Next-Generation Agricultural Technologies: Assessing Market and Policy Implications

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The historical impact of newer technologies in agriculture has been to increase the supply of food and fiber by increasing output per unit of input. Increases in market supply of food and fiber, net of demand changes, result in lower prices. Generally, this has been good for society in terms of meeting the social need for affordable nutrition and shelter for a growing population. However, lower food and fiber prices may not necessarily be good for farmers because they may result in lower farm incomes. Profitable and viable farms are required for the sustainable use of natural resources. This implies that a new technology may enhance farm productivity, enhance resource conservation but result in lower farm incomes. Such social impacts need to continue to be studied as newer technologies become available. Understanding the market impacts of such technologies is necessary to design food and fiber policies that will ensure that all components of the sustainable use of resources is addressed from both social and economic perspectives. We use market theory to assess the potential impacts of newer technologies on selected farm products. We use changes in supply that could potentially result from newer technologies to estimate the changes in the prices and farm revenues of selected agricultural products. We conclude that newer technologies will reduce the incomes of farmers who produce products that have inelastic demand and increase the incomes of farmers who produce products that have elastic demand.

Keywords: Technologies, Social Impacts, Farm Revenues, Elastic Demand

Introduction/Objectives

The historical impact of newer technologies in agriculture has been to increase the supply of food and fiber by increasing output per unit of input or making it less expensive to produce each unit of food and fiber. These technological improvements are the main reasons why Thomas Malthus' expectation of a decline in the human population due to increases in population outpacing increases in the rate of food production did not come to pass. The role of new and emerging technologies in food production is not new. New technologies that have positively impacted agriculture in the past include the green revolution, industrial revolution, use of chemical pesticides, biotechnologies and the emerging roles of artificial intelligence and machine learning. Each of these technologies, either singularly or working in concert with others have increased the supply of food and agricultural products. It is safe to say that next-generation technologies will have similar impacts in increasing the supply of food and agricultural products. Because most food is allocated through market institutions, increases in production occasioned by newer or next-generation technologies may have differing impacts on the different stakeholders in the food and fiber sector. Although next-generation technologies will result in a net gain for society, there may be groups of winners and losers. In other words, as with most new innovations, there will be a redistributive impact of such newer technologies. The nature of the redistribution may be one that requires tweaking existing food and agricultural policies or designing new ones. Such policy changes require an analysis and understanding of the potential

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market impacts of next-generation technologies. We analyze such impacts in this study. Specifically, we assess the potential impacts of next-generation technologies on consumers of food and fiber. We also assess the potential impact of next-generation technologies on farmers of selected products. We then explore the implications of next-generation technologies for society and public agricultural policy.

Theoretical Model

We use the model of a perfectly competitive market in equilibrium. In such a market, equilibrium is attained when quantity demanded by consumers is equal to quantity supplied which is called the equilibrium quantity. Market equilibrium also results in an equilibrium or market price which is the price that all buyers of the product pay and all sellers of the product receive. Changes in demand result in changes in the equilibrium price and quantity. For example, an increase in demand will result in increases in the equilibrium price and quantity of the product. Conversely, a decrease in demand will result in decreases in both the equilibrium price and quantity. Unlike changes in demand, changes in supply cause the equilibrium price and quantity to move in opposite directions. An increase in supply will result in a decrease in the equilibrium price and an increase in the equilibrium quantity. The equilibrium price will increase and the equilibrium quantity will decrease if there is a decrease in supply.

For any given equilibrium price, consumers derive benefits (total social benefits) which relate to the maximum amount of money that they are willing and able to pay for the product. The difference between the total social benefits and the amount that consumers actually pay is the net consumer benefits or consumer surplus (CS). The CS could be represented mathematically as:

$$CS = \int_0^Q f(Q_d)dQ - P.Q \quad (1)$$

where CS represents consumer surplus, $\int$ is the integral operator as the quantity consumed changes from zero(0) units to Q units, $f(Q_d)$ is the inverse demand function with price as a function of quantity, $\int_0^Q f(Q_d)dQ$ represents total social benefits or the monetary value to society of the equilibrium quantity of the product, P is the price of the product, Q represents the quantity of the product and the product of P and Q (P.Q) is the consumer expenditures on the product. CS changes whenever the equilibrium price and quantity changes. Specifically, lower prices result in higher consumer surplus and higher prices result in lower consumer surplus.

As with consumers, producers also derive benefits (total revenue) from the sale of products. The total producer benefit is represented by the product of the price and corresponding quantity (P.Q) which is also the same as consumer expenditures in equation 1. The net producer benefits, also called producer surplus (PS) is represented by the total benefits less the cost of production. The mathematical representation of PS is:

$$PS = P.Q - \int_0^Q h(Q_s)dQ \quad (2)$$

where $h(Q_s)$is the quantity dependent inverse supply function, $\int_0^Q h(Q_s)dQ$ is the total social cost or monetary cost to society of producing the equilibrium quantity of the product, and other variables are as defined for equation 1. The PS changes whenever the equilibrium price and quantity change. An increase in the equilibrium price increases the PS while a decrease in the equilibrium price decreases the PS. The implication is that higher prices make producers better off while lower prices will make them worse off.

Methods

For the purpose of this study, we must first recognize that some next generation technologies could result in changes in demand. For example, a new technology may enhance the nutritional attributes of a product which will result in an increase in demand for it. This implies that consumers of the product are willing to pay more for any given quantity of the product. We ignore instances where a new product may introduce undesirable attributes to a product because such a technology will not persist in the long-run.

We then limit ourselves to the impacts of next generation technologies on supply. New technologies result in increases in marginal productivity. This implies that any given quantity of the product could be produced at a lower cost to society. Holding demand constant, the increase in supply will result in a lower equilibrium price and higher equilibrium quantity based on the law of demand. We base our analysis of the impact of the new technology on the impact on consumer surplus based on the relative changes in price and quantity. We note that in equilibrium, total consumer expenditures (E) is equal to total producer revenues so that

$$E = TR = P.Q \qquad (3)$$

Taking the log of both sides of equation 3 yields

$$LogTR = LogQ + LogP \qquad (4)$$

Taking the total derivative of equation 4 results in

$$dlogTR = dlogQ + dlogP \qquad (5)$$

Equation 5 indicates that the percent change in producer revenues and consumer expenditures depend on the percent changes in the equilibrium quantity (dlogQ) and price (dlogP).
These percent changes relate to the own-price elasticity of demand which is defined as the percent change in the quantity of a product that is demanded due to a one percent change in the price of the product. Let the own price elasticity ($e_p<0$) for our generic product be given as:

$$e_p = dlogQ/dlogP \qquad (6)$$

We obtain values of estimated own price elasticities from existing studies for selected agricultural products and assume a 10 percent increase in supply (dlogQ) as a result of a new agricultural technology. Equation 6 allows us to obtain estimates of the resulting percent change in price (dlogP) as:

$$dlogP = 10/e_p \qquad (7)$$

Substituting the assumed technology-induced 10 percent increase in quantity, and equation 7 into equation 5 gives

$$dlogTR = 10 + 10/e_p = 10(1 + 1/e_p) \qquad (8)$$

Equation 8 indicates that the impact of a new technology on producer revenues (TR) will depend on the own-price elasticity of demand for the product. If the demand for the affected product is elastic (i.e. e_p>1 in absolute terms), the new technology will result in increased revenues (dlogTR>0) for the affected agricultural producers. If the demand for the affected product is inelastic (ep<1 in absolute terms), producer revenues will decrease (dlogTR<0) as a result of the new technology. Producer revenues will remain unchanged (dlogTR = 0) if the affected product has unitary elasticity (e_p = 1 in absolute terms).

We obtain and use estimates of own-price elasticities for selected products in the United States based on previous empirical studies. We focus on products from selected food groups such as livestock, fruits and vegetables, and grains. The livestock products include beef, chicken, eggs and pork. Fruits and vegetable include apples, bananas, carrots, grapes, lettuce, and oranges. Grains include corn, wheat and rice. The obtained values of the own-price elasticities are substituted for e_p in equation 8 to derive estimates of the percent change in total revenue (dlogTR) that will result from a 10 percent change in the new technology-induced supply.

Results

The results of our analysis are presented on Table 1. The own-price elasticities for fruits and vegetables range from -0.09% for lettuce to -1.38% for grapes (column 2 of the table). The own-price elasticity of -0.19% for apples implies that any new technology that increases the supply of apples by 10% will reduce the price of apples by 52% (column 3). This implies that the welfare of apple consumers will increase substantially because they pay a lower price for a larger quantity of the product. However, the increase in consumer welfare comes at the expense of apple producers. The 52% decrease in the price of apples results in a 42% decrease in the revenue of apple producers. This is because the percentage increase in quantity of apples sold in much less than the percentage reduction in the price of apples. The same technology-induced 10% increase in the supply will result in 10%, 240%, and 101% decreases in the revenues for producers of bananas, carrots, and lettuce, respectively. The technology-induced 10% increase in the supply will result in a 7.25% reduction in the price of grapes and a 2.75% increase in the revenue of producers of grapes. The increase in supply (10%) is beneficial for producers of grapes because the percent increase in quantity exceeds the decrease in price (7.25%). There will be no change in the revenues that accrue to producers of oranges because the percent increase in quantity of oranges that will be supplied will be completely offset by an equal percent change in the price.

Demand is inelastic for all the grains – corn, rice and wheat. As indicated in Table 1, a technology-induced 10% increase in supply will result in price decreases of 303% for corn, 68%

for rice and 476% for wheat. The reductions in producer revenues will be 293%, 58% and 466% for corn, rice and wheat, respectively.

A new technology-induced 10% increase in the supply of the major livestock products will also result in revenue losses for producers. Revenues for producers of beef will decline by 6%. Producers of chicken will experience a 17% decline in revenues. Egg producers will experience an 81% decline in revenues. The revenue loss for pork producers will be a modest 3.7%.

Table 1: Estimated Impact of a New Technology-induced 10% Increase in Product Supply on Prices and Producer Revenues in the United States

Agricultural Commodity	Own-Price Elasticity (%)[a]	Change in Price (%)	Change in Producer Revenue (%)
Fruits and Vegetable			
Apples	-0.19	-52.63	-42.63
Bananas	-0.50	-20.00	-10.00
Carrots	-0.04	-250	-240
Grapes	-1.38	-7.25	2.75
Lettuce	-0.09	-111.11	-101.11
Oranges	-1.00	-10	0
Grains			
Corn	-0.033	-303.03	-93.03
Rice	-0.147	-68.17	-58.17
Wheat	-0.021	-476.19	-466.19
Livestock			
Beef	-0.62	-16.13	-6.13
Chicken	-0.37	-27.03	-17.03
Eggs	-0.11	-90.91	-80.91
Pork	-0.73	-13.70	-3.70

a: Source: Huang, K.S., 1996. American Journal of Agricultural Economics

Conclusions

As with previous technological innovations in agriculture, next generation technologies will be beneficial to society. However, they will come with distributional impacts. Consumers of the affected agricultural products will benefit through paying lower prices for larger quantities of the affected agricultural product. The impact on producers of the agricultural product will depend on the degree of the responsiveness of consumers of the product to changes in its price. For products such as grapes and apples whose demand are very responsive to price changes, producers will benefit from technology-induced supply increases. Producers of products such as lettuce, wheat, eggs and other products whose demand are not very responsive to changes in their prices will experience a loss of revenue. Producers of crops whose demand are not very responsive to price changes need to be aware of the possibility of revenue losses due to new technical innovations and incorporate the information when making long-term investment plans. Technology-induced supply increases results in increases society's wellbeing through the production of larger quantities that are sold at lower prices. Social policies that encourage or subsidize newer technological innovations in agriculture need to be coupled with policies to address the distributional impacts of such technologies on producers. Such a policy will help to keep producers invested in the important activity of producing food and fiber at lower prices while adopting newer technologies.

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