The Effect of Contracting and Consolidation on Farm Productivity

by

Mary Ahearn, Economic Research Service

Jet Yee, Economic Research Service

and

Wallace Huffman, Iowa State University

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Address for Correspondence:

Mary Ahearn
Economic Research Service
1800 M Street, NW
Washington, DC - 20036
Phone: (202) 694-5583
E-mail: mahearn@ers.usda.gov

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Abstract: *Concentration in agriculture, while not new, is accelerating. That process includes both vertical coordination (e.g., increases in contract production) and horizontal coordination (e.g., farm consolidation). One of the potential benefits of increased concentration is increased efficiency, as cost economies are exploited. The major purpose of this paper is to examine the causal linkages among agricultural total factor productivity, contracting and consolidation of the farm sector, and other variables for the period 1978-96. The paper includes a description of the trends in the use of contracts and other key structural change measures over time.*

Introduction

The industrialization and consolidation of the food system is proceeding at a rapid rate. This is especially evident, and of great policy interest in the farm production component of the food system. Under the new supply chain models of the organization of the agricultural-food system, coordination of the system to best meet consumer demands for food attributes is the primary driver. The increased use of contracting is a means for attaining that goal and one indicator of this organizational change in farming. Contracting for the land input under either share or cash leases has a long history in US agriculture, at least since agricultural censuses were initiated in the late 1800s. Since 1950, the share of leased land in farms has been steadily increasing and currently accounts for about 45 percent of acres in farms. Most of the land contracts are cash contracts, but that varies by region and commodity. More closely associated with the discussion on trends in industrialization is the recent increase in contracting for the marketing and production of commodities, beginning with poultry, vegetables and fruits, at least by 1960. In addition, contracting for hired labor is common in the production of fruits and vegetables, and it has developed rapidly since the passage of the 1986 Immigration and Control Act (Martin and Taylor 1995).

The principal-agent model is the most common economic framework employed to consider contracting issues. This framework can address the two most commonly cited reasons for parties entering into contracts, namely risk management (i.e., efficient risk sharing) and minimization of production and/or transaction costs (i.e., efficiency). Enhanced efficiency is clearly linked to agricultural productivity. In the case of land contracts, Allen and Lueck (1995 and 1999) have provided evidence that risk management is not an important factor in explaining choice of land contracts. They find that transaction costs (e.g., enforcement costs) are the more important factors. Cash rental leases are consistent with optimal contracting when landowners are more risk adverse than tenants who may be risk neutral (Macho-Stadler and Perez-Castrillo 2001, pp. 15-40).

Recent research has examined production and marketing contracts, especially for livestock. Risk management and efficiency are the focus. In a study of the poultry industry, Knoeber (1989) and Knoeber and Thurman (1994) found that the terms of broiler contracts can be explained largely by the incentives to produce more efficiently. Growers are rewarded based on relative performance, i.e., relative to other growers, or a tournament. Knoeber (1989) also argues that contracts in poultry production speed the adoption of innovations because the decisions to adopt are made at the integrator rather the farm level. Because growers are compensated based on relative performance, they are not reluctant to adopt the new innovations because other growers are also adopting them. The recent work by Key and McBride (2002) also finds important increases in productivity resulting from contracting in the hog sector. They argue that a major reason for productivity gains of producers having contracts is due to better information as a result of knowledge transfers from integrators to growers.

One of the most important policy questions associated with industrialization of agriculture is whether it leads to anti-competitive market power or greater system efficiency. If efficiency gains follow structural change, then these gains should be evident in measured productivity. Productivity gains can be realized on the farm and by downstream processors. This paper examines the relationship between farm sector productivity and farm structural change, emphasizing contracting and consolidation. This objective is carried out by testing twelve different hypotheses. Before we turn to that issue, we begin with a description of structural changes in the farm sector.

Basic Trends in the Farm Sector

A brief summary of major changes in the organization of U.S. agriculture since 1948 is presented, including a description of trends in total factor productivity (TFP), factor proportions, contracting, consolidation, entry and exit of farms, and farm household labor allocations.

Productivity and Factor Proportions. Over the past century, productivity has been the major force behind the changes in U.S. agricultural output. Between 1948 and 1994, the rate of growth in total factor productivity in agriculture was 1.94 on an annual average basis (Ahearn, Yee, Ball, and Nehring, 1998). Using 1948 as the base year (i.e., 1948 =100), the 1994 index of agricultural output was 237, compared to the index of all farm inputs of 97 **(Figure 1)**. That is, measured aggregate inputs actually declined during that period while output more than doubled. The labor input for U.S. agriculture declined dramatically and steadily over 1948 to 1985, and then declined very slowly to 1996. Capital-service input rose to the early 1980s and then declined at a steady rate. Hence, over 1948 to 1980, the capital-to-labor ratio was rising very rapidly, about 3 percent per year. But over 1980 to 1996, the capital-to-labor ratio actually declined at a rate of about 1 percent per year. Likewise the intermediate input-to-labor ratio rose by more than 3.5 percent per year over 1948 to 1980, but thereafter it rose very slowly. Also, over 1960 to 1996, hired and contract labor, which has the least human capital, became a larger share of total farm labor input (Huffman 2002). This change was, however, not uniform across the country. The largest changes in the composition of the workforce were in the fruit, vegetable, and horticultural crop growing states, e.g., California, Florida, Arizona, Washington.

Contracting. The most notable and longstanding use of contracting in agriculture is the use of land contracts, both cash and share-rent contracts. Production and marketing contracts have been in use for about five decades. For a few commodities, contracts have covered virtually all of production and marketing, but they have become important at different points in time. Contractors with production contracts and landlords with share leases, directly take a share of the value of gross output. Since 1979, the share of gross output going to share landlords and operators has declined, while contractors' share has increased.[1] Operators still receive the largest share of gross output, 82% in 1999, compared to the share of landlords', 4%, and contractors', 14% (USDA, 2001a).

In 2000, there were about 51,000 U.S. farms with production contracts and 179,000 farms with marketing contracts (Banker, 2002). Farms with either type of contract were only 10% of total farms, but the use of production and marketing contracts varies considerably by commodity **(figure 2).** Today, a majority of poultry and hogs are produced under production contracts, and more than 20% of cattle and 10% of vegetables are produced under production contracts. Marketing contracts cover a majority of fruit and dairy products and more than 20% of cotton and vegetables. The charts in the appendix illustrate the trends over time in the use of contracts,

[1] At the same time, the terms for sharing costs have also changed.

production and marketing, for five commodity groups: poultry, hogs/pigs, cattle, vegetables and fruits/nuts.

Regional differences in contracting exist for all commodities. The Deep South, Midwest, and California account for most of the farm production that is under production contracts. In Alabama, Georgia, and North Carolina, more than one-half of agricultural production is produced under production contracts. In Alabama and Georgia, broiler production is the number one commodity, and in North Carolina, hogs and broilers are the top two commodities grown under production contracts (USDA, 2002).

Consolidation. Because the aggregate amount of agricultural land has been relatively fixed during the 20th century, the change in the number of farms is closely correlated with the change in the size of farms. **Figure 3** shows the change in the number of farms and average acres operated per farm over time. However, the rising average acres operated per farm over time masks the growth in the share due to small farms. Most of today's farms are small farms by some definition (USDA, 1998), and many are classified as retirement and lifestyle farms (Hoppe, 2001). After 1978, the total number of farms has remained about 2 million, declining only slightly in the 4 agricultural censuses since 1978. The number of large farms (>1,000 acres) and smallest farms (<50 acres) has increased, but the number of mid-sized farms has declined. However, the size distribution and the trends in size class vary considerably by state. **Figure 4** presents information showing which states had the most rapid growth in farms doubling in size during the last two censuses (between 1992 and 1997). They tend to be in located in the most rural states.

Entry-Exit. The relatively slow rate of decline in the number of farms over time masks a significant rate of exit and entry. A healthy rate of entry into agriculture is an indicator that anti-competitive barriers to entry do not exist. For example, in 1997 62% of the farms that existed in

1992 were still in existence, and 38% of the 1992 farms exited. However, roughly the same number of farms entered farming during the period as exited. Hence, little change in the number of total farms between the 1992 Census of Agriculture and the 1997 Census occurred. Exits, entrants, and surviving farm rates vary by inter-census-time period and state. **Figure 5** shows the exit rates by state between 1992 and 1997.

Farm Household Labor Allocations. The majority of workers on U.S. farms are the operators and their families, contributing at least two-thirds of the labor hours worked. By definition, all operators work on the farm, but also 40 percent of spouses, primarily female, work on the farm (Ahearn, et al., 2002). In addition, most farm families (70% in 1999) have at least one family member working in a non-farm occupation and in about half of those families both the operator and spouse work off the farm (USDA, 2001a). Operators, are more likely than spouses to work off the farm, 56 percent compared to 46 percent (USDA, 2001a). Over all only 10 percent of total farm household income is from farm sources (Hoppe, 2001; Mishra, et al., 2002; USDA, 2002). Also, has been the case for some time, off-farm income has played a major role in closing the income gap between farm and non-farm households and in reducing income inequality among farm operator households (Ahearn, Strickland, and Johnson, 1985). The most recent Census of Agriculture reports that off-farm income of farm households increased 300 percent between 1988 and 1998 (USDA, 2001a).

Conceptual Issues: Review of Literature

A single integrative economic framework for linking productivity and structure does not exist. However, an assortment of piecemeal theories exists and makes useful contributions. We have already briefly reviewed the contracting literature, which is rooted in principal-agent theory emphasizing efficiency in production and risk sharing. We briefly review other strands of the literature below including: productivity measurement (rooted in production economics), sources of productivity growth, structural change and technology adoption, and the economics of farm household labor allocations.

Productivity Measurement. A large literature exists on measurement of productivity, both in the general economics and agricultural economics. The agricultural economics literature started with Barton et al., (1947) and continued with Griliches (1960), Diewert (1976), AAEA Taskforce (1980), Jorgenson et al., (1987), Capalbo and Antle (1988), Craig and Pardey (1990), Jorgenson and Stiroh (2000), and most recently, Ball and Norton (2002). Jorgenson, Ho, and Stiroh (2002) show that U.S. agriculture accounts for 21% of all U.S. growth in productivity over 1958-1999 (but only 1.3 percent of gross domestic product), and it ranks in the top 4 of 37 sectors in average productivity growth over this period.

A general focus of the productivity measurement research, at least after Griliches (1960), has been to incorporate quality change in inputs. The USDA estimates of productivity, as well as others (e.g., Craig and Pardey, 1990), have adjusted the labor input for changing demographics, such as educational attainment of the farm labor force, fertilizer and agricultural chemicals for effective ingredients, land for irrigation, and tractors for horsepower.

Determinants of Productivity Growth. A smaller but significant literature exists on explaining the trends in farm total factor productivity (TFP). Most of the literature focuses on the importance of investments in public and private research and development and public extension (Griliches, 1963; Huffman and Evenson, 1993; Alston, Craig, and Pardey, 1998; and Yee et al., 2002). More recently and directly relevant to our work, the research by Huffman and Evenson (2001) expanded the traditional model to address questions about the relationship between farm productivity and farm structure. Huffman and Evenson (2001) describe structural change as a possible "channel" to TFP growth, and include several measures of structural change in a simultaneous equations model. While they include structural change variables in their TFP equations, they do not include TFP in their structural change equations. This paper will build on and expand the research of Huffman and Evenson by developing and estimating a model that will allow for TFP and a key measure of structural change, farm size, to be simultaneously determined.

Some recent work has explored convergence in TFP growth rates across states. McCunn and Huffman (2000) showed that a type of conditional convergence in TFP growth exists by region over 1948-1982, but they reject unconditional convergence. Ball, et al. (2002) apply an ad hoc convergence test over 1960 to 1996 and found some evidence of narrowing in the range of TFP growth over 1960-87 followed by an increase over 1987 to 1996 period.

Farm Structural Change. In contrast to the productivity measurement literature, which is solidly rooted in production theory, the literature on the changing farm structure, while very large, lacks a consensus and clear direction. The large literature on structural change in agriculture results from a continual interest to policy makers, producers, and society in general. The USDA has a compilation of reports on agricultural structure change, including USDA, 1979; Lin, Coffman, and Penn 1980; USDA 1981; USDA 1998; USDA 2001b; and annual Family Farm Reports focused on structure issues, such as the recent paper by Hoppe (2001). Other significant volumes include reports by the U.S. Senate (1980), Office of Technology Assessment (1986) and the more technical treatment of structure issues in Hallam (1993). The motivation for this enduring interest includes issues associated with social sentiments regarding family farms and more recently recognition of the amenities of farm landscapes usually associated with family farms (OECD).

Several useful review articles address the diversity and conflict among competing conceptual models (e.g., Harrington and Reinsel, 1995). Cochrane's technology treadmill is perhaps the most widely recognized hypothesis on structural change forces (Cochrane, 1958). Cochrane's hypothesis focuses on the impact of technological innovation reducing real per unit cost of output at the farm level and with competition encouraging farmers to adopt new technologies. As adoption becomes widespread, prices of farm commodities fall differentially across the country and possibly by size of farm, triggering structural adjustments. Technology adoption certainly plays a prominent role in the structural change process, but many factors are believed to play important roles in this process. Other schools, including asset fixity, economies of size, and political economy, also make contributions to understanding the structural change process in U.S. agriculture.

Household Production and Labor Allocations. Because farm households provide most of the labor on the farm and have a tripartite choice of time allocation (farm, off-farm, and leisure hours), the household production literature is a relevant link to our work. The household production model is an extension of the basic labor-leisure model (e.g., Becker, 1965; Gronau, 1977) and agricultural household models (e.g, see Strauss, 1986; Huffman, 2002). The conceptual model combines the decisions of agricultural households relating to production, consumption, and labor supply into a theoretically consistent model. The individual is assumed to allocate time to farm work, off-farm work, and leisure in such a fashion that the optimal allocation is achieved when the marginal values of time devoted to the activities are equal. Because of the dependence of farm households on off-farm income sources and the fixed supply of household labor, an important component of this literature is the empirical literature on estimating off-farm labor participation and supply. Huffman (1980) was the first in the literature to estimate off-farm labor supply/participation models for farm households using aggregate county data. Extensions in this literature include Sumner (1982), Lopez (1984), Jensen and Salant (1986), Huffman and Lange (1989), Lass, Findeis, and Hallberg (1989), Tokle and

Huffman (1989), Lass and Gempesaw (1992), El-Osta and Ahearn (1996), Findeis (1992), Huffman and El-Osta (1997) and Mishra and Goodwin (1997).

Model

We choose to focus on farm size and part-time farming as our two key structural variables. Recall that with total land in farms approximately fixed, the number of farms varies inversely with the average acres per farm. We employ a 3-equation model with feedback across the equations. The three equations are for productivity, farm size (measured as a constructed land rent per farm) and, because of the extensive supply of hours to off-farm work by farm households, the odds that farm operators work off-farm at least 200 days per year. The set of exogenous variables include public agricultural research stocks (from originating state and spillins); public extension; infrastructure in highways; indicators for specialization, contracting, and government programs (payments and set asides); ratio of capital rental-to-hired farm wage, ratio of manufacturing wage relative to the hired farm wage, share of college educated farm operators; indicators for exit and entry of farmers, dairy production, weather; and geographic region. See Table 1 for the variable list.

Structural Dimensions. Although other structural indicators are related to farm size and off-farm labor supply, we view these as secondary to size and off-farm work, and so include them as separate regressors. For example, the degree of commodity specialization, or the lack of diversification, is a separate regressor. The importance of the dairy enterprise is also a separate regressor; it is a specialization that requires a high intensity of labor, which has significant impacts on how a farm family organizes its resources, including labor supply to off-farm employment activities. Vertical coordination for the whole of the agricultural sector is especially difficult to quantify at any point in time, let alone over several decades. It involves linkages among multiple industries, upstream and downstream, that may be changing over time. An exception is production contracting where historical statistics from the various Censuses of Agriculture document an increasing trend. We also include a unique set of dynamic structural variables that have been developed from a panel data set constructed from five Censuses of Agriculture: 1978, 1982, 1987, 1992, and 1997. These variables are the share of farms which exit during a period, the share of new entrants during a period, and the share of farms that have increased their acres operated by at least double (Korb 2002).

Government Investments and Interventions in Agriculture. Government involvement in the agricultural sector is pervasive and significant. Some government policies are designed to impact agriculture, and other government policies that impact agriculture, are likely not designed to do so, e.g., macroeconomic policies. In that case, the impact is a secondary impact. Of course, it is extremely difficult to identify the intended impacts of many government policies on agriculture, given the nature of our system of government. Rausser (1992) classifies agricultural policies into two groups: those that correct for market failures, lower transaction costs, or enhance productivity, and other policies that result from manipulation by special interest groups. Generally, the intended impacts of government agricultural policies are not to alter the structure of agriculture, likely because a consensus on the ideal structure does not exist and because of our recognition of the efficiency of the marketplace for allocating resources.[2] Exceptions to this would be programs such as the Limited Resource Farmer program, Farm Service Agency's "lender of last resort" programs, and certain aspects of the tax code. In addition, payment limitations on receipt of direct payments could also be considered an explicit policy designed to minimize the impacts of policies on agricultural structure. Regardless of the primary intent of government intervention, our hypothesis is that significant impacts on structure and productivity occur. The major government policies affecting productivity and/or structure include: public research and extension, investments in highway infrastructure, and commodity and conservation programs.

Research and Extension. Research and extension are undertaken by both the public and private sectors. The output of agricultural research includes higher yielding crop varieties, better livestock breeding practices, more effective fertilizers and pesticides, and better farm management practices. Also, a significant share of agricultural research expenditures is devoted to so-called maintenance research (Huffman and Evenson, 1993, p. 114). Public agricultural research is performed in state agricultural experiment stations, land grant and other universities, and the USDA's Agricultural Research Service, Forest Service, and Economic Research Service. Various aspects of the system have been thoroughly studied by several authors (e.g., Huffman and Evenson (1993); Alston, Norton, and Pardey (1998); National Research Council (1995); Fuglie, et al. (1996).

Agricultural research is also performed by the private sector, mainly in the areas of farm machinery, agri-chemicals and pharmaceuticals, plant breeding and food processing. Private research expenditures have increased dramatically during the past three decades and now surpass that of the public sector (Fuglie, et al. 1996; Fuglie, 2000.)[3] For U.S. agriculture, the real rate of return is estimated to be high (Evenson, 2002). Hence, we expect the impacts of agricultural research and extension to be significant in our model.

Limited research exists on the effects of public research and extension on farm structure. A classical article is the one by Schmitz and Seckler (1970) on the adoption of the tomato harvester. In the past, the implications of an agricultural research agenda were not considered

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[2] All modern farm bills make reference to the importance of preserving the family farm, but an operational definition of that group is not communicated and a transparent plan for accomplishing that goal is not contained in the Act.
[3] Unfortunately, we do not consider the role of private R&D in our empirical model in this paper. It is part of our future agenda.

among planning priorities, but today a significant interest in recognizing structural implications of research priority setting exists. For example, ARS conducted a program evaluation to determine that two-thirds of its programs at the time of the review had potential to contribute to the competitiveness of small farms (USDA, 2000). The USDA has asked the National Research Council to review the relationship between publicly funded research and the evolving structure of agriculture (National Research Council, 2001).

The role of agricultural extension is to extend useful information to farmers and other constituents at a level that can be useful in application and problem-solving. Extension agents disseminate information on crops, livestock, and management practices to farmers and demonstrate new techniques as well as consult directly with farmers on specific production and management problems. In particular, supplying farmers with good information on new technologies can speed the adoption process, which generally increases the rate of return on research expenditures. Unlike research where impacts are distributed over a considerable period of time, e.g, 20-35 years, agricultural extension input can be expected to have an almost immediate impact on agricultural productivity.

The bulk of public extension funding now comes from state and county governments rather than the federal government (Ahearn, Yee, and Bottum, 2002). Furthermore, the private sector is increasing involvement in extension activities. For example, private crop consultants offer advice on pest and nutrient management for a fee. The empirical evidence on the social rate of return to public agricultural extension shows a greater variation and, in general, lower levels than for research (Fuglie, et al. 1996; Evenson 2002).

Infrastructure. The transportation of agricultural inputs and outputs in modern agriculture requires good infrastructure, especially roads and communications. Aschauer (1989) argued declining public capital stocks were a drag on productivity in the nonfarm sector during the 1970s. Since that time, several studies have investigated the impact of public infrastructure (highways and streets, water and sewer systems, schools, hospitals, conservation structures, mass transit, etc.) on productivity outside of agriculture. For the nonfarm sector, the empirical evidence is that public infrastructure has a positive and statistically significant impact on output and productivity. This finding is even more impressive given that much public infrastructure spending goes for improving the environment and other objectives that are not captured in output or productivity (as conventionally measured). This finding also implies that the rate of return to public infrastructure investment may be under-estimated because of the neglect of environmental and other benefits.

Few studies, however, have examined the effects of public infrastructure on agricultural productivity in the United States. For a cross-section of 66 countries, Antle (1983) did find a positive contribution of transportation and communication infrastructure on agricultural productivity. More recently for the United States, Gopinath and Roe (1997) at the national level and Yee, et al. (2002) at the state level found a significant positive impact of highway infrastructure on productivity. Transportation infrastructure, as a provider of access to the local labor market, is also important in explaining off-farm labor supply of farm households.

Commodity Programs. Legislation in the 1970s established a two-tier price system with target prices and commodity loan rates (Rasmussen, 1980). The literature is mixed on how government commodity programs have affected farm structure. This is in spite of the fact that it has been widely studied. Tweeten (1993) provides a literature review, describes the conflicting results, and an analysis of how payments have affected farm numbers from 1950-1987. He concludes that government payments modestly increase farm numbers in the short run and slightly decrease farm numbers in the long run. Empirical measurement of the program impacts can be captured by the dollar value of the subsidies transferred to participants and by the acres of land that a participant was required to set aside in order to be eligible for payments. The set-aside requirement was a policy decision that varied by year, depending largely on world stocks of commodities.

Conservation Programs. A variety of conservation programs have been established during our study period. The largest program during the period is the Conservation Reserve Program, established in 1985. “Small farms,” defined as those with less than $250,000 in sales, currently receive more than 80 percent of government conservation payments. Other programs provide technical assistance for conservation, such as those delivered by the Natural Resource and Conservation Service, formerly the Soil Conservation Service, but measures of those activities are not included in our model.

Other Dimensions. A variety of other dimensions affect productivity levels and/or structure. Kislev and Peterson (1981) explained farm size as related to the importance of the price of capital relative to the price of labor. Other effects include regional fixed effects and weather.

Hypotheses

We formalize our expectations about relationships in the model into twelve hypotheses dealing with farm structure, market forces, government policies, and selected other issues. The hypotheses associated with farm structure are:

Hypothesis I: An increase in contracting has no effect on agricultural productivity, farm size, or the odds of off-farm work; with the alternative being positive impacts on TFP, size, and off-farm work;

Hypothesis II: An increase in specialization has no effect on agricultural productivity, farm size, or the odds of off-farm work; with the alternative being positive impacts on TFP, size, and off-farm employment;

Hypothesis III: The annual rate of new entrants, exits, and consolidation of farms has no effect on agricultural productivity, farm size, or the odds of off-farm work; with the alternative being positive impacts on TFP and size but negative impacts on off-farm work;

The hypotheses associated with market forces are:

Hypothesis IV: An increase in the farm machinery rental relative to the farm wage has no effect on agricultural productivity or farm size; with the alternative being reduced productivity and size;

Hypothesis V: An increase in the manufacturing wage relative to the farm wage has no effect on the odds of off-farm work of farmers; with the alternative being a positive effect on the odds of off-farm work.

The hypotheses associated with public policy are:

Hypothesis VI: An increase in public agricultural research (both originating state and spillins) has no effect on agricultural productivity or farm size; with the alternative being positive effects;

Hypothesis VII: An increase in public agricultural extension has no effect on agricultural productivity or farm size; with the alternative being positive effects;

Hypothesis VIII: An increase in federal highway capital has no effect on agricultural productivity or odds of off-farm work; with the alternative being positive effects;

Hypothesis IX: An increase in farm commodity program payments has no effect on agricultural productivity, farm size, or odds of off-farm work; with the alternative being positive effects on productivity and size and a negative effect on the odds of off-farm work;.

The other hypotheses are:

Hypothesis X: An increase in agricultural productivity has no effect on farm size; with the alternative being a positive effect;

Hypothesis XI: An increase in farm size has no effect on agricultural productivity or odds of off-farm work by farmers; with the alternative being positive for productivity and negative for odds of off-farm work;

Hypothesis XII: An increase in off-farm work has no effect on agricultural productivity or farm size; with the alternative being negative effects.

Estimating the Model and the Results

The model contains multiple equations with feedback where productivity, farm size (measured as a constructed land rent per farm) and the odds that farm operators works off-farm (at least 200 days per year) are explicitly treated as endogenous variables. We make some strong but not implausible assumptions to achieve identification. See Table 2. We estimate the model by three-stage-least squares, incorporating cross-equation correlation of disturbances but ignoring autocorrelation. We choose to limit our analysis to the 1978 to 1996 time period.

The estimated coefficients for the structural model are reported in Table 2. They show surprisingly good performance. A large share of the estimated coefficients is significantly different from zero and the share of the variation explained is good, 45 percent for the TFP equation, 80 percent for the size equation and 30 percent for the off-farm participation equation.

Hypothesis I is rejected. An increase in contracting increases agricultural productivity and farm size, and the impacts are significantly positive. It also increases the odds of off-farm work of farm operators, perhaps due to substitution of contractor's information for farmer-initiated information searches and the reduction in farm work time from not having to engage in marketing the product. This could free up more time for other things, including off-farm work.

Hypothesis II is rejected. An increase in specialization increases agricultural productivity and farm size. It also increases the odds of off-farm work of farm operators, perhaps because it allows them to free up blocks of time for off-farm employment activities.

Various parts of hypothesis III are rejected. The rate of entry of new farms is not significantly related to productivity, farm size, or the odds of off-farm work. This seems to indicate that new entrants are not significantly different than surviving farms in ways that are key determinants of productivity, farm size, or off-farm work. The exit rate of farms is significant and positively related to productivity, indicating that less efficient farms were exiting the sector.

The exit rate was not significant in explaining farm size, but it was negatively and significantly related to the odds of off-farm work. Perhaps, this is because the farmers who are more likely to work both on and off the farm are also the ones who are more likely to leave farming altogether to pursue full-time off-farm work activities. Our results also support the argument that consolidation in agriculture has led to increased productivity in the sector and farm size. Our consolidation measure is positively related to off-farm work. Perhaps this is because, given that farmland is relatively fixed, as more land is concentrated in a smaller share of farms, a larger share of operators operate smaller farms facilitating the probability of off-farm work.

Hypothesis IV is rejected. A decrease in the machinery rental to wage for hired farm labor increases agricultural productivity. This suggests that there has been a labor saving bias to new technology. The result also shows the importance of agriculture's ties to the rest of economy as machinery is made in the nonfarm sector and labor moves between the farm and nonfarm sectors. It did not have a significant effect on farm size, indicating size neutrality.

Hypothesis V is also rejected. An increase in the manufacturing wage relative to the wage for hired farm labor increases the odds of off-farm work of farmers. The manufacturing wage is an opportunity wage for farmers in most of the United States. Although farmers could choose to close their farm business, many have chosen to continue in farming by operating a small farm and engaging in off-farm work.

Turning to public policy effects, we reject Hypothesis VI. An increase in public agricultural research in the originating state and spillins from other states increase agricultural productivity and farm size, and the effects are statistically positive at the 5 percent level. The impact of spill-in R&D is almost as large as the impact of a state's own R&D. Some might consider this surprising given that a state's R&D would be directly targeted to the state's agriculture. On the other hand, there are R&D investments from several states with similar agriculture that are being captured by the spill-in measure.

Hypothesis VII is rejected for agricultural productivity but not for farm size. An increase in public agricultural extension increases significantly agricultural productivity, but it has no significant effect on farm size. Hence, public extension, but not public agricultural research, has a neutral effect on farm size.

Hypothesis VIII is rejected. An increase in highway infrastructure has a significantly positive effect on agricultural productivity and odds of farmers' off-farm work.

Hypothesis IX is rejected for two of its three parts. An increase in government commodity program payments increases agricultural productivity. One simplistic reason is because our output measure used to compute TFP is valued at the subsidized price, i.e., market price and per-unit government payments, share-weighted. Other explanations may be that farmers use part of the commodity payments to purchase newer and more efficient farm machinery, which increases productivity. Related to the commodity programs, the acreage of land that was diverted from production as a requirement of commodity program participation has a significant and negative impact on productivity. We were not clear on the expected sign of this variable because those diverted acres were not included in the land input measure of productivity, hence, both the quantity of inputs and outputs were expected to be lessened when acres were required to be diverted. Since operators could choose which acres to set-aside, they would be expected to choose their least productive acres and the output on the acres in production would be valued at the subsidized price. Another type of program, the dairy program, is designed to manage output prices at above market prices through government purchases of product. Hence, no direct payments are made under the dairy program, and so we accounted for this program by including a dummy for dairy production. The sign on this variable is negative, indicating that greater dairy production in a state decreased state productivity. Thus, these commodity programs are not neutral with respect to on-farm effects.

An increase in government commodity program payments increases farm size. This finding is consistent with Cochrane's "cannibalism" tendency of payment recipients to out-bid farmers not receiving payments for farmland (Cochrane 1958). The lack of significance of payments on the odds of farmers working off farm was surprising and not consistent with prior results (El-Osta and Ahearn, 1996; Mishra and Goodwin, 1997) or with our own results for a somewhat different model specification and longer time period, 1960-96 (Ahearn, Yee, and Huffman, 2002). We expect the lack of significance to be related to the shorter time period; although not significant in our model, at least the sign was negative. The government conservation payment variable was significant and negative in the off-farm work equation, however. Most of these payments are for keeping land out of production in conserving uses, and are geographically concentrated in very sparsely populated areas with little off-farm work opportunities. In addition, most of these payments go to farmers at or near retirement age, so it is likely that their effect is to allow farmers to retire from both farm and off-farm work earlier than they would otherwise.

Hypothesis X is rejected; an increase in agricultural productivity reduces farm size. The same amount of output can be obtained from a smaller farm size. Hence, a type of substitution effect for obtaining output seems to be occurring.

Hypothesis XI is rejected. We find that an increase in farm size reduces, rather than increases, agricultural productivity. This suggests that on average a type of diseconomies of size is operating. Huffman and Evenson (2001) also found that farm size reduced crop TFP. The result may also be related to our state-level of aggregation. For example, several small farm states, like Connecticut, were among the highest 10 states in terms of TFP in 1996, while Texas, Oklahoma, Montana, and Wyoming were among the lowest 6 states in terms of productivity levels in 1996.[4] Alternatively, this could be the result of the commodity mix, by state. A large share of cow-calf producers in a state may contribute to lower TFP indexes and larger farm sizes in those states. This result was consistent for other minor variations on model specification, including alternative measures of farm size. Larger farm size does, however, reduce the odds of off-farm work. Farm size and off-farm work are a type of substitute.

Hypothesis XII is rejected. An increase in off-farm work of farmers reduces farm productivity and farm size. With off-farm work, a farmer's time and effort are diverted to non-farm activities and this can change the timeliness of farming activities in ways that reduce agricultural productivity, e.g., see Wozniak (1993). Off-farm work is a substitute for farm size.

Concluding Remarks

It is widely recognized that the farm sector is industrializing at a rapid rate, and that this trend varies by commodity. We tested twelve hypotheses about linkages among agricultural productivity and farm structure. Most of them were rejected. In particular, an increase in contracting increases TFP, farm size, and part-time farming. In the future, we will examine the effects of treating other measures of structure, such as specialization, as endogenous and of introducing private R&D as an exogenous variable.

The industrialization of agriculture is generally thought to include both vertical coordination (e.g., increases in contract production) and horizontal coordination (e.g., farm consolidation). Contracting in agriculture, and other developments leading to increased concentration in production and processing, have become very controversial in public policy discussions as observers debate whether increases in efficiency or increases in anti-competitive

[4] We are also concerned that there is some nonagricultural upward bias in the agricultural rents of states dominated

market power is dominating the outcomes. If the changing market structure is leading to welfare-improving efficiency gains these could be reflected in agricultural total factor productivity measures. While our results do not rule out the presence of anti-competitive market power as a result of trends in industrialization, they do show evidence that contracting and consolidation have led to increased productivity in the sector.

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by small farms, in particular, that there are some urbanizing influences in their rent measures.

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Table 1. Variable definitions

Variable	Definition
tfp	Level of total factor productivity (relative to Alabama in 1987)
size	Real land rental per farm
off	Proportion of farm operators who worked 200 or more days off farm
ownrd	Own research stock
spillin	Spillin research stock
ext	Extension stock per farm
hiway	Highway stock
hiwaya	Highway stock adjusted for the share of agriculture in a state's GDP
spec	Specialization computed as a herfindahl index, based on 10 commodity categories
contract	Proportion of farms with production contracts
compay	Real commodity payments per farm
conpay	Real conservation payments per farm
setaside	Diverted acres per farm
college	Proportion of farm operators with a 4-year college education or more
kw	Farm machinery rental divided by hired farm labor wage (lagged one year)
mw	Manufacturing wage divided by hired farm labor wage (lagged one year)
drought	Drought dummy
flood	Flood dummy
dairy	Dummy variable equal to 1 if dairy is greater than 20% of total cash receipts
exit	Exit rate per year
entry	Entry rate per year
sizeincr	Annualized share of the survival farms that increased in size by at least 100% during the census period

Notes:

"l" in front of a variable denotes taking the log (e.g., ltfp).

Regional dummy variables are included in each equation. The regions considered in this paper are:

1 – Northeast (NE): CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT
2 – Southeast (SE): AL, FL, GA, KY, NC, SC, TN, VA, WV
3 – Central (CENT): IN, IL, IA, MI, MO, MN, OH, WI
4 – Northern Plains (NP): KS, NE, ND, SD
5 – Southern Plains (SP): AR, LA, MS, OK, TX
6 – Mountain (MOUNT): AZ, CO, ID, MT, NV, NM, UT, WY
7 – Pacific (PAC): CA, OR, WA

Table 2

Three stage least squares estimates of productivity and structure model, 1978-96 (n = 912)

Variables	ltfp		lsize		l[off/(1-off)]	
	coeff.	t-stat.	coeff.	t-stat.	coeff.	t-stat.
Endogenous variables						
ltfp			-0.399	-2.322		
lsize	-0.255	-7.942			-0.716	-15.962
l[off/(1-off)]	-0.441	-8.671	-0.783	-8.186		
Exogenous variables						
lownrd	0.054	2.868	0.248	9.284		
lspillin	0.048	3.029	0.088	2.782		
lext	0.095	4.088	0.007	0.202		
lhiwaya	0.121	5.569				
lhiway					0.171	12.345
lspec	0.098	3.731	0.383	7.656	0.163	4.281
lcontract	0.018	3.074	0.038	2.820	0.035	3.880
lcompay	0.017	2.069	0.039	2.122	-0.011	-0.958
lconpay					-0.077	-6.671
setaside	-0.002	-5.214				
lkw	-0.218	-4.757	0.044	0.398		
lmw					0.472	7.436
lcollege					0.271	8.730
lexit	0.711	8.755	-0.421	-1.825	-0.233	-2.348
lentry	0.063	1.665	0.109	1.210	-0.042	-0.755
lsizeincr	0.191	3.580	1.084	9.872	0.859	11.739
drought	-0.050	-3.457				
flood	-0.020	-1.639				
dairy	-0.206	-7.546			-0.101	-3.025
Regions						
SE	-0.185	-4.896	-0.037	-0.486	0.357	8.321
CENT	0.093	2.395	0.762	9.561	0.793	12.123
NP	-0.110	-2.126	0.527	4.712	0.623	6.837
SP	-0.286	-7.880	0.133	1.382	0.457	8.336
MOUNT	-0.056	-1.126	1.003	10.283	0.999	11.479
PAC	0.045	1.020	1.002	11.416	0.855	11.358
Intercept	2.236	3.636	1.933	1.352	2.853	7.209
R^2	0.446		0.795		0.305	