Cooperative Extension Service
College of Tropical Agriculture and Human Resources
University of Hawai'i at Mānoa

Economic Issues
Apr. 2006
EI-9

Growth and Stability of Agricultural Production in Hawaii: A Portfolio Analysis

Junning Cai and PingSun Leung
Department of Molecular Biosciences and Bioengineering

Two previous CTAHR Economic Issues publications, EI-3 (*Agriculture's Contribution to Hawaii's Economy—An Update*) and EI-4 (*The Linkages of Agriculture to Hawaii's Economy*) have examined agricultural industries' economic contribution and their linkages to the rest of Hawaii's economy[1] (see Notes, p. 11).

The present publication examines the growth and stability of agricultural production in Hawaii over the past four decades. This examination provides information about individual agricultural industries' growth and stability characteristics as well as their impacts on the growth and stability of the entire agricultural sector.[2] We have also assessed how diversification within Hawaii's agricultural sector has affected its stability.

A portfolio of agricultural industries

Hawaii's agricultural sector is like a portfolio composed of a variety of individual agricultural industries (Table 1). This industry portfolio's performance is determined by the performance of each industry in it as well as its industry composition (i.e., each industry's weight in the portfolio).

High growth of individual agricultural industries would lead to high growth of the entire agricultural sector; and an agricultural sector made up of a higher percentage of rapidly growing industries would grow faster.[3]

Similarly, low (growth) variation (i.e., more consistent growth rates) of an individual agricultural industry would tend to make the entire agricultural sector grow more stably. Variation of the entire agricultural sector is also affected by co-variation between agricultural industries. For example, an industry with a tendency to move in the opposite direction, relative to the general agricultural trend, could help reduce the variation of the entire agricultural sector.

Variation of the entire agricultural sector depends not only on individual industries' variations and co-variations but also on their composition in the sector.[4] The following analysis also examines the impacts of "diversified agriculture" on the stability of Hawaii's total agricultural sector. On the one hand, as new industries tend to have relatively high growth variations at their starting stages, diversification towards them (i.e., increasing their shares in the total agricultural sector) may have a negative impact on Hawaii's agricultural stability. However, as a highly diversified agricultural sector is generally believed to be more stable than one concentrated in a few industries, diversification may enhance the stability of Hawaii's agricultural sector.

Growth and stability characteristics of Hawaii's agricultural industries

Table 2 shows the annual growth rates of total production value of Hawaii's agricultural sector from 1964 to 2003.[5] These four decades of agricultural development could be divided into two two-decade periods. During the first period from 1964 to 1983, Hawaii's total agricultural production value was on a slightly upward trend but had fluctuated significantly.[6] From 1984 to 2003 the production value declined for most of the time but remained relatively flat in the early 2000s (Table 2 and Figure 1).

These aggregate agricultural growth patterns were shaped by the growth and stability performance of individual agricultural industries, which is illustrated by the two graphs in Figure 2.

Published by the College of Tropical Agriculture and Human Resources (CTAHR) and issued in furtherance of Cooperative Extension work, Acts of May 8 and June 30, 1914, in cooperation with the U.S. Department of Agriculture. Andrew G. Hashimoto, Director/Dean, Cooperative Extension Service/CTAHR, University of Hawai'i at Mānoa, Honolulu, Hawai'i 96822.

Table 1. Industry portfolio of Hawaii's agricultural sector in 1964 and 2003.
(For each commodity and year, production is expressed in farmgate sales in 2003 dollars and the percentage relative to total agricultural production.)

	1964		2003	
	(1,000 $)	(%)	(1,000 $)	(%)
Crops	**774,890**	**79.8**	**464,169**	**84.3**
sugarcane	497,189	51.2	64,400	11.7
fruit	207,402	21.4	129,668	23.6
pineapples	195,579	20.2	102,849	18.7
papayas	5,670	0.6	13,069	2.4
bananas	3,791	0.4	9,225	1.7
guavas	170	0.0	925	0.2
tropical specialty fruit	2,192	0.2	3,600	0.7
vegetables and melons	28,095	2.9	53,328	9.7
tomatoes	5,115	0.5	10,150	1.8
taro	3,099	0.3	2,700	0.5
herbs	–	–	7,245	1.3
ginger root	665	0.1	3,600	0.7
others	19,217	2.0	40,478	7.3
tree nuts	23,178	2.4	56,400	10.2
macadamia nuts	6,560	0.7	32,330	5.9
coffee	16,619	1.7	24,070	4.4
floriculture and nursery products	14,833	1.5	95,601	17.4
orchids	–	–	23,439	4.3
lei flowers	–	–	3,704	0.7
foliage	–	–	16,966	3.1
cut flowers	–	–	14,183	2.6
potted flowering plants	–	–	5,563	1.0
other nursery products	–	–	30,391	5.5
seed crops	–	–	50,470	9.1
other crops	4,192	0.4	3,457	0.6
Livestock	**195,618**	**20.2**	**58,737**	**10.7**
milk	63,723	6.6	21,449	3.9
cattle	53,306	5.5	17,192	3.1
eggs	46,489	4.8	9,396	1.7
hogs	19,146	2.0	4,345	0.8
honey	286	0.0	1,177	0.2
others	12,669	1.3	5,178	0.9
Aquaculture	–	–	**27,650**	**5.0**
algae	–	–	11,848	2.1
shellfish	–	–	9,719	1.8
finfish	–	–	1,740	0.3
others	–	–	4,343	0.8
Total	**970,507**	**100.0**	**550,556**	**100.0**

Data source: Statistics of Hawaii Agriculture, various issues.

The upper graph in Figure 2 shows the growth and stability performance of Hawaii's agricultural industries during 1964–1983. Three industries (i.e., macadamia nuts, floriculture and nursery products, and papayas) were located in the northwest quadrant of this graph. These industries have the most desirable growth and stability characteristics (i.e., above-average growth rates but below-average growth variations) during 1964–1983. Coffee, ginger root, guavas, honey, and seed crops were located in the northeast quadrant with above-average growth rates and above-average growth variations. Most of Hawaii's agricultural industries (i.e., bananas, pineapples, tropical specialty fruit, taro, tomatoes, other vegetables and melons, other crops, cattle, eggs, hogs, milk, and other livestock) were located in the southwest quadrant, indicating that they had below-average growth rates during 1964–1983; yet their growth was steadier than the average. Sugarcane was the only industry located in the southeast quadrant, which indicates that its growth performance was slightly below average during 1964–1983, while the variation of its growth rate was above average.

The lower graph in Figure 2 shows the growth and stability performance of Hawaii's agricultural industries during 1984–2003, which has changed significantly compared to the situation during 1964–1983.

Only floriculture and nursery products still stayed in the northwest quadrant, while papayas and macadamia nuts have slipped into the southwest quadrant with its below-average growth rate during 1984–2003. Although tomatoes' growth and stability performance during 1984–2003 was very similar to its situation during 1964–1983, tomatoes has relocated from the southwest to the northwest quadrant because of Hawaii agricultural sector's reduced average growth rate during 1984–2003 compared to the situation during 1964–1983.

Four industries (coffee, guavas, honey, and seed crops) still remained in the northeast quadrant despite their declined mean growth rates during 1984–2003 compared to 1964–1983, while the decline in ginger root's growth rate was too large to remain in this quadrant. With its deteriorating growth performance but improving stability performance, sugarcane had relocated from the southeast to southwest quadrant.

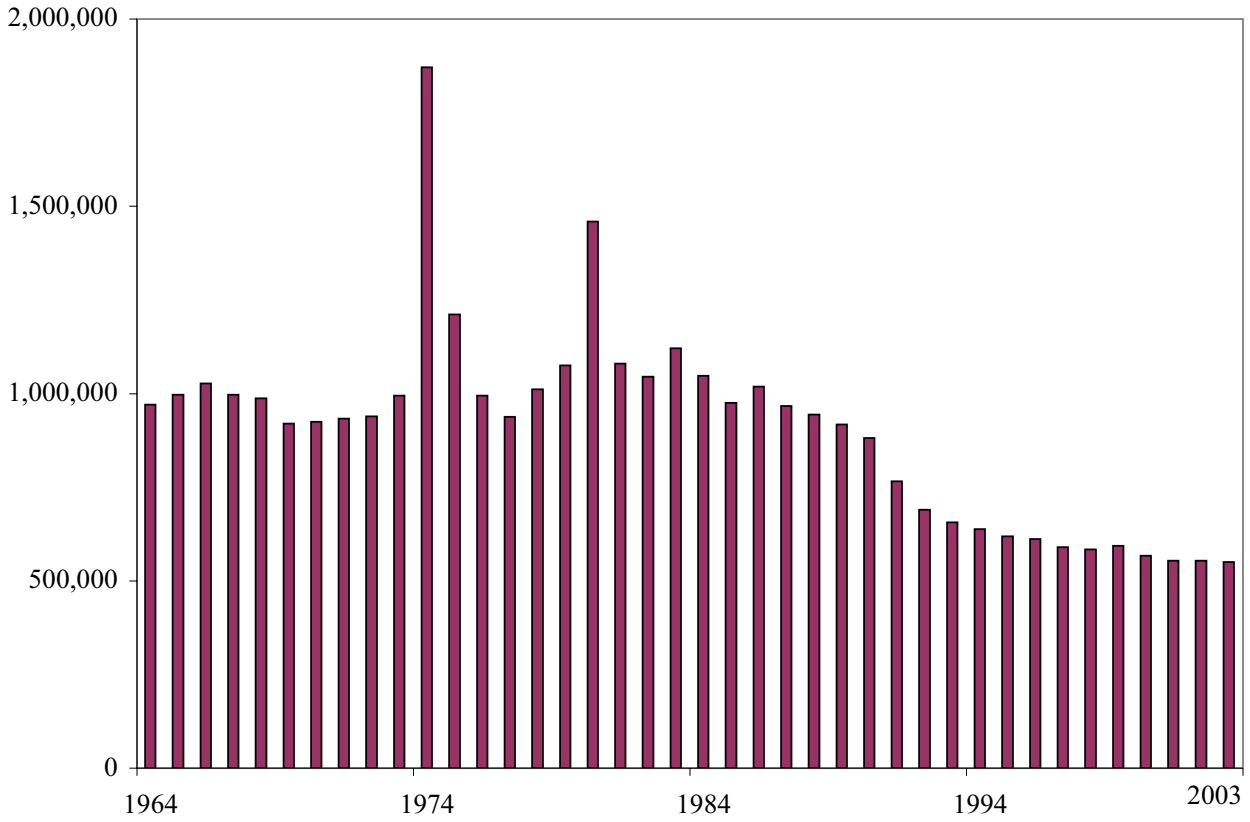
Similar to the situation during 1964–1983, pineapples, livestock, and vegetables and melons (excluding tomatoes) still remained in the southwest quadrant with lackluster but more steady growth performance.

Table 2. Annual growth in the value of Hawaii's agricultural sector.

Year	Growth	Year	Growth	Year	Growth	Year	Growth
1964	–8.1%	1974	88.2%	1984	–6.5%	1994	–2.7%
1965	2.7%	1975	–35.3%	1985	–6.9%	1995	–3.0%
1966	3.1%	1976	–17.8%	1986	4.5%	1996	–1.1%
1967	–3.0%	1977	–5.7%	1987	–5.1%	1997	–3.6%
1968	–0.9%	1978	7.8%	1988	–2.3%	1998	–1.1%
1969	–6.9%	1979	6.3%	1989	–2.8%	1999	1.7%
1970	0.6%	1980	35.7%	1990	–4.0%	2000	–4.5%
1971	0.9%	1981	–26.0%	1991	–13.1%	2001	–2.4%
1972	0.6%	1982	–3.2%	1992	–9.9%	2002	0.0%
1973	5.8%	1983	7.3%	1993	–5.0%	2003	–0.6%

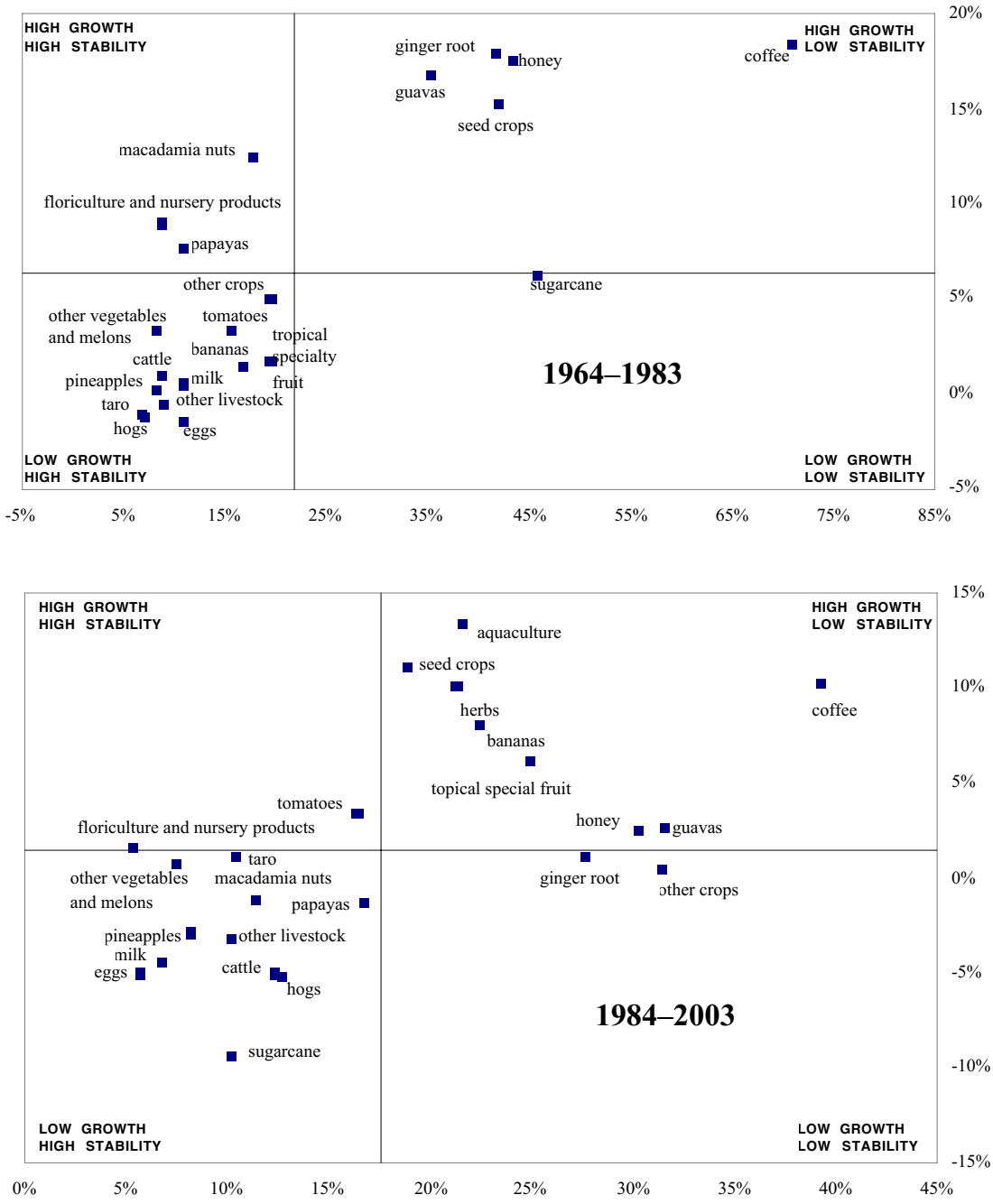
Calculations are based on data from various issues of Statistics of Hawaii Agriculture and State of Hawaii Data Book. Percentages are the annual growth rates of Hawaii's total agricultural farmgate sales measured in 2003 dollars.

Figure 1. Annual value of agricultural production in Hawaii, 1964–2003.



Note: Agricultural production is measured by total agricultural farm-gate sales in thousands of 2003 dollars.

Figure 2. Growth and stability of Hawaii's agricultural industries.



Vertical and horizontal axes measure agricultural industries' growth and stability, respectively. The coordinate of each industry measures the mean (vertical axis) and standard deviation (horizontal axis) of its growth rates during 1964–1983 or 1984–2003. The origin in each graph represents the average growth and standard deviation of all the agricultural industries during each of the two periods. The coordinate of the origin in the upper graph is (21.9%, 6.3%), which indicates that agricultural industries' average growth rate during 1964–1983 is 6.3%; and the average standard deviation of their growth rates is 21.9%. The coordinate of the origin in the lower graph is (17.5%, 1.5%).

Idiosyncratic growth and stabilizing capacity of Hawaii's agricultural industries

The above analysis has examined individual agricultural industries' growth and stability characteristics. We now examine their idiosyncratic growth and stabilizing capacity, which, based on William Sharpe's portfolio analysis model, can be measured by their "alphas" and "betas." [7]

Conceptually, the growth performance of an agricultural industry is affected by common and idiosyncratic factors. Common factors are those that tend to affect most of agricultural industries (e.g., weather, land prices, transportation costs, government policies, etc.). In contrast, factors that only affect specific industries are idiosyncratic factors (e.g., diseases, export market condition, import competition, etc.)

Based on Sharpe's approach, an agricultural industry's responsiveness to the common factors can be measured by its beta. A negative beta indicates that this industry tends to grow when the common factor makes the entire sector decline, while a positive beta indicates that this industry tends to move in the same direction as the entire sector. Agricultural industries' betas can be used to measure their stabilizing capacity. An industry with its beta lower than the portfolio beta has high stabilizing capacity since it is less responsive to the general agricultural trend or even countercyclical when its beta is negative.[8] On the contrary, an industry with its beta higher than the portfolio beta has low stabilizing capacity. In general, the higher an industry's beta, the lower its stabilizing capacity and vice versa.

Besides responding to the common factor, the growth of an agricultural industry is also influenced by factors independent of the general agricultural trend. Such "idiosyncratic" growth can be measured by its alpha. An industry with alpha greater than the portfolio alpha has high idiosyncratic growth, while an industry with alpha below the portfolio alpha has low idiosyncratic growth.[9]

Based on Sharpe's approach we have estimated the alpha and beta of each agricultural industry in Hawaii during each of the two periods (i.e. 1964–1983 and 1984–2003). The results are reported in Table 3 and illustrated in Figure 3.[10]

For the period of 1964–1983, there were eight industries (papayas, guavas, vegetables and melons, ginger root, coffee, macadamia nuts, floriculture and nursery products, and honey) in the northwest quadrant of the left graph in Figure 3. These industries' alphas were greater than the portfolio alpha, indicating that they had high idiosyncratic growth during 1964–1983 (Table 3). Their betas were smaller than the portfolio beta, indicating that they had high stabilizing capacity during the period. Such industries with both high idiosyncratic growth and high stabilizing capacity are often called "star" industries because of their outstanding contribution to both growth and stability of the entire agricultural sector. "Vegetables and melons" and "floriculture and nursery products" continued to be star industries during 1984–2003 (Figure 3). This may reflect their comparative advantage in serving local markets over Hawaii's major crops (e.g., sugarcane and pineapples) that are mainly for export. Besides, the high idiosyncratic growth of floriculture and nursery products may also benefit from federal research funds and the introduction of new varieties from UH-CTAHR. Guavas, ginger root, and honey also marginally remained in the star quadrant during 1984–2003 (Figure 3).

Coffee, the most shining star during 1964–1983, has shifted to the northeast quadrant during 1984–2003 (Figure 3). Industries in this quadrant are often called "question mark" industries in that they have outstanding idiosyncratic growth but below-average stabilizing capacity. Coffee's persistent high idiosyncratic growth may reflect the fact that Hawaii is the only U.S. state growing coffee and has benefited from its distinct regional branding such as Kona coffee. Papayas and macadamia nuts were another two industries turning from star industries during 1964–1983 to question-mark industries during 1984–2003 (Figure 3). Pineapples and other livestock also belonged to the question-mark quadrant during 1984–2003, shifting from the southwest quadrant (Figure 3).

Industries in the southwest quadrant are often called "cash cow" industries because of their below-average idiosyncratic growth but above-average stabilizing capacity. While pineapples, bananas, tropical specialty fruit, tomatoes, taro, seed crops, cattle eggs, hogs, and milk were cash-cow industries during 1964–1983, only the livestock industries remained so during 1984–2003 (Figure 3).

As the exact opposite of a "star" industry, a "dog" industry is located in the southeast quadrant with an alpha smaller than the portfolio alpha and a beta greater than the portfolio beta. Such "dog" industries have not only below-average idiosyncratic growth but also rela-

Table 3. Idiosyncratic growth and stabilizing capacity of Hawaii's agricultural industries.[1]

	1964–1983		1984–2003	
Industry	Stabilizing capacity (beta)[2]	Idiosyncratic growth (alpha, %)[2]	Stabilizing capacity (beta)[2]	Idiosyncratic growth (alpha, %)[2]
sugarcane	1.85	1.4	1.41	–4.6
fruits				
pineapples	–0.15	0.0	1.08	0.0
papayas	0.00	7.9	1.37	0.0
bananas	0.00	0.0	0.00	0.0
guavas	0.00	15.8	0.00	0.0
tropical specialty fruit	0.52	0.3	0.00	0.0
vegetables and melons				
tomatoes	0.23	0.0	0.00	0.0
taro	0.00	0.0	–1.19	0.0
herbs	--	--	0.00	12.9
ginger root	–1.04	20.5	0.00	0.0
other vegetables and melons	–0.13	3.6	0.00	2.3
tree nuts				
macadamia nuts	0.38	11.4	1.18	0.0
coffee	–1.31	21.7	4.13	24.1
floriculture and nursery products	0.00	8.8	0.47	3.2
seed crops	0.00	0.0	0.00	7.6
livestock				
milk	0.00	0.0	0.00	–3.9
cattle[3]	–0.12	0.0	0.00	–5.7
eggs	0.00	0.0	0.00	–5.3
hogs	0.00	0.0	0.00	–6.4
honey	0.74	15.7	0.00	0.0
other livestock	0.00	0.0	1.83	0.0
aquaculture	--	--	0.00	16.0
Portfolio[4]	0.94	1.7	0.87	–0.2

[1]An industry's idiosyncratic growth and stabilizing capacity characteristics are measured by its alpha and beta, respectively. For example, coffee's beta of –1.3 and alpha of 22% during 1964–83 indicate that it tended to grow (or decline) by 1.3% when the entire agriculture declined (or grew) by 1% during this period; and independent with the general agricultural trend, its idiosyncratic growth was 22%.
[2]Industries' alphas and betas are estimated based on Sharpe's portfolio analysis model. Alphas and betas insignificant at 20% were set to zero.
[3]Includes beef, dairy, and dairy replacement operations.
[4]The portfolio alpha and beta of each year are the weighted sums of individual industries' alphas and betas; each industry's weight is its share in the agricultural sector in that year. The portfolio alpha and beta during 1964–83 or 1984–2003 are the average portfolio alpha and beta during these two periods.

tively low stabilizing capacity. Sugarcane is the only "dog" industry identified in our study (Figure 3).

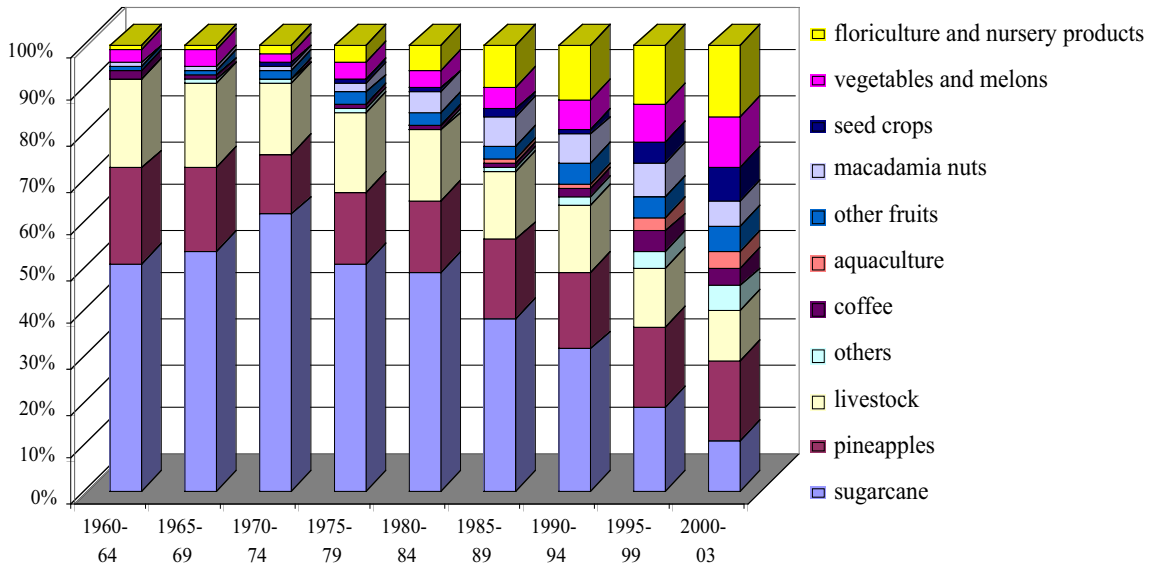
A comparison of Figure 2 and Figure 3 indicates that most agricultural industries' idiosyncratic growth (captured by Figure 3) is consistent with their overall growth (captured by Figure 2). That is, an industry with relatively high idiosyncratic growth also tends to have relatively high overall growth. "Seed crops" and "other vegetables and melons" were two exceptions during 1964–1983. The former had above-average overall growth but below-average idiosyncratic growth during 1964–1983, while the latter had below-average overall growth but above-average idiosyncratic growth during 1984–2003.

The comparison of Figure 2 and Figure 3 also indicates that although some diversified agricultural industries (e.g., coffee during 1964-1983, aquaculture and herbs during 1984–2003, and guavas, ginger root, seed crops and honey during both periods) had relatively high growth variations by themselves (Figure 2), they had relatively high stabilizing capacity for the entire agri-

Figure 3. Idiosyncratic growth and stabilizing capacity of Hawaii's agricultural industries.

1. Vertical and horizontal axes measure agricultural industries' alphas and betas, respectively. Industries in the northwest quadrant have alphas greater than the portfolio alpha (indicating their relatively high idiosyncratic growth independent of the general agricultural trend); and they have betas less than the portfolio beta (indicating their relatively high stabilizing capacity). Industries in the northeast quadrant have relatively high idiosyncratic growth (i.e. their alphas greater than the portfolio alphas) but relatively low stabilizing capacity (i.e., their betas greater than the portfolio beta). Industries in the southwest quadrant have relatively low idiosyncratic growth but relatively high stabilizing capacity; and industries in the southeast quadrant have relatively low idiosyncratic growth as well as relatively low stabilizing capacity.
2. The "triangle" symbol in the left graph represents seven industries (bananas, taro, seed crops, hogs, milk, eggs, and other livestock) during 1964–1983 that have both alphas and betas insignificantly different from zero. Six industries (bananas, guavas, tropical specialty fruit, tomatoes, ginger root, and honey) during 1984–2003 belonged to this category.

Figure 4. Industry composition in Hawaii's agricultural sector.



An industry's ratio represents the share of its production in Hawaii's total agricultural production.

cultural sector (Figure 3). This phenomenon reflects the power of diversification, which allows individual industries' variations offsetting one another and hence reduce the variation of the entire sector.

Diversification and agricultural stability in Hawaii

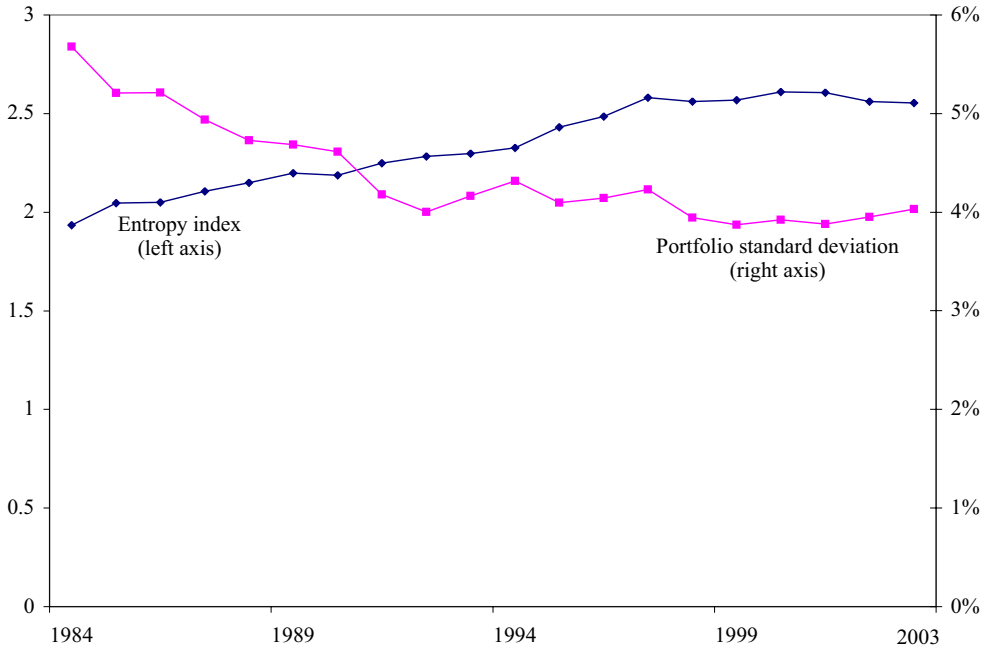
"Diversified agriculture" has been proposed as a strategy for sustainable agricultural development in Hawaii since the early 1900s.[11] One purpose of this diversification strategy is to enhance agricultural stability by actively encouraging a shift from plantation crops such as sugar and pineapples, to a cornucopia of agricultural products.

Figure 4 shows that during the period 1960–2003, Hawaii's agriculture has successfully changed from highly dependent upon sugar and pineapples into one that contains a variety of agricultural industries. As indicated by the entropy index (as a measure of diversity) in Table 4,[12] these changes in industry composition have increased the diversity of Hawaii's agricultural sector for most of the time during 1964–2003.

The diversity has increased most significantly during the second period (i.e., 1984–2003), especially from mid 1980s to mid 1990s, and seems to reach a plateau since 1997 (Figure 5). To assess how diversification has affected agricultural stability in Hawaii during 1984–2003, we have computed Hawaii agricultural sector's portfolio standard deviation (as a measure of its stability) in each year during this period.[13] The results are illustrated in Figure 5.

Figure 5 shows that Hawaii's agricultural sector's portfolio standard deviation has manifested a downward trend for most of the time during 1984-2003 before leveling off in the early 2000s. It also shows an obvious negative correlation between the portfolio standard deviation and the entropy index. These results indicate that increased agricultural diversity has contributed to reducing agricultural variation in Hawaii during 1984–2003.

Figure 5. Entropy index and portfolio standard deviation of Hawaii's agricultural sector, 1984–2003.



The entropy index measures the degree of diversification within Hawaii's agricultural sector; a high index indicates a more diversified agricultural sector. The portfolio standard deviation measures the stability of Hawaii's agricultural growth; a small deviation indicates that the sector grows more steadily. Simple correlation, r, between the portfolio standard deviation and the entropy index is 0.90 (p-value = 0.000).

Table 4. Agricultural diversity in Hawaii, 1964–2003 as expressed by entropy index.[1]

Year	Index	Year	Index	Year	Index	Year	Index
1964	1.67	1974	1.06	1984	1.93	1994	2.33
1965	1.63	1975	1.51	1985	2.05	1995	2.43
1966	1.62	1976	1.82	1986	2.05	1996	2.48
1967	1.62	1977	1.93	1987	2.11	1997	2.58
1968	1.62	1978	1.87	1988	2.15	1998	2.56
1969	1.69	1979	1.84	1989	2.20	1999	2.57
1970	1.71	1980	1.57	1990	2.19	2000	2.61
1971	1.69	1981	2.01	1991	2.25	2001	2.61
1972	1.74	1982	1.93	1992	2.28	2002	2.56
1973	1.71	1983	1.91	1993	2.30	2003	2.55
Average	1.67	Average	1.74	Average	2.15	Average	2.53

[1]The diversity of Hawaii's agriculture is measured by its entropy index. The minimum entropy index is zero, which would occur when the sector is completely specialized in a single industry. The greater the entropy index is, the more diversified the sector would be.

Concluding remarks

We have applied portfolio analysis to assess the growth and stability characteristics of Hawaii's agricultural industries as well as their idiosyncratic growth and stabilizing capacity during 1964–1983 and 1984–2003. Our analysis has identified several star industries (e.g., aquaculture, herbs, seed crops, vegetables and melons, and floriculture and nursery products) during 1984–2003. Expansion of these industries during this period has helped increase both Hawaii's agricultural sector's growth and stability. If these industries maintain their idiosyncratic growth and stabilizing capacity, their expansion would continuingly benefit the growth and stability of Hawaii's agricultural sector. Our analysis has also shown that several matured agricultural industries (e.g., pineapples, papayas, and macadamia nuts) have become question-mark industries during 1984–2003 with slightly above-average idiosyncratic growth and below-average stabilizing capacity. In the future, whether these industries will return to the "star" quadrant where they (except pineapples) used to belong during 1964–1983, or become "dog" industries like the sugarcane industry, depends on whether they will utilize their own comparative advantages to stimulate growth.

We have also assessed diversification within Hawaii's agricultural sector and its impact on the sector's growth and stability. The results show that Hawaii's agricultural sector has become increasingly diversified during the four decades from 1964 to 2003, especially for the last two decades; and the increased diversity has enhanced the stability of Hawaii's agriculture. As the degree of agricultural diversity has ceased to increase since the late 1990s, the impact of Hawaii's agricultural sector's industry composition on its stability has remained relatively steady in the early 2000s. It remains to be seen whether this is merely a temporary pause or reflects that agricultural diversification in Hawaii has reached a plateau.

Due to data limitations we have used agricultural production value as a measure of the general performance of the agricultural sector. Pending data availability, similar portfolio analysis can also be conducted using agricultural income or employment, which would provide more insights about the contribution of individual industries and their composition to agricultural growth and stability in Hawaii.

While the present study shows that agricultural diversification has had a positive impact on the stability of Hawaii's agriculture, a step further would be to use portfolio analysis models to examine growth-stability tradeoffs in Hawaii's agriculture and identify industry compositions that would lead to optimal growth-stability tradeoffs.

Acknowledgments

This document benefited greatly from the constructive comments and suggestions of the following colleagues: Jim Hollyer (ADAP/CTAHR, UHM), Victor Huang (Finance, UHM), Matthew Loke (HDOA), James Mak (Economics, UHM), and Stuart Nakamoto (HNFAS/CTAHR, UHM). The remaining errors are ours. Funding support from the Office of Associate Dean and Associate Director for Research in CTAHR is greatly appreciated.

Notes

[1] The two publications are available at http://www.ctahr.hawaii.edu/oc/freepubs/pdf/EI-3.pdf and http://www.ctahr.hawaii.edu/oc/freepubs/pdf/EI-4.pdf.

[2] While growth measures an industry or sector's development performance, measure of stability provides another important dimension, especially for agricultural industries that tend to have higher crop-specific variation due to variations in weather patterns, pest infestations, disease outbreaks, etc.

[3] The entire agricultural sector's growth rate (G) is equal to the weighted sum of individual agricultural industries' growth rates (g_i) with the weight (s_i) being the share of industry *i* in the sector, i.e., $G = \sum_i s_i g_i$.

[4] The volatility of the entire agricultural sector can be measured by its "portfolio variance", which is equal to the weighted sum of individual agricultural industries' variance and covariance, i.e., $\sigma_p^2 = \sum_i s_i^2 \sigma_i^2 + \sum_i \sum_{j \neq i} s_i s_j \sigma_{ij}$, where σ_p^2, σ_i^2, and σ_{ij} denote, respectively, the portfolio variance, the variance of industry *i*, and the covariance between industries *i* and *j*.

[5] The production value of agriculture is measured by the value of agricultural farm-gate sales in constant dollars (i.e., adjusted for inflation).

[6] Both of the extremely high agricultural growth periods in 1974 and 1980, and subsequent declines, were mainly caused by fluctuations in sugar prices.

[7] William Sharpe's paper, "A simplified model for portfolio analysis" (Management Science, vol. 9, no. 2, 1963, 277–293), introduced a simplified way of conducting mean-variance portfolio analysis. Deborah J. Brown and Jim Pheasant's paper, "A Sharpe portfolio approach to regional economic analysis" (Journal of Regional Science, vol. 25, no. 1, 1985, 51–63), applied Sharpe's approach to industry portfolio analysis. See also Deborah J. Brown and Keith C. Brown's paper, "Using the Sharpe Portfolio Model to choose economic sectors for expansion in a rural Indiana county" (Interfaces, vol. 13, June 3, 1983, 13–19).

[8] The portfolio beta of the agricultural sector measures agricultural industries' average responsiveness to the common factors. It is equal to the weighted sum of the betas of individual agricultural industries in the sector, i.e., $B = \sum_i s_i \beta_i$, where B, β_i, and s_i denote, respectively, the portfolio's beta, industry *i*'s beta, and industry *i*'s weight in the entire agricultural sector.

[9] Similar to the portfolio beta explained in footnote 8, the portfolio alpha of the entire agricultural sector measures agricultural industries' average idiosyncratic growth. It is equal to the weighted sum of the alphas of individual industries in the sector, i.e., $A = \sum_i s_i \alpha_i$, where A, α_i, and s_i denote, respectively, the portfolio's alpha, industry *i*'s alpha, and industry *i*'s share in the entire agricultural sector.

[10] The model used to estimate alphas and betas is $g_i = \alpha_i + \beta_i G + \varepsilon_i$, which implies that industry *i*'s annual growth rate g_i is determined by its idiosyncratic growth rate α_i, its response to the growth of the entire agricultural sector $\beta_i G$ (where *G* represents the annual growth rate of the entire agricultural sector; and β_i is a stability parameter measuring the responsiveness of industry *i* to the entire sector's volatility), and the random element ε_i.

[11] Smith, J.G., 1902. Annual Report of the Hawaii Agricultural Experiment Station in 1901, U.S. Department of Agriculture, Office of Experiment Stations, page 361.

[12] A sector's entropy index is computed by $-\sum_{i=1}^{N} s_i \ln s_i$, where s_i represents industry *i*'s share in the sector's revenues; and N represents the number of industries in the sector. The minimum entropy index is zero, which would happen when a sector completely specializes in only one industry. The more industries a sector contains, the higher its entropy index would be. Given the number of industries, a sector's entropy index would be higher when its revenues are distributed more evenly across these industries.

[13] The agricultural sector's portfolio standard deviation is equal to the square root of its portfolio variance, which can be computed according to the formula introduced in footnote 4.