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IMPACTS OF TECHNOLOGY ADOPTION ON THE U.S. RICE ECONOMY – THE CASE OF HIGH YIELDING SEMIDWARFS

Rice -- Varieties

Shoichi Ito

Warren R. Grant

M. Edward Rister

Ito is a graduate research assistant, Department of Agricultural Economics, Texas A&M University; Grant is an agricultural economist, National Economics Division, ERS, USDA at Texas A&M University; Rister is an associate professor, Department of Agricultural Economics, Texas A&M University.

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The Case of High Yielding Semidwarfs

Abstract

The rapid adoption of new Southern developed semidwarf high yielding varieties is having tremendous impacts on all segments of the U.S. rice economy. This will tend to improve the position of rice growers in the South relative to producers in California, increase deficiency payments and rice exports, and benefit rice consumers due to lower rice prices.

Key Words: Technology, rice economy, Lemont, Newbonnet, semidwarfs.

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Introduction

Recent technological improvements in rice varieties are impacting the rice economy. California yields jumped from an average of 55 hundredweight (cwt.) per acre during the 1970's to over 70 cwt. during 1984 and 1985 in association with increased research emphasis. Yields in the South, historically below California yields, have risen sharply during 1984 and 1985. Much of this increase in the South is due to the recent release of semidwarf varieties and the technology associated with growing those varieties -- Lemont from Texas and Newbonnet from Arkansas.

Historically, yield-improving varieties have been adopted rapidly by rice producers, although not uniformly across States. Labelle, a recent popular variety, was adopted rapidly, gaining up to 90 percent of the Texas acreage during the late seventies and early eighties (RMA). Lemont, developed in Texas, was released in 1983 for seed expansion. Expansion of Lemont plantings by producers was rapid. In 1985, semidwarfs were planted on 65 percent of the rice acreage in Texas, 50 percent on Arkansas and Mississippi, and 40 percent on Louisiana (Stansel). During the last 25 years, Lemont is the first variety which has been widely adopted throughout the Southern rice producing States.

The popularity of Lemont in Texas is a reflection of its high yield -- an average of 15 cwt. per acre above Labelle. Even in other States, the yields of Lemont during 1985 averaged 12 cwt. higher than traditional varieties (Stansel). Newbonnet, a more recent semidwarf release from Arkansas, has produced a 10 cwt. higher yield than other varieties grown in that area (Stansel).

The sharp increases in yields associated with new varieties has impacted production, market prices, and net returns to producers. In addition, deficiency payments and carryover stocks have increased, as a result of the increased supplies, lackluster demand, and relatively favorable Government farm program provisions for rice.

How does the introduction of rice yield-improving technology impact the rice industry? Who benefits? Who loses? In this research, the impacts of semidwarfs such as Lemont and Newbonnet on production, market prices, net returns to producers, consumption, and exports are estimated for the period 1983 through 1990.

Methods

The steps followed in this analysis were to estimate the rate of adoption of the semidwarf varieties based on adoption rates of traditional varieties adjusted to reflect two years of information for the semidwarfs. Then the supply-demand-price response was simulated with and without the semidwarfs included. The impacts on various industry segments were estimated with results from the two simulations.

Model for Rate of Adoption

Griliches (1957) developed a model for the adoption rate of a hybrid corn variety in the U.S. His basic model is:

$$(1)\ \ln(P/(K-P)) = a + bT,$$

where
- P = adoption rate of a variety,
- K = upper limit of adoption rate, i.e., K=.95, .90, etc.,
- a = intercept,
- b = coefficient for T, and
- T = year trend, i.e., year=1, 2, ...

With this equation, Griliches estimated characteristics of new variety adoption behavior of corn producers. The new variety is very slowly adopted by innovators at the beginning because of uncertainty associated with potential yields and related cultural practices. The adoption spreads rapidly when producers realize that innovators have benefited from adopting the new variety. As the adoption rate approaches 80 to 85 percent of the total planted area, the rate of increase slows down. Thus, the trend of adoption rate of a new variety draws an S-curve over time.

In this analysis, Griliches's basic model was used with K=.95 (i.e., upper adoption rate limit is 95 percent) and the adoption rate estimated using data from 1972 to 1979 for Labelle in Texas. Then, the estimated model was adjusted to the 1984 and 1985 adoption pattern of semidwarfs.[1] After this adjustment, rates of adoption of semidwarfs between 1986 and 1990 were estimated by equation (1) (Table 1). The case of Labelle was also used for Louisiana. For Arkansas and Mississippi, the patterns of Starbonnet were used and adjusted for the semidwarfs adoption rates in 1984 and 1985. Data for acreage and production by varieties were obtained from the Rice Millers Association.

Simulation Model and Assumption

Grant, Beach, and Lin developed a dynamic, general equilibrium, deterministic, simulation model for rice in 1984. This model analyzed rice supply-demand sectors and price relationships among producers, millers, and retailers. This model was reestimated with two additional years of data and developed as a dynamic, general equilibrium, stochastic simulation model. To estimate the impacts of the new semidwarf varieties, the estimated adoption rates were integrated into the yield equations of this simulation model. Simulations were then made with and without the semidwarfs included. The results indicate the impacts on acreage, yield, production, prices and demand.

In using this simulation model for this study, several assumptions

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[1] The adoption rate for semidwarfs in Texas at the end of two years was higher than the adoption rate for Labelle.

were necessary. Some of these assumptions may not reflect the real world completely. For the preliminary phase of analysis, the assumptions are:

1) 35 percent acreage reduction program each year,
2) All producers are in compliance with Government programs,
3) $50,000 payment limit has no impact on producers,
4) Loan rates at $7.20 for 1986, $6.84 for 1987 and $6.50 for 1988 through 1990,
5) 2% yearly increase in production, milling, and freight costs,
6) Loan repayment rates keyed to estimated Thai rice price,
7) Yield difference between semidwarfs and the traditional varieties are set at: 10.5 cwt. in Arkansas[2] ; 12.0 cwt. in Louisiana; 11.0 cwt. in Mississippi[3] ; 15.0 cwt. in Texas (Stansel),
8) Program farm yields assumed constant between 1986 and 1990 based on 1981-1985,
9) Yields in California assumed the same for both situations, and
10) Stochastic procedure with 50 iterations.

Results

Adoption Rates of Semidwarfs

Texas producers are taking advantage of the fact that Lemont was developed in Texas (Table 1). The adoption rate in Texas during 1984[4] was about 30 percent, much higher than in any other state (RMA). In 1985, however, Arkansas, Mississippi, and Louisiana adopted semidwarfs rapidly and reached 50 percent, 50 percent, and 40 percent, respectively, while

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[2] Yield difference for Arkansas was calculated assuming 25 percent acreage planted to Lemont and 75 percent acreage planted to Newbonnet.

[3] Yield difference for Mississippi was calculated from 50 percent acreage planted to Lemont and 50 percent acreage planted to Newbonnet.

[4] The years in this paper indicate marketing years. The rice marketing year, 1984, is from August 1984 through July 1985.

Texas reached 65 percent (Stansel). Texas is estimated to have the highest adoption rate among the four States, and is projected to achieve a 95 percent level by 1989. Arkansas, Mississippi, and Louisiana adoption rates are estimated to approach 80 percent, 80 percent, and 75 percent, respectively, by 1989.[5]

Simulation Results

Simulation results for this analysis reflect the difference between a situation which has the semidwarfs and a situation in which the semidwarfs are excluded.[6] The differences in production, farm returns, mill returns, domestic demand, exports, export value, food value, and deficiency payments are described by States or U.S. total.

Production

The U.S. total rice production trended downward between 1984 and 1990 according to the results (Tables 2a and 2b). The decrease would be much slower with the semidwarfs, however, than without the semidwarfs (base solution). As the semidwarf varieties are adopted, the estimated difference in total production increases. In 1984, production was estimated at 139 million cwt. with the semidwarfs, and 137 million cwt. without the semidwarfs, a difference of 1.5 percent. In 1990, the difference was 13.4 percent between production of 123 million cwt. with the semidwarfs and 109 million cwt. without the semidwarfs.

Market Prices

The farm price decreased sharply in late 1985 and after due to the introduction of the market loan repayment system. It was lowest at

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[5] Arkansas and Mississippi adoption rates include both Lemont and Newbonnet.

[6] The latter scenario is intended to represent what would have been the case had the semidwarfs not been developed at this point in time.

$4.42/cwt. with the semidwarfs in 1986. After 1986, however, the farm price increased sharply to $7.66/cwt. with the semidwarfs by 1990. Throughout the estimated period, the difference in prices with and without semidwarfs is very small relative to large differences in production. This is because the farm price is keyed to and reflects the world price, while the U.S. producton is only a small proportion of world rice production. In 1990 the farm price with the semidwarfs was $7.66/cwt., 2.3 percent lower than the farm price without semidwarfs.

Net Returns to Producers

U.S. farm returns above cash costs showed different behaviors when comparing returns before and after Government payments (Tables 3a and 3b). Excluding government payments, net returns to producers with the semidwarf simulations ranged $80 million to $108 million above the level without the semidwarfs included during 1985 and 1990. Including Government deficiency payments to those returns during the same period, however, showed more advantage by $93 million to $133 million with the yield improving varieties. Specifically, the returns with the semidwarfs in 1985 increased to $993 million, $133 million above the level without the semidwarfs. After 1985, on the other hand, the returns remained about $100 million above the level without semidwarfs, reflecting the constant government program farm yields.

Farm returns above cash costs for individual States reflect an advantage to Texas, Louisiana, Arkansas, and Mississippi producers when they adopt the new varieties (Tables 3a and 3b). California, however, gained an advantage over the Southern areas during the late seventies and early eighties with yield improving varieties. The areas adopting the new technology usually gain, to the detriment of competing areas. Advances in one area usually lead to intensified research efforts in competing areas to regain a competitive relationship.

Government Payments

The marketing loan repayment program (introduced in mid-April, 1986) totaled $108 million with semidwarfs in 1985 (1985/86 marketing year), (Table 4). In 1986, it increased to $372 million followed by decreases to $269 million and $93 million in 1987 and 1988, respectively. The values of the marketing loan repayment reflect a world market price. Accordingly, the highest payment in 1986 is due to an estimated low market price, while the loan payment decreased to zero in 1989 and 1990 during which the market prices were estimated to be above loan rates.

Loan repayments without the semidwarfs follow the same trend as the situation with the semidwarfs. The repayments without the semidwarfs in 1986, 1987 and 1988 are $351 million, $246 million and $76 million, respectively, $21 million, $23 million and $17 million lower than with semidwarfs, respectively. An expected lower production and higher farm price without semidwarfs contribute to less government costs. Loan repayments without the semidwarfs in 1989 and 1990 were also zero due to estimated market prices above loan rates.

Deficiency payments with the semidwarfs sharply increased to $532 million in 1985, when the payments without the semidwarfs were estimated at $488 million (Table 4). After 1985, the payments for both with and without the semidwarfs trended close to each other, primarily because of the farm program yield at a constant level. Deficiency payments reached the highest levels in 1987 at $533 million with semidwarfs and $535 million without. After 1987, however, both situations trend downward, decreasing to $412 million with the semidwarfs and $416 million without the semidwarfs in 1990; the difference, almost negligible, is due to slight differences in acreage response.

Total government payments, which are the sum of loan repayments and the deficiency payments, increased till 1986, reaching $892 million with the semidwarfs and $872 million without, then decreased continuously to $412 million with and $416 million without by 1990 (Table 4).

Trade

Volumes of exports with and without the semidwarfs are a sharp contrast. Exports are encouraged by the adoption of semidwarfs. Although exports with the semidwarfs trended down after 1986, the volume was higher than the situation without the semidwarfs (Tables 2a and 2b). Exports were estimated at 45.1 million cwt. with the semidwarf and 43.4 million cwt. without the semidwarfs in 1984. The volume of exports with the semidwarfs increased to 67.1 million cwt. in 1986 in comparison to 61.1 million cwt. without the semidwarfs in 1986, a difference of 9.8 percent. After 1986, the volume of exports with the semidwarfs decreased slower than the volume without the semidwarfs. They decreased to 51.0 million cwt. with the technology and 40.5 million cwt. without the technology during 1990. The difference increases over time to 26 percent by 1990.

The value of trade fluctuated between 1984 and 1990 (Table 4). The value with the semidwarfs always stayed above the value without the semidwarfs; the difference of the values between the two increased over time. The export value with semidwarfs was $867 million, only $31 million (3.7 percent) more than the value without in 1984; however, it increased to $942 million, $147 million (18.5 percent) more, in 1990.

As mentioned earlier, the volume of exports with the semidwarfs was larger throughout the estimated period than without. The fact, that export value with the semidwarfs also exceeded the value without, reflects an elastic export market.

In both situations, with and without semidwarfs, the values were lowest in 1987, although prices reached the lowest point in 1986. After 1987, however, export value increased in spite of a decreasing volume of exports, reflecting the general increase in rice prices.

Rice Mills

The volume of rice milled shows the same trend as production reflecting the larger amount of production with the semidwarfs. Quantity of rice milled with the semidwarf simulation increased by 13 percent in 1990 over the no semidwarf simulation (Tables 2a and 2b). The volume with the semidwarfs was largest (142 million cwt.) in 1986.

Throughout the estimated period, milled value with the semidwarfs exceeded the milled value without the semidwarfs, reflecting an elastic total market. This difference in milled values increased over time to $123 million in 1990, an 8.9 percent difference (Table 4). Increasing prices after 1986 and 1987 are correlated with increasing milled values.

Domestic Consumption

Domestic consumption for food increased gradually during the estimated period (Tables 2a and 2b). The volume for direct food use rose at a faster rate until 1986. The rate of growth in direct food use slowed after 1986, reflecting an increasing price. In 1990, direct food consumption reached 26.9 million cwt. with semidwarfs (a 15.0 percent increase over the 1983 figure) and 26.7 million cwt. without (a 14.6 percent increase over the 1983 figure). The difference in volumes between the two scenarios grew over time. However, the volume with semidwarfs was only 0.7 percent larger than without semidwarfs in 1990.

Retail values for direct food consumption increased sharply after a slight decrease in 1986 (Table 4). Retail values were estimated to reach $1,365 million with the semidwarfs and $1,394 million without the semidwrfs by 1990. Throughout the simulation period, the value with semidwarfs was smaller than the value wthout the semidwarfs, despite a larger volume consumed with the semidwarf scenario. These expenditure differences illustrate the inelastic nature of the domestic market, i.e., movement of greater quantities into these markets without a corresponding shift in demand results in lower total revenue from those markets.

Implications to the U.S. Rice Economy

The rapid adoption of high yielding semidwarf varieties impacts all segments of the U.S. rice industry. First, the simulations (both with and without semidwarfs) point to decreased production during 1984 to 1990. These results suggest a decline in the number of producers. The adoption of the high yielding varieties and associated production technology slightly accelerate this adjustment, because rice acreage is slightly smaller with the semidwarfs than without. Producer net returns above costs with semidwarfs would decline more slowly than without semidwarfs. These two facts indicate that the average net returns to producers are greater with the semidwarfs than without. These adjustments, not uniform across States, favor Texas, Louisiana, Arkansas, and Mississippi. California loses in a relative sense.

Second, increases in aggregate net return and deficiency payments to producers indicate increases in profits per producer, particularly with a decrease in the number of producers. This is more pronounced wth the semidwarf simulation. Third, as long as the government holds program yields constant, total government payments will not differ much between the two situations.

Fourth, exports will be greater with the semidwarfs than without. The difference in total value of U.S. exports between the two simulations is still positive, reflecting an elastic U.S. export market. Most of any increase in production due to the adoption of semidwarfs go into export markets.

Fifth, mills have a greater net return with the increased volume milled with the semidwarfs than without. Last, the U.S. domestic consumers benefit from the yield improving technology. Although their consumption increases slightly with the semidwarf simulation over the without semidwarf, consumers spend less with the semidwarfs reflecting an inelastic market.

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Table 1--Adoption rate of semidwarf varieties

	1984	1985	1986	1987	1988	1989	1990
Arkansas	.020	.500	.630	.700	.760	.800	.800
Louisiana	.021	.400	.500	.600	.680	.750	.750
Mississipppi	.014	.500	.630	.700	.760	.800	.800
Texas	.297	.650	.764	.860	.915	.950	.950

Data sources: RMA; Stansel

Table 2a. Supply, utilization, and prices with high yielding semidwarf varieties[a]

	Supply			Utilization											
				Rough Rice				Milled Rice							
Year	Begin Stocks	Prod	Total	Seed	Ex-port	Mill	Ending Stocks	Food	Brew-ers	Feed	Hulls	Ex-port	Farm Price	Mill Price	Retail Price
	Million hundredweight												Dol./cwt.		
1983	71.5	98.9	170.4	3.5	1.8	109.2	55.9	23.4	9.7	12.6	19.1	44.4	8.73	19.79	49.09
	(-)	(6.2)	(6.2)	(0.2)	(0.4)	(4.1)	(4.1)	(0.8)	(0.2)	(0.5)	(0.5)	(3.3)	(.51)	(.70)	(1.44)
1984	55.9	139.0	185.9	3.9	1.9	110.3	69.8	24.6	9.2	12.7	18.7	45.1	8.08	18.89	48.40
	(6.2)	(2.0)	(2.0)	(0.1)	(0.4)	(5.1)	(5.3)	(0.9)	(0.1)	(0.6)	(0.6)	(4.1)	(.25)	(.06)	(1.40)
1985	69.8	136.3	206.1	3.7	2.0	121.1	79.3	25.4	9.6	13.8	19.9	52.4	7.21	17.40	47.08
	(5.3)	(3.0)	(6.5)	(0.1)	(0.4)	(5.1)	(10.4)	(1.0)	(0.3)	(0.6)	(0.8)	(4.0)	(.27)	(.00)	(1.50)
1986	79.3	133.9	213.2	3.6	2.3	142.3	65.0	26.1	9.9	16.5	22.7	67.1	4.42	12.72	42.49
	(10.4)	(3.9)	(12.1)	(0.2)	(0.5)	(6.2)	(9.2)	(1.2)	(0.4)	(0.7)	(0.9)	(4.5)	(1.53)	(2.33)	(3.30)
1987	65.0	131.3	196.3	3.6	2.3	137.5	52.9	26.3	10.2	16.1	22.8	62.1	4.79	13.46	43.87
	(9.2)	(4.5)	(11.8)	(0.2)	(0.5)	(5.2)	(9.7)	(1.3)	(0.5)	(0.6)	(0.9)	(3.5)	(1.83)	(2.52)	(3.53)
1988	52.9	129.3	183.2	3.6	2.2	132.7	43.7	26.5	10.5	15.5	22.3	57.9	5.78	15.09	46.21
	(9.7)	(5.1)	(12.9)	(0.2)	(0.5)	(4.9)	(10.3)	(1.2)	(0.7)	(0.6)	(0.9)	(3.4)	(1.67)	(2.50)	(3.54)
1989	43.7	126.7	170.4	3.5	2.1	128.4	36.4	26.7	10.8	15.0	21.6	54.3	7.00	17.03	48.88
	(10.3)	(5.5)	(13.9)	(0.2)	(0.5)	(5.1)	(10.6)	(1.2)	(0.8)	(0.6)	(0.9)	(3.6)	(1.62)	(2.43)	(3.50)
1990	36.4	123.2	159.6	3.5	2.1	124.4	29.6	26.9	11.0	14.5	21.0	51.0	7.66	18.18	50.71
	(10.6)	(5.7)	(14.6)	(0.2)	(0.5)	(5.5)	(10.7)	(1.2)	(0.9)	(0.7)	(0.9)	(3.8)	(1.59)	(2.39)	(3.54)

[a] Standard deviation of 50 stochastic estimations are in parentheses.