Scale, Diversification and Economic Performance of Agricultural Producers

by

Catherine Morrison Paul and Richard Nehring

Various factors, including production scale and diversification, off-farm employment, innovative adoption and other farm and farmer characteristics, determine farmers' economic welfare. A recent study analyzes the impact of such factors on the performance, and thus the potential competitiveness, of different types of U.S. farms. Ê

U.S. farm size in acres has been increasing in the past two decades; farms in major agricultural regions grew by about 17 percent between 1980 and 2000. Agricultural production is also highly and increasingly concentrated in large farms, with "large" and "very large" family farms (see Table 1 for a definition of terms) making up only eight percent of all farms in 1998, but accounting for 53 percent of agricultural production. The USDA documents that these large farms were profitable in 1998, although farms in most smaller typology groups reported insufficient income to cover expenses. Such patterns suggest that significant scale economies exist in modern agriculture, and that this technological reality is putting critical pressure on the small family farm.

In addition to the apparent importance of scale economies, product diversity (scope economies) seems to contribute considerably to farms' economic performance. *The Family Farm Report,* for example, states that: "…diversification is a significant factor explaining differences in the level and variability of income between higher and lower performing small farms. Financially successful small farms tend to be more diversified." The report also documents that production of multiple outputs is most prevalent for high-sales farms, and that diversification affects input mix as well as economic performance. The largest farms, however, tend to specialize in livestock.

Off-farm employment is another form of expansion in the scope of revenue-producing farm operations that is especially feasible in urban-influenced areas. The USDA reports that non-farm income sources now dominate net farm income in the U.S., and also finds that "farm households relied heavily on off-farm jobs," with 55 percent of all farm households reporting that either the operator, spouse or both worked off-farm to increase "total operator household income." Nationwide patterns in off-farm employment (the ratio of off-farm income/total income) are shown in Figure 1.

Economic performance of U.S. farms has also been increasingly influenced by technical change. In particular, enhanced cost effectiveness from the adoption of inputs such as genetically modified (GM) seed may improve farms' competitiveness. Rapid adoption of transgenic crops suggests that this innovation has been beneficial to farmers. But

Figure 1. The Importance of Off-farm Income by ASD*: 2001 (Off-farm Income/Total Income)

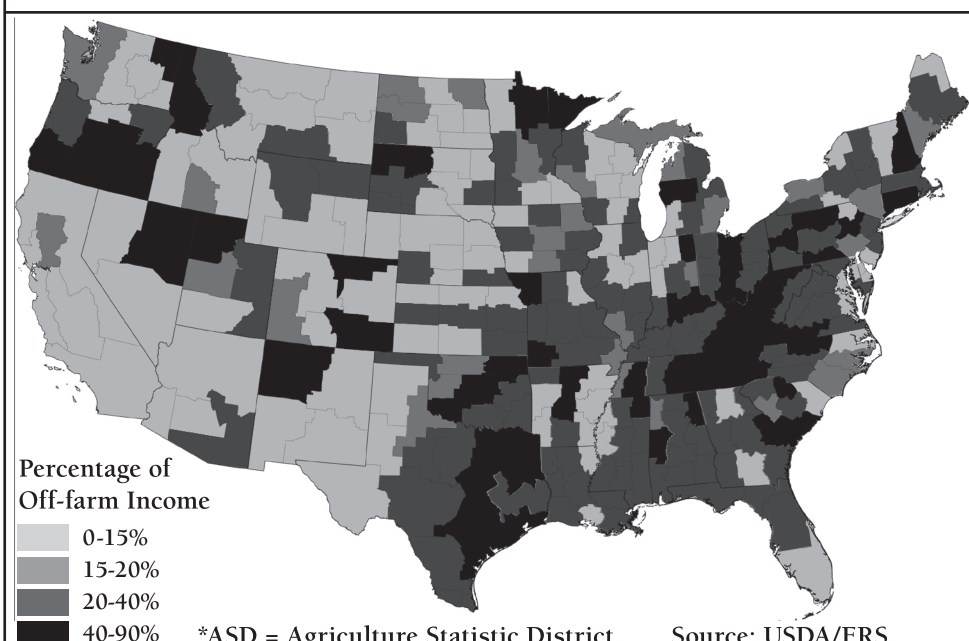

Table 1: Definition of Terms

Farm Typologies

Small Family Farms (sales less than $250,000):

1. Limited-resource. Any small farm with: gross sales less than $100,000, total farm assets less $150,000, and total operator household income less than $20,000. Limited-resource farmers may report farming, a nonfarm occupation, or retirement as their major occupation.

2. Retirement. Small farms whose operators report they are retired (excludes limited-resource farms operated by retired farmers).

3. Residential/lifestyle. Small farms whose operators report a major occupation other than farming (excludes limited-resource farms with operators reporting a nonfarm major occupation).

4. Farming occupation/lower-sales. Small farms with sales less than $100,000 whose operators report farming as their major occupation (excludes limited-resource farms whose operators report farming as their major occupation).

5. Farming occupation/higher-sales. Small farms with sales between $100,000 and $249,999 whose operators report farming as their major occupation.

Other Farms

6. Large family farms. Sales between $250,000 and $499,999.

7. Very large family farms. Sales of $500,000 or more.

8. Nonfamily farms. Farms organized as nonfamily corporations or cooperatives, as well as farms operated by hired managers.

Economic Terms

Scale economies: Given scale economies the average cost of production decreases as farm size increases. The existence of scale economies suggests that farms can achieve lower average costs by becoming larger.

Scope economies: Given scope economies it is cheaper to produce several outputs on one operation than it is to produce each output in separate operations. The existence of scope economies suggests that farm households can achieve cost savings by diversifying into production of multiple commodities or part time off-farm employment.

Input jointness or production systems: Input jointness suggests that the adoption of certain technologies, such as GM corn, requires the concomitant use of several inputs (i.e. GM seed, alternative pesticides, custom labor and specialized application machinery), rather than simply the purchase of new seeds.

Technical efficiency: The ratio of current to maximum possible or "best practice" production, the latter representing fully efficient production practices.

Cohort: Individual observations grouped on the basis of geographic location and type of agricultural activity.

Source: USDA, Economic Research Service

GM adoption may also augment the importance of production systems; i.e., there may be linkages (input jointness) between adoption of these seeds, and the use of particular pesticides, labor practices or machinery for tilling.

These production relationships largely determine how efficiently farms of different sizes and with different output and input mixes might be producing. However, specific farm/farmer characteristics may also affect performance. The USDA identifies key dissimilarities in hours worked, age, education, debt and management methods of farmers that affect overall agricultural productive performance and the benefits obtained from innovation, and thus are important to recognize for effective policy implementation. Some types of farmers may simply be producing in a technically inefficient manner, which will affect their competitiveness.

Data and Overall Findings

We used USDA farm-level survey data to quantify these kinds of factors underlying the economic performance of U.S. farms. The data include 20,810 observations, across 5 years (1996-2000), for farms in ten midwest states, on farm outputs, inputs and characteristics. Using such a detailed micro level dataset allows us to represent multiple revenue-generating activities (or "outputs"), a variety of inputs used for farm production, and specific farm household characteristics.

The outputs from the farms surveyed are corn, soybeans, other crops and animal products (dairy, livestock), as well as income generated from off-farm employment. The inputs are labor, fuel, fertilizer, seed, feed, capital (machinery and structures), land, other livestock-specific materials, other crop-specific materials and other general expenses. Farm and farmer characteristics include farmer age, education, debt/asset ratio and the proportions of land rented to others and devoted to GM (corn and soybean) crops.

These data are summarized in Table 2. They are grouped on the basis of farm typologies, which we have divided into four primary types or cohorts: residential farms (typologies 1-3), very small family farms (typology 4), higher sales small family farms and large family farms (typologies 5-6), and very large family and "corporate" farms (typologies 7-8). Operators of small farms tend to be the oldest, with the least education, but have the lowest debt-asset ratios and the least rented land. They also have the second highest (after residential) ratio of off-farm to farm business income, and appear less likely to plant GM corn but about as likely to plant GM soybeans as farmers in other typologies.

For the outputs, our estimates show significant scale and scope economies. This supports the notion that not only the scale of production, but also output diversification (expanding the portfolio of commodities produced, and particularly increasing the amount of livestock production), contributes to performance. However, revenue from off-farm employment tends to combat the cost disadvantages of small-scale production, implying that the increasing prevalence of off-farm income for small farmers improves their competitiveness. Off-farm employment also significantly affects input use; it augments the productive role of labor by 21 percent and doubles the importance of fuel. Our measures also indicate that animal outputs require the largest input "share," with corn second, and soybeans third.

For the inputs, we find that input mix affects economic performance, and is more fixed within cohorts, and in the short run, than across cohorts, and in the long run. That is, in the short term input rigidities due to lack of mobility, or limited potential to adapt production systems because of past ("sunk") investments, may inhibit the performance of some types of farmers. Expansion in the scale of production combined with input mix adaptations, as well as output diversification, is most likely to enhance competitiveness.

The largest input share or contribution is that of labor when off-farm income is recognized; the value of labor on the farm in terms of its contribution to farm revenues is larger than its opportunity (market) cost. This is also true for seed, although not for land, capital (machinery) and livestock inputs. Overall, off-farm income is a key contributor to farm revenues. Seed, feed and specialized crop expenses (largely pesticides) seem the most important drivers of overall farm productivity, perhaps because they are the variable inputs that determine the productivity of the other more fixed inputs—particularly land.

Table 2: Summary Statistics, 2000, Averages

		All Farms	Residen-tial	Small Family	Large Family	Very Large &Corp.
Revenues						
Farms		3,638	883	200	1,533	1,022
Corn	$[1]	24,765	4,202	2,665	52,819	143,391
Soybean	$	17,877	4,332	3,814	36,779	93,030
Other crop	$	29,855	3,476	5,106	40,456	303,127
Animal	$	43,683	5,428	6,100	50,811	483,217
Off-farm	$	26,941	36,742	13,510	14,133	9,540
Expenses						
Labor	$	24,481	29,597	17,213	30,080	83,716
Fuel	$	2,609	660	1,118	5,011	14,101
Fertilizer	$	10,775	2,367	2,303	21,850	60,135
Seed	$	4,840	955	1,380	9,333	30,025
Feed	$	14,609	2,120	1,816	15,548	165,875
Animal inputs	$	8,651	737	1,149	5,892	120,251
Crop inputs	$	6,245	1,416	1,290	12,220	36,769
Other inputs	$	12,694	4,317	5,237	21,564	71,158
Machinery/ Structures	$	12,547	3,878	5,565	23,383	63,513
Land	$	34,411	13,808	17,660	64,722	133,209
Age	Yr	53.7	53.7	61.41	51.99	48.65
Education	(2)	2.57	2.65	2.19	2.46	2.88
Debt/Asset	%	12	8	5	14	19
Rented land	%[3]	47	35	17	52	51
GM corn	%[4]	30	21	21	30	32
GM soy	%[5]	58	58	63	56	61

[1] inflation adjusted
[3] rented land as a % of acres operated
[4] biocorn acres as a % of total corn acres
[5] biosoy acres as a % of total soybean acres
[2] 1=no high school, 2=high school/equivalent 3=some college 4=4 year degree, 5=graduate school

Source: USDA, Economic Research Service

We also find farmers' measured technical efficiency to be high, at 93-94 percent of their "best practice" potential, and that this does not vary significantly by type of farm. The only significant performance impact of farm or farmer characteristics is that higher debt is counter-productive; a high debt/asset ratio implies reduced competitiveness. Generally, economic performance is more closely tied to output scale and diversity and input mix than to technical inefficiency, or to farmer traits such as age or education.

Differences across Farm Typology and Time

If our economic performance measures are broken down by farm type, we find slightly larger potential scale and scope economies, and lower efficiency, for small family farms than for other farm types. Recognizing off-farm income increases measured scale and technical efficiency, especially for small family farms. In addition, scale economies appear to be decreasing, and efficiency increasing, over time. These results suggest that farmers are, as a group, taking advantage of the potential to reduce costs through expansion of scale, output diversification, substitution toward more cost-effective input mix and technical efficiency.

Distinguishing farm types provides few additional insights about differential performance. Farms in the upper level typologies (generally larger size) seem to require almost as many inputs for a given amount of output production as do family farms, when income from off-farm activities is recognized and all other factors are held constant. We also find falling input use for a given output level in some years, consistent with technical progress, although not in 1999 (and essentially constant in 2000). One interpretation of these patterns is that the mixes or values of outputs and inputs differ for farms in the larger typologies and over time—that larger farms produce higher-valued outputs and inputs, using higher-quality and higher cost inputs, including more livestock, less "other" crops and more machinery.

This seems consistent with the evidence. Input "shares" or contributions are notably higher for feed, capital, and animal and other specialized inputs, and lower for labor for farms in the larger typologies. This supports the notion of varying input mix across cohorts, even if inputs are quite fixed within cohorts. The contribution of labor seems also to be decreasing over time, along with that of seeds and specialized crop inputs, and the roles of energy, fertilizer, and capital seem to be increasing. These patterns suggest that movements toward greater capital-intensity, lower labor-intensity and more animal-output intensity enhance performance.

Output mix across cohorts does not appear as variable as for inputs, although corn and livestock proportions are higher and off-farm income lower for the larger farm typologies. Also, inputs devoted to soybean production are somewhat greater, and to "other" crops lower, for the large than small family farms. The output patterns over time are even less definitive, although input shares devoted to corn and animal production seem to be dropping slightly, and those to soybeans rising.

Finally, the (small positive) cost-savings impacts of planting GM corn are somewhat less substantive for farms in the larger as compared to the smaller typologies. The estimated impacts of planting GM soybeans are more variable across typology, year and specification, but all have a negligible (in magnitude) measured productivity effect.

In sum

Both scale and scope (diversification) economies appear to have central roles in explaining productivity patterns of U.S. agricultural producers. Inputs seem less joint across cohorts, but not within cohorts; input mix varies across cohorts, and somewhat over time. Although rigidities within cohorts may exist due to production systems, greater shares or intensity of capital and animal-oriented inputs, and animal output, seem related to greater economic performance.

Further, off-farm income appears empirically as well as anecdotally to be an important aspect of farm households' economic performance and economic viability, especially for small farms that are near urban areas. This seems the primary route to the success of small farm households in the future, given the cost-savings associated with growth in scale of production (consolidation) and diversity (especially large-scale livestock production) that reduce small farms' competitiveness.

The views presented here are those of the authors, and may not be attributed to the USDA.

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The Food Quality Protection Act and California Agriculture

by
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The Food Quality Protection Act (FQPA) of 1996 was the most wide-reaching revision of federal pesticide law in twenty years. Many of the FQPA's impacts are yet to be felt by California farmers. In seeking to further protect consumers, the FQPA will pose new challenges for California agriculture. The changes that may occur maybe quite expensive, and perhaps counterproductive from the perspective of consumers' health. Ê

The Food Quality Protection Act (FQPA) was unanimously passed by Congress in 1996 and hailed as a landmark piece of pesticide legislation. It amended the Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), and the Federal Food, Drug, and Cosmetic Act (FFDCA), and focused on new ways to determine and mitigate the adverse health effects of pesticides. FQPA is different from past legislation; it is based on the understanding that pesticides can have cumulative effects on people, and that policy should be designed to protect the most vulnerable segments of the population. Recent research at UC Berkeley has investigated some of the impacts that FQPA's provisions—many of which have yet to be fully implemented—may have on California growers and consumers.

FQPA's Main Provisions

The publication of the National Research Council report *Pesticides in the Diets of Infants and Children* showed that pesticide residues have disproportionate effects on children. Children eat and drink more as a percentage of their body weight than adults; they also consume fewer types of food. These dietary differences account for a large part of the exposure differences between adults and children. The committee also found that pesticides have qualitatively different impacts on children because children are growing at such a rapid pace. This concern for the differential impact pesticides have on children is reflected in regulatory changes required by the FQPA. For instance, the "10X" provision of the FQPA requires an extra ten-fold safety margin for pesticides that are shown to have harmful effects to children and women during pregnancy.

The FQPA has also resolved the "Delaney Paradox" created by the Delaney Clause of FFDCA. Prior to FQPA, the Delaney Clause prohibited the use of any carcinogenic pesticide that became more concentrated in processed foods than the tolerance for the fresh form. This was supposed to protect consumer health, yet it had the paradoxical effect of promoting other non-carcinogenic pesticides that created other (possibly more serious) health risks for consumers. FQPA standardizes the tolerances for pesticide residues in all types of food, and looks at all types of health risks.

The federal Environmental Protection Agency (EPA) must now ensure that all tolerances are "safe," defined as "a reasonable certainty that no harm will result from aggregate exposure to the pesticide." Historically, pesticide exposure was regulated through single pathways, either through food, water or dermal exposure. Now the EPA must consider all pathways of pesticide exposure, including cumulative exposure to multiple pesticides through a common mechanism of toxicity. This means that even though pesticides may be sufficiently differentiated that they are used on different crops to control different pests, they can have similar health effects on people. The result is that in some instances, pesticide tolerances for seemingly different insecticides must be regulated together based on their cumulative effects.

The Costs of Banning Organophospates

When FQPA was first signed into law, 49 organophosphate (OP) pesticides were registered for use in pest control throughout the country, and accounted for approximately one third of all pesticide sales. OP insecticides are highly effective insect control agents because of their ability to depress the levels of cholinesterase enzymes in the blood and nervous system of insects. It has been suggested that while dietary exposure to a particular OP may be low, the cumulative effects of simultaneous exposure to multiple OP insecticides could cause some segments of the U.S. population to exceed acceptable daily allowances. Reducing the risk from these aggregate effects is specifically addressed in the FQPA and is one of the reasons the EPA has chosen OP pesticides for the first cumulative risk assessment.

Due to their popularity and widespread use, many in the agricultural community are worried about FQPA implementation resulting in increased

Table 1. Price and Production Changes from Organophosphate Ban

Crop	Percent Change in Price	Change in Production (tons)	
		California	Rest of U.S.
Alfalfa	0.93	-184,845	48,783
Almond	0.48	-1,356	n/a
Broccoli	16.0	-111,285	2,083
Carrots	>0.01	-5	-3
Cotton	1.69	-1,148	-19,214
Grapes	0.05	-999	-265
Lettuce, head	0.36	-12,778	-3,864
lettuce, leaf	0.46	-1,510	-148
Oranges	0.32	-40,517	-28,137
Peaches/ Nectarines	0.32	-1,561	-2,016
Strawberries	0.26	-508	-743
Tomatoes, fresh	0.03	-388	-223
Tomatoes, Processed	0.16	-10,849	114
Walnuts	0.58	-1,091	n/a

restrictions on OP pesticides. By the time EPA released the *Revised OP Cumulative Risk Assessment* in 2002, 14 pesticides had already been canceled or proposed for cancellation, and 28 others have had considerable risk mitigation measures taken. Risk mitigation may include:

- ÊLimiting the amount, frequency, or timing of pesticide applications Ê
- ÊChanges in personal protective equipment requirements (for applicators) Ê
- ÊGround/surface water safeguards
- ÊSpecific use cancellations
- ÊVoluntary cancellations by the registrant

Economic theory suggests that these increased restrictions and cancellations from the eventual implementation of FQPA will result in a reduced supply of commodities currently relying on OP pesticides for pest control. This will result in higher prices for consumers and a lower quantity sold. In order to estimate the possible welfare effects on the state of California, UC Berkeley researchers have conducted a study on the effects of a total OP pesticide ban on 15 crops. The estimated price and quantity changes are presented in Table 1.

Results of the economic analysis suggest that the total loss to producers and consumers in California from banning all OP use will be approximately $200 million. There is significant uncertainty, as the final level of OP restrictions are uncertain; this is only an order of magnitude estimate of the effects. However, these effects only represent about two percent of the total revenue generated by the 15 crops studied in California. While the overall effects seem small, they may be more intense in some segments than others. The researchers found that the degree of impact rests on the effectiveness of alternative pest control strategies producers have to choose from when faced with an OP ban. In some cases, OP pesticides have no close substitutes, and cancellation will have larger effects. For instance, the losses in broccoli, one of the crops most sensitive to an OP ban, are driven by the lack of an alternative insecticide to treat cabbage maggot.

Prices and Nutrition

As illustrated above, it is generally true that removing a pesticide from the production process will result in an increase of the price of the treated commodity. If consumers respond to the increased prices by reducing consumption of the affected fruits and vegetables (and perhaps shifting consumption to less nutritious foods), they may suffer a loss of health benefits associated with the change in consumption. Scientific evidence suggests a protective effect of fruits and vegetables in prevention of cancer, coronary heart disease, ischemic stroke, hypertension, diabetes mellitus, diverticulosis, and other common diseases. The level of protection suggested by these studies is often quite dramatic. A recent review of several studies found that "the quarter of the population with the lowest dietary intake of fruits and vegetables compared to the quarter with the highest intake has roughly twice the cancer rate for most types of cancer."

Negative health outcomes from a change in dietary behavior may offset direct health benefits of a pesticide ban such as reduced exposure to carcinogenic residues on produce. A recent study investigates the possible magnitude of such offsetting health effects. Using data on what over 18,000 people eat and previous findings on how people respond to changes in the price of fruits and vegetables, the authors simulated some of the health effects of a small increase in produce prices. Specifically, they examined the effects of a one-percent increase in the price of broad categories of fruits and vegetables on coronary heart disease and ischemic stroke, two of the most common causes of death in the United States. The results are reported in Table 2.

For a one percent increase in the average price of all fruits and vegetables, the simulations indicate an increase of 6,903 cases of coronary heart disease and 3,022 ischemic strokes. In order to offset these 9,925 cases in a population of 253.9 million people, a pesticide action would have to prevent one in 25,580 cancers. This is almost four times as protective as the mean risk of pesticide uses that were banned between 1975 and 1989. Although these results can not be applied directly to most individual pesticide bans—which typically only affect the price of a few crops—the study shows that pesticide regulations that reduce relatively small risks at high cost may actually have a negative impact on overall consumer health. Furthermore, the research also suggests that low-income consumers may be the hardest hit by the negative health impacts of price-induced dietary changes.

Table 2. Cases of Heart Disease and Stroke Induced by 1% Increase in Price

Disease	All Fruits	All Vegetables	All Fruits & Vegetables
Coronary Heart Disease	1,442	2,951	6,903
Ischemic Stroke	744	1,482	3,022
Total	2,186	4,433	9,925

Source: Cash, Sunding, and Zilberman. *Health Trade-offs in Pesticide Regulation,* 2002. Results reported are the simulation means from a series of Monte Carlo trials (n=100,000).

Conclusions

The Food Quality Protection Act is a wide-reaching law that will have a large impact on California agriculture in the coming years. While an increased awareness of the effects of agricultural chemicals on vulnerable groups—especially infants—is a welcome addition to the nation's pesticide laws, regulators need to take into account the potentially high costs of additional pesticide bans on both producers and consumers. These costs can be measured not just in dollars, but also in dietary changes that may have negative health consequences. In implementing the regulations required by the FQPA, EPA should keep in mind that this most recent overhaul of the pesticide laws specifically grants the agency discretion in setting standards when use of the pesticides prevents other risks to consumers or avoids "significant disruption in domestic production of an adequate, wholesome, and economical food supply."

We are among those who, everything being equal, would prefer to consume fewer pesticide residues in our own diets. Yet too narrow of a regulatory focus that ignores economic responses and countervailing health risks is misguided, as the net effect of public health would be negative. This point is especially salient when one considers that certain pesticide uses have been canceled by the EPA on the basis of consumer risks that were less than one in a million over a lifetime of exposure. Ultimately, other less costly interventions such as labeling requirements and food preparation education campaigns may prove to be more effective means of achieving consumer safety in regards to agricultural chemical use.

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