	306.50	565.84
	2675	5	219.00	328.86
	2676	4	436.25	471.12
	2678	1	314.00	.
	2679	8	289.50	700.37
308		**210**	**95.25**	**193.66**
	3081	19	186.53	267.12
	3082	5	246.40	121.68
	3083	9	150.22	233.84
	3084	3	32.33	21.08
	3085	6	67.17	44.02
	3086	11	72.82	84.00
	3087	3	135.33	107.80
	3088	3	38.00	5.65
	3089	118	70.35	104.39

Appendix. Continued.

3-digit SIC	*4-digit SIC*	*Count*	*Average employment*	*Std. Dev.*
329		**14**	**42.64**	**51.63**
	3291	6	31.83	28.55
	3295	29	45.66	49.15
	3296	1	150.00	.
	3297	2	33.00	35.36
	3299	2	24.00	5.66
344		**340**	**37.65**	**77.83**
	3441	53	63.28	101.12
	3442	12	71.08	108.27
	3443	36	53.23	64.53
	3444	40	45.18	44.95
	3446	10	18.90	30.62
	3448	12	34.42	48.13
	3449	22	95.41	167.72
353		**48**	**41.88**	**61.25**
	3531	5	58.80	83.71
	3532	4	107.25	37.11
	3534	1	8.00	.
	3535	10	41.30	74.53
	3536	3	16.67	24.58
	3537	6	86.33	51.97
354		**104**	**44.61**	**61.25**
	3541	22	51.41	101.78
	3542	12	23.75	23.14
	3544	45	17.60	20.66
	3545	23	78.13	98.05
	3546	6	285.17	328.81
	3547	1	14.00	.
	3548	3	26.67	11.72
	3549	3	12.00	7.00
355		**101**	**41.22**	**88.09**
	3552	79	45.25	94.71
	3554	3	52.00	36.67
	3555	2	18.00	2.83
	3556	3	35.00	32.79
	3559	33	34.36	60.54
356		**94**	**137.39**	**225.90**
	3561	2	62.5	53.03
	3562	9	442.33	468.36
	3563	2	67.00	63.64
	3564	8	31.50	24.69
	3565	5	121.28	141.98
	3566	7	209.28	183.60
	3567	3	62.00	97.90
	3568	6	76.00	57.98
	3569	27	65.30	171.51

Appendix. Continued.

3-digit SIC	*4-digit SIC*	*Count*	*Average employment*	*Std. Dev.*
371		**92**	**218.53**	**412.20**
	3711	8	488.75	741.08
	3713	6	43.00	60.69
	3714	62	221.16	329.07
	3715	5	93.00	53.64
382		**29**	**115.90**	**257.98**
	3821	3	12.67	7.02
	3822	2	61.00	55.15
	3823	8	59.13	71.41
	3824	1	111.00	.
	3825	1	855.00	.
	3826	2	26.00	8.48
	3829	2	13.00	9.90