School of Economic Sciences

Working Paper Series
WP 2008-7

Do the Largest Firms Grow and Diversify the Fastest? The Case of U.S. Dairies

By

Melhim, A., Donoghue, E., and Shumway, C.R.

2008

WASHINGTON STATE UNIVERSITY
World Class. Face to Face.

Do the Largest Firms Grow and Diversify the Fastest?

The Case of U.S. Dairies

Almuhanad Melhim

Erik J. O'Donoghue

C. Richard Shumway

Corresponding Author:
Almuhanad Melhim
School of Economic Sciences
Washington State University
Pullman, Washington 99164-6210
Phone: (509) 335-1492
Fax: (509) 335-1173
Email: amelhim@wsu.edu

Date of Submission:
August 6, 2008

Almuhanad Melhim is a graduate research assistant in the School of Economic Sciences, Washington State University. Erik J. O'Donoghue is an economist with the Economic Research Service, U.S. Department of Agriculture. C. Richard Shumway is a professor in the School of Economic Sciences, Washington State University. Senior authorship is equally shared.

The authors gratefully acknowledge the significant contributions of the anonymous reviewers to the quality of this paper. This project was supported by the Washington Agricultural Research Center, the USDA Cooperative State Research, Education and Extension Service Hatch grant WPN000275, and the USDA Economic Research Service.

Do the Largest Firms Grow and Diversify the Fastest?

The Case of U.S. Dairies

Abstract

We analyze growth and diversification of U.S. dairy farms by examining changes in ten size cohorts and new entrants through three successive censuses. We reject Gibrat's law and the mean reversion hypothesis of growth. Growth rates appear bimodal where the smallest and largest farm cohorts grow fastest. All cohorts diversify but the largest farms do not diversify as rapidly as medium-sized farms. New entrants are generally large, and they diversify more rapidly than comparably-sized incumbents. These data suggest that scale economies persist even for the largest cohort of U.S. dairy farms and scale economies dominate scope economies for large farms.

Do the Largest Firms Grow and Diversify the Fastest?

The Case of U.S. Dairies

In recent decades, the U.S. dairy sector has been undergoing significant structural changes. These changes include industry consolidation, size and geographic concentration of agricultural production, contractual and integrated production schemes, and increasing numbers of large operations.

While similar statements could describe most agricultural industries, the changes have been particularly dramatic in the dairy industry. Overall, the number of U.S. farms declined by 21% between 1974 and 2002, whereas the number of farms with milk cows declined by an astounding 79% (USDA 2002). Remarkable in its own right, this rapid drop in number of dairies is even more astonishing since the number of dairies declined by 71% in the preceding decade (Matulich 1978). These changes represent an ongoing consolidation trend that shows no sign of abating. Indeed, the number of dairies fell another 15% in the three years following the last Census of Agriculture (USDA 2005, 2006). Thus, only 5% as many farms with milk cows operated in 2005 as in 1964.

With 60% as many milk cows on farms in 2005 as in 1964, the dairy industry has become much more concentrated. In fact, between 1992 and 2002, all farm groupings with fewer than 500 milk cows exhibited negative growth rates. The number of farms with less than 50 milk cows decreased the most rapidly (more than 50%) while the number of farms with 200-499 milk cows decreased the least (9%). In contrast, the number of farms with 500-999 milk cows grew by 36% while the number with 1,000 or more milk cows more than doubled.

Further, the U.S. dairy industry has become more geographically concentrated, particularly in the West. The abundance of land, a favorable climate, and the availability of inputs has allowed dry lot dairy farms to capture scale economies with larger herds (Miller and Blayney 2006; Herath, Weersink, and Carpentier 2004; Sumner and Wolf 2002).

The rapid changes in this industry suggest several important empirical research questions and testable hypotheses with regard to firm and industry growth that could have implications for public and private decision making. For example, profit-maximizing, price-taking firms are expected to grow if they can exploit scale and/or scope economies. Scale economies exist if the firm experiences decreasing average costs as output increases, and scope economies exist if the average total cost of production decreases as a result of increasing the number of goods produced.

The movement towards larger dairy farms is being driven in part by the fact that dairy farmers can generally increase profits as they expand their operations (Jones 1999). Some early empirical literature characterized the dairy industry as having an "L-shaped" average cost curve (Matulich 1978). While there are exceptions (Alvarez and Arias 2003; Kumbhakar 1993), recent literature on the U.S. dairy industry has shown evidence of a slightly declining average cost curve over wide ranges of size (e.g., Tauer and Mishra 2006; Mosheim and Lovell 2006; MacDonald et al. 2006). None found conclusive evidence of decreasing returns to scale even at the largest farm size examined.[1] Inferential evidence of scale and scope economies was also reported for the Washington dairy industry by Skolrud et al. (2007). Large farms grew faster than medium-sized farms, and dairy farms also become more diversified over time. Such empirical findings suggest that structural change in the dairy industry is likely to continue.

If dairy farmers experience no average cost penalty as they expand farm size, an obvious concern is just how far economies of scale and/or scope will push this industry. If the largest food production firms experience economies of scale and scope and if those economies do not dissipate, it is conceivable that the perfectly competitive nature of this industry could eventually disappear. Although a variety of circumstances can obviously produce quasi-competitive pricing, one characteristic of a perfectly competitive industry is that there are many firms.

If economies of scale and/or scope actually exist over all observed firm sizes and are sufficiently great to allow large firms to grow faster than medium-sized farms, then we would expect movement toward a single firm. The agricultural production sector is currently so far from consolidating ownership under a single firm that the thought seems unimaginable. Yet, if the rate of decline experienced over the last four decades in the number of farms with milk cows were to continue for 12 more decades, the entire market for milk in the U.S. could be supplied by just 10 firms. Such a small number could potentially exercise market power in the milk industry.

In addition to the concern about possible exercise of market power, concentration in the dairy industry raises substantial concerns about environmental degradation and adverse impacts on viability of rural communities. Air and water pollution from confined animal production units is expected to increase with more industry concentration. Although large dairy farms are relatively more involved in manure removal than small farms are, nearly 40% of farms with more than 700 milk cows do not remove manure from the farm (MacDonald et al. 2006). The growing market share of large dairy farms may push small dairy farmers to seek additional off-farm income to compensate for declining on-farm profit. Increased off-farm work can decrease the scale and technical efficiency of small dairy farms and lead to even higher exit rates among small farms in the long run (Cornejo, Nehring, and Erickson 2007).[2] When insufficient off-farm employment opportunities are available, it can erode the viability of rural communities.

In this paper, we further examine structural trends in the dairy industry. We extend the analysis by Skolrud et al. (2007) for Washington dairies to determine whether cost economies are evident at both national and multi-state regional levels. We avoid their selection bias in drawing inferences about scope economies by including all dairy farms in our sample. Our nonparametric approach and use of the 1992, 1997, and 2002 Agricultural Censuses contribute essential missing links in understanding how structural change is occurring at the firm level in the dairy industry. Although we do not address policy questions directly, our findings have important policy relevance with respect to market concentration, environment, and viability of rural communities. They also create an informational base that is particularly relevant for econometric analysis of causal factors. For example, they document substantial evidence of scope economies in the growth of dairy farms, an issue that remains neglected in empirical research on this industry.

This paper seeks answers to three fundamental research questions. First, what pattern of growth do farms exhibit? In particular, do the largest dairy farms grow at least as rapidly as medium-sized farms? If they grow less rapidly, it would suggest that convergence toward an equilibrium size is occurring even if that equilibrium size has not been observed. On the other hand, if the largest farms grow at least as fast as those in the medium size cohorts, we must conclude that farms are not yet approaching an equilibrium size. Second, do farms become more diversified over time? If they do, it would provide inferential evidence of increasing economies of scope. Third, if they do become more diversified over time, do the largest farms diversify more rapidly than medium-sized farms? If they diversify less rapidly, it would suggest that a change in the relative importance of scale and scope economies could cause medium-sized farms to grow the fastest in the future. If, however, the answer to all three questions is yes, then even without further analysis, we would conclude that the largest farms are expected to continue to grow the most rapidly, and no equilibrium farm size is currently in sight. That would imply that major structural changes will likely continue in this industry, at least in the near future. In addition to seeking answers to these three growth and diversification questions, we examine incumbent firms and new entrants separately for comparison purposes since various factors could induce different levels of scale and scope economies on these farms (e.g., operator experience).

This paper is organized in four additional sections. We first develop the method of analysis. A description of the data follows, which leads to the reporting and discussion of our results concerning farm growth, output diversification, and farm entry and exit patterns in the third section. We conclude and address major decision-making implications in the final section.

Method of Analysis

We apply both nonparametric and statistical methods to answer the three research questions. We partition initial farms into ten non-overlapping size cohorts based on the magnitude of agricultural sales (exclusive of government payments), with an equal number of farms in each cohort. We track incumbent farms in the ten initial size cohorts through two successive censuses, determine differences in growth rates, levels of diversification, and industry exit rates. We also track new entrants to determine their similarity to incumbent firms.

We examine growth and diversification at both national and regional levels. We contrast the structural trends in dairy farm structure across major dairy production regions. Our regional analysis includes two traditional and one non-traditional dairy production regions. While the former accounts for the majority of dairy operations, the latter has a bigger share of large farms.

We address the first question (growth pattern) by examining the relationship between initial cohort size and the mean growth rate of each incumbent cohort. This relationship will provide inferential evidence concerning whether farms are converging to an equilibrium size. Positive growth of a cohort's mean size indicates that, on average, farms in the cohort are likely operating under increasing returns to scale and/or scope. Farms in cohorts that are growing the most rapidly are likely among the most effective in reaping these economies.

We also examine the first question statistically for the U.S. by testing whether incumbent farms have grown in accordance with Gibrat's law (Sutton 1997) or in accordance with the mean reversion hypothesis (De Wit 2005). These two hypotheses are consistent with the assumptions of constant and diminishing returns to scale, respectively. Under Gibrat's law, firms of all observed sizes are hypothesized to face the same distribution of possible growth rates. If so, they follow a random walk growth pattern. By growing unpredictably, firms have no steady-state equilibrium size. In contrast, under mean reversion, growth rates are hypothesized to be inversely related to firm size. In this case, larger firms grow more slowly than smaller firms and possibly decline in size, which implies that firms converge to a steady-state equilibrium consistent with a "U-shaped" average cost curve. The remaining alternative is that cost economies persist and are sufficiently great that larger firms grow faster than smaller firms. This case suggests that firms have not yet reached a steady-state equilibrium and would imply rejection of a "U-shaped" average cost curve.

The bulk of prior empirical evidence, based mainly on corporate firm growth, has failed to reject the random walk assumption of growth and has supported Gibrat's law (Geroski 2005). The empirical evidence on the growth of farms, however, has been inconclusive. For example, although several of the previously cited studies found evidence of increasing returns to scale for larger farms, Kostov et al. (2005) implicitly rejected that hypothesis as well as rejecting Gibrat's law in favor of the mean reversion hypothesis for a sample of Irish dairy farms.

We test whether incumbent dairy farms have grown in accordance with Gibrat's law or mean reversion hypotheses using two separate linear regressions between the annual growth rates of individual farms and their initial sizes. One regression uses annual growth rates for the 1992-1997 period and the other uses annual growth rates for the 1992-2002 period. The least squares model is specified as follows:

(1) $y_{it} = \beta_{0t} + \beta_{1t} r_i + \varepsilon_i$, i = 1, …, N, t = 5-year or 10-year,

where y_i is the annual compound growth rate of the incumbent farms between the 1992 census and the 1997 or 2002 census, r_i is the size of farm i in the 1992 census, and ε_i is independently and identically distributed white noise. All farms that were in the 1992 sample and continued to generate positive agricultural sales in successive censuses were included in the regression.

The hypothesis tests are t-tests of the significance of β_{1t}. If the parameter is not significantly different from zero, the null hypothesis that cohorts grew in accordance with Gibrat's law is supported. A significantly negative coefficient provides support for the mean reversion hypothesis, while a significantly positive coefficient supports the hypothesis that cost economies were sufficiently great that larger firms grew relatively faster than smaller firms.

To address the second and third questions about increasing diversification, we calculate each farm's share of agricultural revenue from sales of milk and dairy products, cattle, grain, and other agricultural outputs in each census. Evidence of increasing diversification over time and inferential evidence of economies of scope would occur if subsequent censuses reveal a decreasing share of dairy sales in total agricultural sales.

Data

We use the 1992, 1997, and 2002 Agricultural Censuses to construct our sample. Based on the Census Farm Number (CFN) and Personal Operation Identification System (POIDS) codes, we track individual farms through subsequent censuses based on the legal entity for tax purposes. Except for retired and residential/lifestyle farmers, the national incumbent sample contains all farms classified as dairy farms in the 1992 Census of Agriculture. It includes all farms for which the owner checked farming as his/her main occupation and for which some of the farm's agricultural income in 1992 came from the sale of milk and dairy products. About 85,000 farms reporting milk cows in the 1992 Census are included in our sample. Similarly, sub-samples representing dairy's traditional and non-traditional production regions are created to implement the regional analysis. Following the Economic Research Service (ERS) regional classification, we select the Northern Crescent and the Heartland to represent traditional production regions and the Fruitful Rim to represent non-traditional regions.[3] These three regions account for 54%, 18%, and 4%, respectively, of the national sample of dairy farms.

For each sample, dairy farms in the 1992 Census of Agriculture are ranked based on their value of agricultural sales exclusive of government payments. These farms constitute our ten equally-sized cohorts. For the national sample, new farm entrants in 1997 constitute our 11th cohort, which we follow through the 2002 census. Similarly, we include new farm entrants in 2002 as our 12th cohort.

We compute summary statistics for each cohort in each census to determine changes in size distribution characteristics of dairy farms over time. They include: (1) number of surviving farms, (2) mean size, (3) median size, (4) size range, (5) size standard deviation, (6) size skewness, (7) size kurtosis, (8) number of exiting firms, and (9) share of agricultural revenue from the sales of milk and dairy products, grain, cattle, and other agricultural commodities.[4] Incumbent (surviving) farms in subsequent censuses do not change their cohort assignment. Therefore, size ranges of cohorts in the 1997 and 2002 censuses overlap due to the growth or decline in the size of individual farms within each cohort, but they represent all surviving farms in each cohort. For entrants, we record the statistical information and also calculate the number of entrants in each of the ten 1992-size-defined cohorts.

To permit valid calculations of firm growth between the 1992 census and each subsequent census, agricultural receipts are deflated by the index of prices received. Milk and dairy product sales are deflated by the index of prices received for dairy products. Sales from cattle, grain, and other agricultural outputs are deflated by the indexes of prices received for meat animals, feed grains and hay, and all farm products, respectively (USDA 2001, 2005).

Results

We discuss our findings with regard to each of the questions raised in the objectives: (1) Do dairy firms in the largest size cohorts grow at least as rapidly as firms in medium size cohorts? (2) Do firms become more diversified over time? (3) If they do become more diversified over time, do larger firms diversify more rapidly than medium-sized firms? Answers to these questions are provided by examining results for the incumbent cohorts at both national and regional levels. We also report the results of the two hypothesis tests associated with the first question (i.e., Gibrat's law and mean reversion hypothesis) for the national sample. We then discuss findings with regard to entry and exit of firms over the 10-year data period between the 1992 and 2002 censuses. Before providing results with regard to the questions, we describe the distributional properties of the data for the incumbent cohorts.

Firm Distribution by Cohort and Census

We report summary statistics for the national and regional samples in table 1. Most farms with milk cows were relatively small. Although we excluded retired and residential/lifestyle farmers, nearly half of our national sample sold less than $100,000 worth of agricultural goods in 1992. Only between 10 and 15% of farms had sales in excess of $300,000.[5] The size distribution of dairy farms in traditional regions was very similar to the national, but the distribution in the non-traditional region was represented by a much larger portion of large farms. Nearly 60% of dairy farms in the Fruitful Rim region had sales in excess of $300,000, and 20% of farms had sales in excess of $1 million.

For all samples, cohorts 1-9 had medians that were very similar to their means, and they had small standard deviations. In each sample, the median and mean values for cohort 10 were very different, suggesting that this cohort was right-skewed and contained some very large farms. Additionally, the standard deviation for cohort 10 was much larger than the others due to its open-ended range.

We report summary statistics for each incumbent cohort for 1997 and 2002 in tables 2 and 3. Range widths were reported in lieu of size ranges since cohort sizes overlapped in these censuses. The most dramatic and prevalent results for each of the first nine cohorts were: (1) the gap between median and mean farms increased over time, (2) the values of the higher moments became much larger, and (3) the size range of each cohort widened greatly. For cohort 10, the gap between median and mean farms and the size of its standard deviation also increased over time, but its skewness and kurtosis coefficients were actually smaller in 1997 and 2002. Consequently, for each of the first nine cohorts in both 1997 and 2002 censuses, size distributions of surviving firms became considerably flatter and more asymmetric with a thicker left tail. Size heterogeneity of the farms within each of these cohorts increased. A few farms in each cohort experienced substantial growth which explains some of the increase in size heterogeneity. In contrast, the tenth cohort became somewhat more symmetric and peaked. Its distributional variance appears to have been driven by fewer extreme deviations and more frequent modestly sized ones.

To graphically document the dynamic changes in size distribution of U.S. dairy farms over the ten-year period, we classified cohorts 5-9 as medium-sized firms. These firms received agricultural revenue in 1992 ranging from $100,000 to $300,000. Firms in cohort 10 were classified as large firms. The remaining cohorts (1-4) were classified as small firms. We graphed the probability distribution functions of each size group in the three censuses in figure 1. The distribution of each size group became more right-skewed over time. All three also had firms that became smaller in subsequent censuses. Downsizing was most evident for some of the small firms but was nontrivial for all size groups.

Firm Growth

Mean growth rates varied considerably among the incumbent cohorts. After adjusting for inflation between the censuses, the surviving dairy farms grew at an average compound rate of 1.3% per year between the 1992 and 1997 censuses and 1.4% per year between the 1992 and 2002 censuses.

For the U.S. sample, the most rapid growth rates occurred in the tails of the 1992 size distribution (see the first panel of figure 2). Cohorts 2-6 grew less than 1% per year over the ten-year period. In contrast, the smallest cohort grew at a compound rate of 3.8% per year, making it the most rapidly growing cohort. Each of the three largest cohorts also grew rapidly, and the largest cohort grew 2.8% per year. These growth patterns created a bimodal growth distribution. The bimodal growth distribution was also evident over the five-year period between 1992 and 1997. Thus, it is readily apparent that the answer to the first question is clearly yes for all U.S. dairies – large dairy firms (cohort 10) grew faster than medium-sized firms (cohorts 5-9).

However, the growth pattern of dairy farms differed across regions (see the second – fourth panels of figure 2). Farms in the Northern Crescent region had a bimodal growth distribution that was even more pronounced for the largest cohorts than the national distribution. The bimodality was much less evident for farms in the Heartland and Fruitful Rim regions. Except for cohort 1, all cohorts in the Heartland region grew at annual rates less than 2% while most of the cohorts in the Fruitful Rim region grew at annual rates of at least 4%. Largest farms (cohort 10) grew faster than the medium sized farms (average of cohorts 5-9) in the Heartland region but less rapidly in the Fruitful Rim region.

The estimated U.S. parameters for equation (1) are reported in table 4. The parameter estimates associated with the annual growth rate for both periods are positive and statistically significant, even at the 1% level. They imply that the estimated annual growth rate of the mean firm in cohort 10 would have been 1% greater than the mean firm in cohort 9 between 1992 and 1997 and 3% greater between 1992 and 2002. These statistics provide evidence for the hypothesis that firm growth is positively related to initial size, and they document that the relationship is stronger for the longer time horizon. The results for both periods imply that the size distribution has not yet reached steady-state equilibrium.

Consequently, the nonparametric examination of rates of growth by cohort and the results of the statistical hypothesis tests for dairy farms both render support to the view that a steady-state equilibrium firm size has not yet been reached in the dairy industry. This is not inconsistent with previous evidence of an “L-shaped” average cost curve in dairy production. Such a structure implies that the minimum efficient size is not unique, so large farms can still operate under scale efficiency. The only qualification to this conclusion applies to the Fruitful Rim region where medium-sized dairies grew the fastest. However, note that most of the medium-sized farms in the Fruitful Rim region were as large as dairies in the largest U.S. cohort.

Firm Size and Diversification

Cohorts 5-6 were the most specialized and the smallest cohort was the least specialized in milk and dairy product sales as their source of agricultural revenue in 1992 (figure 3). On average, a little more than 2/3 of agricultural revenue came from milk and dairy product sales for farms in the smallest cohort while close to 80% came from this sales category for farms in cohorts 5 and 6. The largest cohort followed cohorts 1 and 2 as the least specialized, with 75% of agricultural income coming from this sales category.

In successive censuses (see the second and third panels of figure 3), dairy farms of all sizes became less specialized in milk and dairy product sales in favor of other production activities. By 2002, the share of agricultural revenue that came from cattle, grain, and other agricultural sales increased substantially for virtually all cohorts.

To verify the extent to which this trend was due to changes in production rather than changes in relative output prices, we report relative prices for cattle, grain, and other outputs for each census in table 5.[6] Cattle prices declined trivially relative to dairy product prices, while grain and other prices increased by 9 percent and 7 percent respectively. While the increase in grain and other agricultural product relative prices partially explain the increased diversification, they can only explain up to 20 percent of the shift to grain, less than half the shift to other agricultural products, and none of the very large diversification into cattle sales. Thus, the increased diversification in sales must have been due primarily to changes in output mix.

Across cohorts, specialization in milk production followed a different pattern in both 1997 and 2002 than in 1992. The smallest cohort was the least specialized and the largest cohort was the most specialized in each subsequent census. The graphical evidence of less diversification in the larger cohorts than in the smaller ones was confirmed statistically by the correlation between firm size and diversification tendency. Correlation coefficients between cohort number and the percent of agricultural revenue that came from the sale of milk and dairy products was 0.37, 0.81, and 0.92 in 1992, 1997, and 2002, respectively. These statistics document a clear tendency toward greater specialization as firm size increased, and this tendency strengthened over time.

Between censuses, all cohorts in each of the three regions became more diversified with less reliance on milk and dairy-related outputs. The initial size only influenced the extent of the adjustment. Thus, our results imply that the answer to the second question is also clearly yes, dairy farms of all sizes (and in each of our regions) became more diversified.

To explore whether the largest firms diversified more rapidly than medium-sized firms, we examined the percent of agricultural sales from milk and dairy products for the medium-sized (cohorts 5-9) and large (cohort 10) farms for each census (see figure 4). Although U.S. medium-sized dairy farms were the most specialized in 1992, they became increasingly less specialized than large farms in successive censuses. The drop in milk and dairy product sales as a share of total agricultural revenue between 1992 and 1997 and between 1992 and 2002 was greater for medium-sized than for large farms. While the three regions differed somewhat in their initial levels of specialization, they all showed the same trends: medium-sized and large farms in each region became more diversified over time, and medium-sized farms diversified more rapidly than the large farms. Further, large farms in the Fruitful Rim diversified much less than large farms in the traditional regions. Thus, the answer to the third question is no, we do not find evidence that the largest dairy farms diversified more rapidly than medium-sized dairy farms.

Firm Entry and Exit

Between each pair of censuses, approximately twice as many dairy farms exited the industry as new farms entered. Over the 10-year period, between two and three farms left for every farm that entered in cohort sizes 1-8, so farm numbers in each of these cohorts declined over time. In contrast, cohort sizes 9 and 10 remained fairly stable, with just over one farm leaving for every farm that entered. Only in the size range of cohort 10, the largest category, did entrants outnumber exits. Overall, we found a fairly strong negative correlation between entry/exit ratio and cohort number.

The distribution of new entrants was different than the distribution of incumbent farms. Their mean size was very large, falling between the means of incumbent cohorts 8 and 9 in 1997 and cohorts 9 and 10 in 2002. Their median size fell between the median sizes of incumbent cohorts 4 and 5 in 1997 and cohorts 7 and 8 in 2002.[7] Standard deviations of entrants were large and in the neighborhood of the cohort 10 incumbents in each period. Additionally, the skewness and kurtosis coefficients were near the highest of any incumbent cohort. Entrants were also highly specialized when they entered the dairy industry with 77% of their agricultural revenue coming from the sale of milk and dairy products.

No major changes in the distribution of entrants occurred over time. Between 1997 and 2002, there was little change in the four moments of the 1997 cohort of new entrants although the range increased slightly. Like incumbents, entrants became less specialized in dairy with only 55% of agricultural revenue coming from milk and dairy product sales by 2002. They diversified as rapidly as medium-sized farms.

Conclusions and Implications for Decision Making

In this paper we examine scale and scope economies in the dairy industry primarily using a nonparametric approach. Our results suggest that both scale and scope economies persist in the largest cohort of dairy farms in the traditional dairy production regions, while scope economies appear to be greater in the medium-sized cohorts across all regions examined. This implies that, to remain profitable in undifferentiated product markets, dairy farms must grow larger.

However, the minimum efficient size may not be unique since we have not ruled out the possibility of a very flat average cost curve in this industry across a wide range of farm sizes as observed nearly 20 years ago by Matulich (1978). Dairy farms of all sizes diversified their output over time. The rate of diversification was highest among smaller producers. Small and medium-sized farms in all regions, especially those found in the Fruitful Rim, diversified faster than the largest farms. This suggests that diversification may improve the competitiveness of these smaller farms and may even be a substitute for scale economies that can only be achieved once the farm grows large enough. New entrants diversified more rapidly than incumbents of comparable size. These findings hold important implications for both private and public decision makers.

If the pattern of growth and diversification that occurred between 1992 and 2002 continues, a new type of industry could develop that is very different from the specialized, relatively small firms that have dominated the dairy industry in the past. In addition to the obvious advantage for expansion held by large farms, small producers and new entrants may capture some of those scale economies by partnering or cooperating with others to invest in large herds or to consolidate. They might also attempt to capture scope economies by adopting alternative technologies or business models that allow more diversified output.

Policy instruments and incentives that focus on helping small- and medium-sized dairy producers consolidate and/or diversify may be needed to slow the decline in number of dairy farms. Most dairy farms in the first nine cohorts qualify as small businesses.[8] Facilitation of new business models, information dissemination, and access to credit for small businesses could all be crucial for consolidation and diversification. Although inconceivable even a few decades ago, continuation of the long-term rapid growth of firm size experienced in the dairy industry might result in a sufficiently concentrated industry to exercise market power. Because such a concentrated industry also has the potential to adversely affect the viability of rural communities (Cornejo, Nehring, and Erickson 2007) and the quality of the environment (MacDonald et al. 2006), policies to facilitate small business growth and diversification could achieve multiple policy objectives. Further, because public concerns about air and water pollution from confined animal production units increase with the geographic concentration of the industry, strengthening policy instruments to mitigate negative environmental externalities could simultaneously promote a less concentrated, competitive industry of small businesses.

Endnotes

[1] The lone exception was Mosheim and Lovell (2006), who found evidence of eventual decreasing returns to scale for herds in excess of 2,000 cows, but only when they didn't account for technical and allocative efficiency. When technical and allocative efficiency was accounted for, they found evidence of increasing returns to scale across all herd sizes examined.

[2] They used the USDA Agricultural Resource Management Survey (ARMS) data to address the role of off-farm income on technical efficiency, scale, and scope economies.

[3] The three regions are part of a nine-region classification by the USDA Economic Research Service based on geographic specialization in production of U.S. farm commodities. The Northern Crescent region includes CT, DE, MA, MD, ME, MI, NJ, NH, NY, VT, and WI and portions of the states of MN, OH, and PA. The Heartland region includes IA, IL, and IN and portions of the states of KY, MN, MO, NE, OH, and SD. The Fruitful Rim region includes FL and portions of the states of AZ, CA, GA, ID, OR, SC, TX, and WA. For more information ,see http://www.ers.usda.gov/briefing/ARMS/resourceregions/resourceregions.htm.

[4] Cattle sales also include dairy cows (cull cows) and calves.

[5] The USDA Economic Research Service classifies farms with at least $250,000 in agricultural sales as commercial farms.

[6] The prices received indexes for dairy products, meat animals, feed grains and hay, and all farm products were used to derive the relative prices for milk and dairy products, cattle, grain, and other agricultural products, respectively.

[7] The differences between censuses could be partially due to the fact we were unable to track farms between 1997 and 2002 as accurately as between 1992 and 1997.

[8] The U.S. Small Business Administration considers dairy cattle and milk production businesses to be "small" if its average annual receipts are below $750,000.

References

Alvarez, A. and C. Arias. “Diseconomies of Size and Fixed Managerial Ability.” *American Journal of Agricultural Economics* 85(2003):134-142.

Cornejo J.F., R. Nehring and K. Erickson. “Off-Farm Work and Economic Performance of Crop and Livestock Farms.” Paper presented at AAEA annual meeting, Portland OR, 2007.

De Wit, G. “Firm Size Distributions an Overview of Steady-State Distributions Resulting from Firm Dynamics Models.” *International Journal of Industrial Organization* 23(2005):423-450.

Geroski, P.A. “Understanding the Implications of Empirical Work on Corporate Growth Rates.” *Managerial and Decision Economics* 26(2005):129-138.

Herath, D.P., A.J. Weersink, and C.L. Carpentier. "Spatial and Temporal Changes in the U.S. Hog, Dairy and Fed-Cattle Sectors, 1975-2000.” *Review of Agricultural Economics* 27(2004):49-69.

Jones, B. "Growth in Dairy Farms: The Consequences of Taking Big Steps or Small Ones When Expanding." Madison: University of Wisconsin, Center for Dairy Profitability, 1999.

Kostov, P., P. Patton, J. Moss, and S. McErlean. “Does Gibrat’s Law hold amongst Dairy Farmers in Northern Ireland?” Paper presented at EAAE meeting, Copenhagen Denmark, 2005.

Kumbhakar, S. “Short-Run Returns to Scale, Farm-Size, and Economic Efficiency.” *The Review of Economics and Statistics* 75(1993):336-341.

MacDonald, J.M., E.J. O’Donoghue, W.D. McBride, R.F. Nehring, C.L. Sandretto, and R. Mosheim. *Profits, Costs, and the Changing Structure of Dairy Farming*. Washington, DC: U.S. Department of Agriculture, ERS, Econ. Res. Rep. 47, 2006.

Matulich, S.C. "Efficiencies in Large-Scale Dairying: Incentives for Future Structural Change." *American Journal of Agricultural Economics* 60(1978):642-67.

Mosheim, R. and C.A.K. Lovell. "Economic Efficiency, Structure and Scale Economies in the U.S. Dairy Sector." Paper presented at AAEA annual meeting, Long Beach CA, 2006.

Miller, J.J. and D.P. Blayney. *Dairy Backgrounder*. Washington, DC: U.S. Department of Agriculture, ERS, LDP-M-145-01, July, 2006.

Skolrud, T.D., E. O'Donoghue, C.R. Shumway, and A. Melhim. "Farm Growth, Consolidation, and Diversification: Washington Dairy Industry." *Choices* 22(2007):125-28. Online version: http://www.choicesmagazine.org/2007-2/grabbag/2007-2-07.htm..

Sumner, D.A. and C. Wolf. "Diversification, Vertical Integration, and the Regional Pattern of Dairy Farm Size." *Review of Agricultural Economics* 24(2002):442-457.

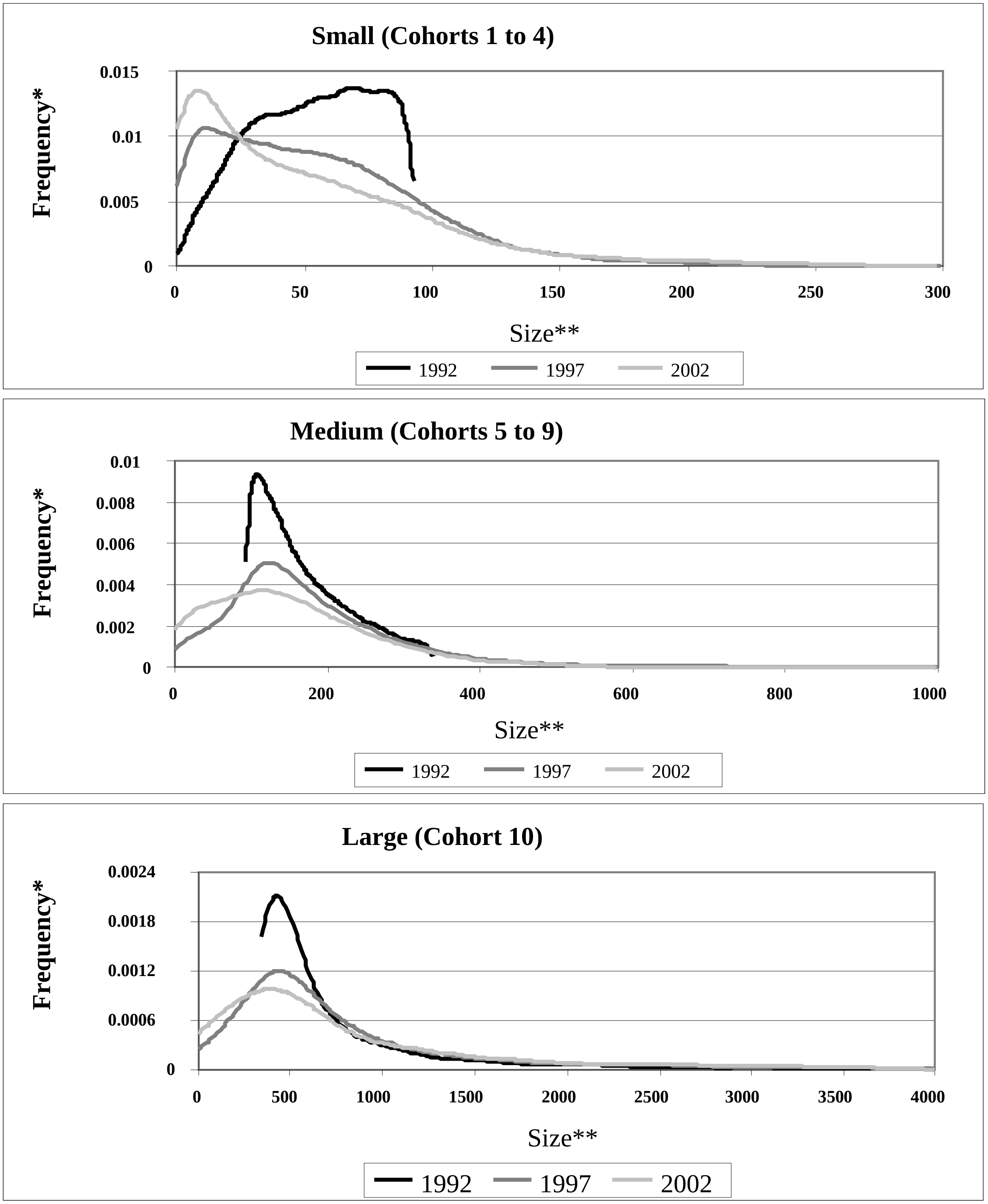
Sutton, J. "Gibrat's Legacy." *Journal of Economic Literature* 35(1997):40-59.

Tauer, L.W., and A.K. Mishra. "Can the Small Dairy Farm Remain Competitive in U.S. Agriculture?" *Food Policy* 31(2006):458-468.

U.S. Department of Agriculture. 1992, 1997, 2002 Census of Agriculture. National Agricultural Statistical Service. Available online: http://www.nass.usda.gov/Census_of_Agriculture.

U.S. Department of Agriculture. 2001, 2005, 2006 Agricultural Statistics. National Agricultural Statistical Service. Available online: http://www.nass.usda.gov/Publications/Ag_Statistics/.

Figure 1. Probability distribution function of farms with milk cows 1992 - 2002 a

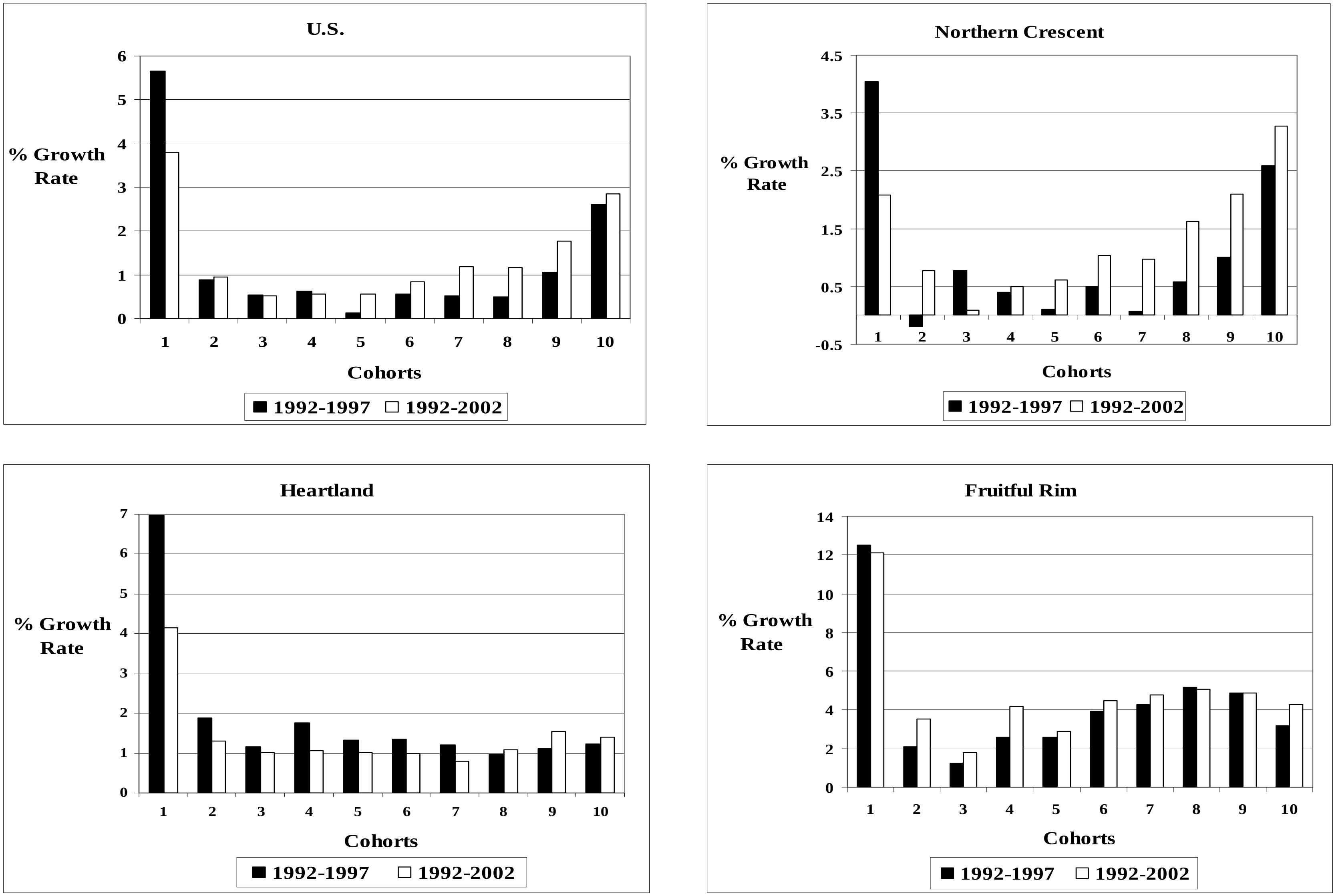


a The size density functions are slightly upward biased due to truncation. To make the graphs more legible, we excluded small, medium, and large farms with 1992 agricultural sales greater than $300,000, $1 million, and $4 million, respectively. At least 97.5% of the farms in each size category are included in the graphs.

* The frequency values are to the power of 10^{-3}.

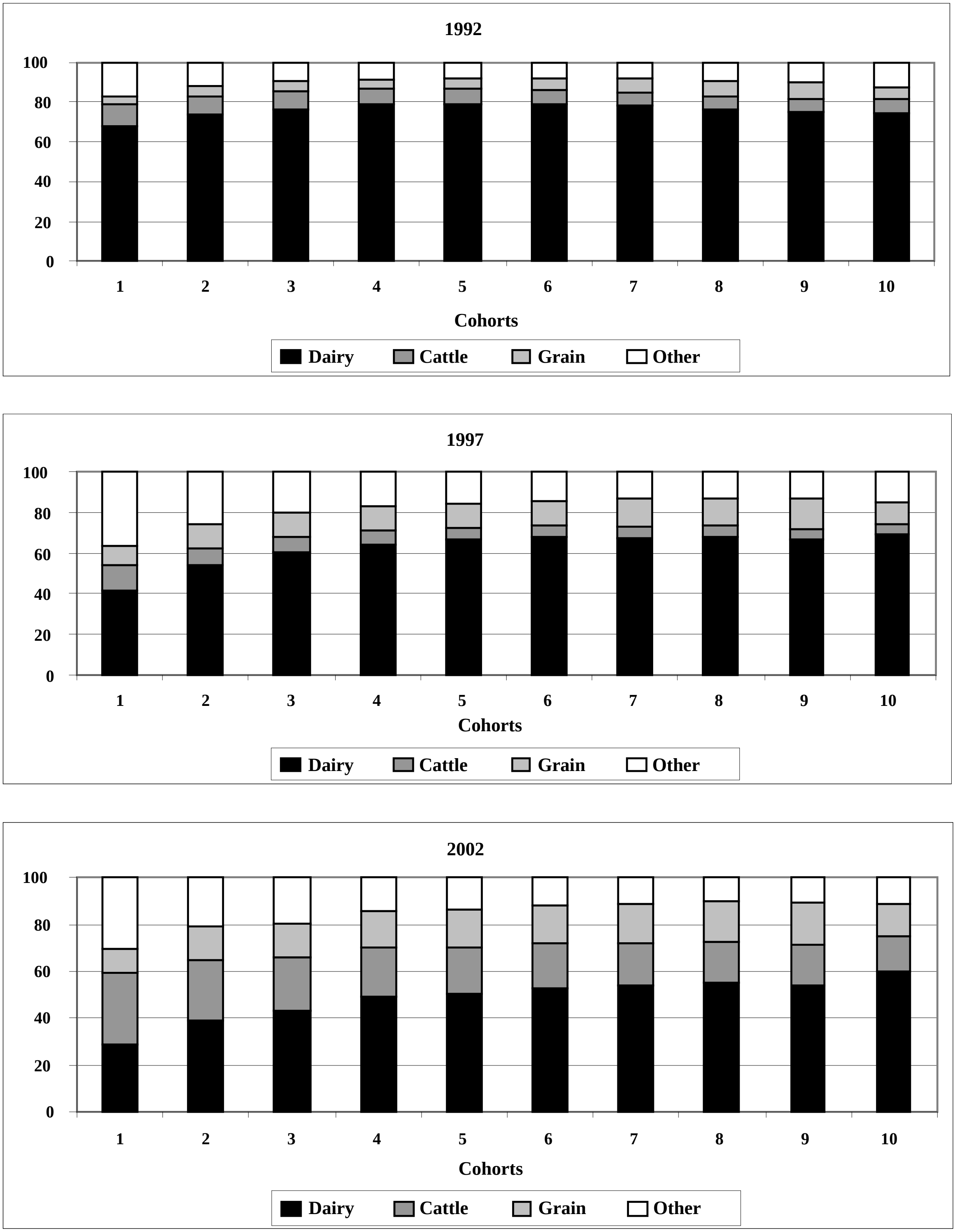
** The size is measured in $1,000 units of agricultural sales.

Figure 2. U.S. and regional annual growth rates



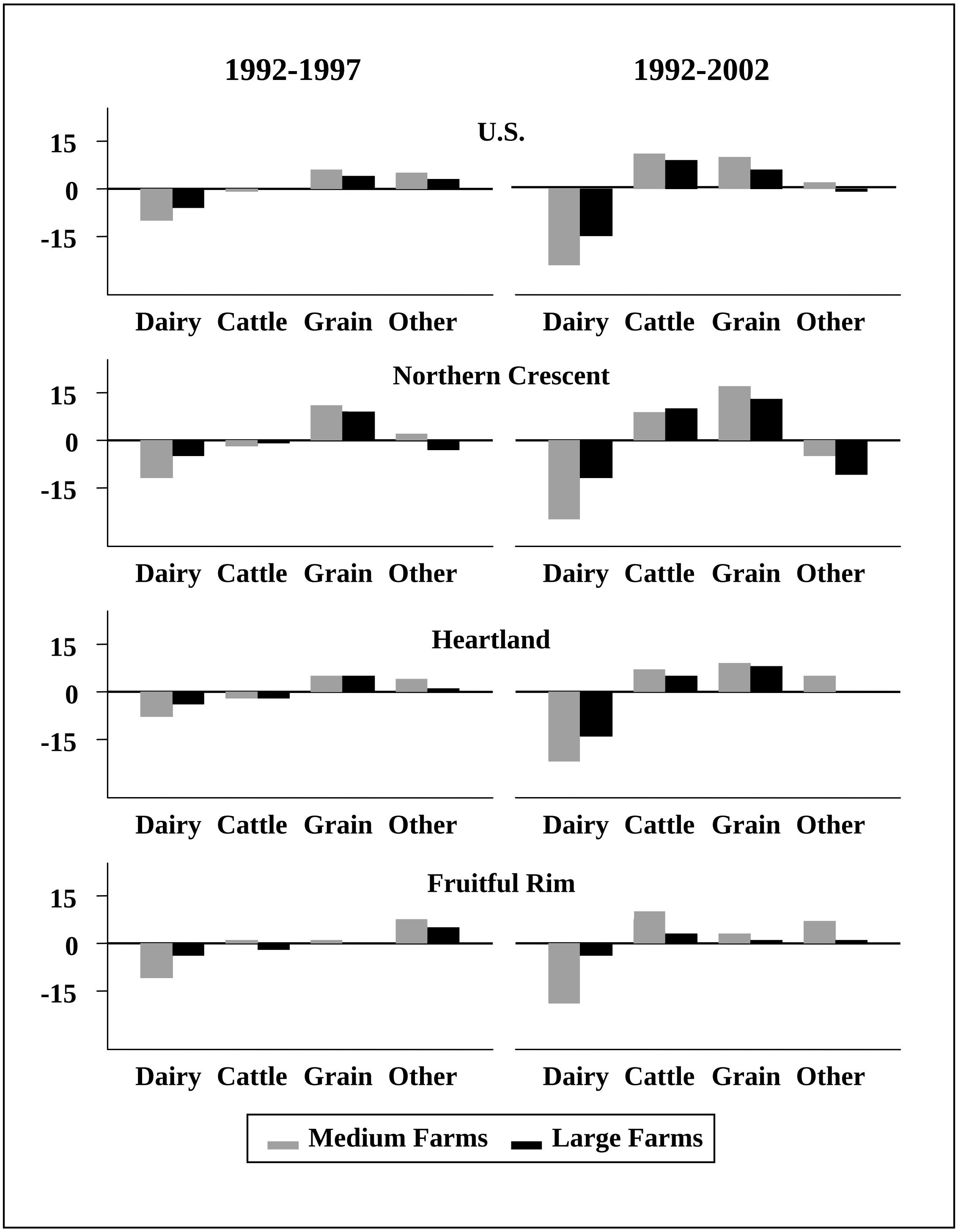
Data source: *Census of Agriculture* (USDA 1992, 1997, 2002)

Figure 3. U.S. farm diversification



Data source: *Census of Agriculture* (USDA 1992, 1997, 2002)

Figure 4. Percent change in portion of farm revenue from different sales categories



Data source: 1992, 1997, and 2002 Agricultural Censuses

Table 1. Agricultural sales range, median, and sample distribution moments for cohorts, 1992, in $1,000 [a]

Cohort	U.S.			Traditional Dairy Regions						Non-traditional Dairy Region		
				Northern Crescent			Heartland			Fruitful Rim		
	Median	Mean	Range	Median	Mean	Range	Median	Mean	Range	Median	Mean	Range
1	23	22*(9)*	<34	26	24*(9)*	<37	26	24*(10)*	<37	26	26*(19)*	<57
2	45	45*(7)*	34-55	47	47*(6)*	37-57	48	48*(6)*	37-57	90	90*(19)*	57-123
3	65	65*(6)*	55-74	65	65*(5)*	57-73	66	66*(6)*	57-75	159	161*(25)*	123-143
4	83	83*(6)*	74-92	82	82*(5)*	73-90	84	85*(6)*	75-94	242	244*(26)*	143-167
5	102	102*(6)*	92-112	99	99*(5)*	90-107	104	104*(6)*	94-114	340	341*(30)*	167-191
6	124	124*(7)*	112-136	117	117*(6)*	107-127	125	125*(7)*	114-136	456	460*(44)*	191-249
7	152	152*(10)*	136-170	139	140*(8)*	127-153	150	151*(9)*	136-167	649	656*(75)*	249-399
8	194	196*(16)*	170-225	172	173*(13)*	153-196	186	188*(14)*	167-213	961	962*(102)*	399-598
9	268	272*(23)*	225-339	228	231*(23)*	196-277	245	248*(23)*	213-293	1458	1475*(217)*	598-1,119
10	508	789*(938)*	>339	377	475*(334)*	>277	390	482*(322)*	>293	2766	3500*(2,449)*	>1,119

[a] Standard deviations are in parentheses. Data source: *Census of Agriculture* (USDA 1992)

Table 2. Agricultural sales range, median, and sample distribution moments for cohorts, 1997, in $1,000 [a]

Cohort	U.S.			Traditional Dairy Regions						Non-traditional Dairy Region		
				Northern Crescent			Heartland			Fruitful Rim		
	Median	Mean	Range Width	Median	Mean	Range Width	Median	Mean	Range Width	Median	Mean	Range Width
1	20	30*(55)*	1,644	22	31*(43)*	687	25	36*(54)*	874	10	50*(151)*	1,771
2	41	49*(58)*	1,771	44	48*(43)*	929	46	54*(58)*	1,105	82	103*(140)*	1,653
3	62	68*(67)*	2,306	63	70*(75)*	2,306	66	72*(55)*	751	159	176*(145)*	1,101
4	82	88*(81)*	3,158	81	86*(80)*	3,158	85	95*(71)*	796	252	286*(274)*	3,227
5	101	106*(73)*	1,940	99	102*(60)*	1,052	105	114*(102)*	1,939	382	398*(257)*	2,566
6	125	131*(93)*	2,522	118	123*(79)*	2,505	130	137*(79)*	1,009	518	572*(429)*	4,213
7	151	160*(114)*	2,390	139	144*(87)*	2,390	151	164*(124)*	2,213	765	828*(526)*	4,449
8	194	205*(135)*	3,500	174	182*(108)*	1,999	188	202*(128)*	2,068	1,150	1,267*(722)*	5,790
9	274	294*(186)*	3,291	235	248*(133)*	2,522	250	268*(160)*	2,465	1,802	1,916*(990)*	8,784
10	564	922*(1,261)*	30,384	414	555*(532)*	7,861	415	526*(443)*	4,740	3,508	4,202*(3,365)*	30,375

[a] Standard deviations are in parentheses. Data source: *Census of Agriculture* (USDA 1997)

Table 3. Agricultural sales range, median, and sample distribution moments for cohorts, 2002, in $1,000 [a]

Cohort	U.S.			Traditional Dairy Regions: Northern Crescent			Traditional Dairy Regions: Heartland			Non-traditional Dairy Region: Fruitful Rim		
	Median	Mean	Range Width	Median	Mean	Range Width	Median	Mean	Range Width	Median	Mean	Range Width
1	14	31*(116)*	4,929	15	29*(75)*	2,000	20	35*(62)*	6,23	9	81*(478)*	4,929
2	35	48*(78)*	1,725	37	49*(73)*	1,250	38	52*(86)*	1,336	62	122*(415)*	5,020
3	52	65*(99)*	2,056	54	63*(92)*	2,056	53	70*(83)*	702	116	183*(310)*	2,329
4	72	84*(125)*	5,020	75	82*(86)*	1,420	70	90*(120)*	2,140	224	350*(718)*	5,983
5	91	103*(118)*	3,472	92	100*(99)*	1,495	86	109*(162)*	3,472	370	431*(471)*	4,269
6	113	128*(157)*	4,312	111	123*(146)*	3,250	112	131*(151)*	2,980	514	677*(965)*	9,566
7	142	163*(186)*	3,410	134	146*(149)*	3,410	132	155*(135)*	1,070	833	991*(1,014)*	8,431
8	183	208*(224)*	4,920	170	192*(197)*	2,520	167	198*(202)*	2,862	1,286	1,494*(1,183)*	8,552
9	255	307*(353)*	8,750	230	269*(275)*	4,522	228	273*(303)*	4,706	1,972	2,240*(1,474)*	10,626
10	551	987*(1,541)*	42,322	416	620*(753)*	9,704	387	524*(585)*	8,043	4,018	5,017*(4,333)*	42,209

[a] Standard deviations are in parentheses. Data source: *Census of Agriculture* (USDA 2002)

Table 4. Coefficient estimates of equation (1) [a]

Year	Intercept	Size of Farm ($1000s)	N	R^2
1997	-1.46**	0.001**	39,896	0.001
	(0.001)	(0.0002)		
2002	-3.95**	0.003**	39,896	0.005
	(0.09)	(0.0002)		

[a] Standard errors are in parentheses. Estimated parameters that are significant at the 0.01 level are marked with two asterisks.

Table 5. Output category prices relative to dairy products price

		Cattle	Grain	Other
Dairy	1992	1	1	1
	1997	0.94	1.17	1.06
	2002	0.99	1.09	1.07

Data source: *Agricultural Statistics* (USDA 2001, 2005)