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How U.S. Agriculture Learned to Grow: Causes and Consequences

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Paper presented at the 45th Annual Conference of the Australian Agricultural and Resource Economics Society, January 23 to 25, 2001, Adelaide, South Australia.

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How U.S. Agriculture Learned to Grow: Causes and Consequences¹

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Introduction

Two key aspects of the evolution of 20th century U.S. agriculture are the following. First, during the 1930s, a remarkable take-off in agricultural productivity growth occurred. This acceleration is surprising not only in the change to a new trend, but also in the persistence of that trend. In the 1960s and in the 1970s even more strongly, doubts were raised about the prospects of food production keeping up with population growth, much less continuing the trend of declining real farm commodity prices. Yet the rate of productivity growth was maintained in the 1980s (even as nonfarm productivity stagnated) and may have accelerated further in the 1990s. Second, while benefits to buyers of farm products are expected to follow productivity growth, as real farm prices have declined, there have also occurred real economic gains to farmers. By the end of the 1950s it had become clear that real farm household incomes were rising after 40 years of stagnation. Real incomes have since risen both absolutely and relative to incomes of nonfarm households (figures 1 and 2). Farmland began to rise in real value in the mid-1950s after declining in real terms between 1910 and 1950. Even the real wages of hired farm workers, which might be thought to be most threatened by technological change, increased in real terms and relative to nonfarm wages after 1950.²

Overall, the growth of productivity and income in U. S. agriculture in the 20th Century is a notable achievement. The question then is what made it happen? And, there is the further question of how productivity and farm income growth are related. Did productivity growth cause farm income growth? Or did farm incomes grow despite productivity growth? Are trends in both the result of common underlying causal factors? Could the relationship between productivity and income have gone either way depending on conditioning factors such as commodity policies and the international market situation?

In this paper I will discuss these questions in two parts. First, theories of growth and second, empirical application to U.S. agriculture.

¹ Alan Lloyd Address, Adelaide, January 25, 2001. Earlier versions have been discussed at seminars at the University of California, Davis, UC Berkeley, Iowa State University, Ohio State University, Washington State University, and Michigan State University. I want to acknowledge helpful comments received at those occasions and from colleagues at the University of Maryland.

² Moreover, in aspects of the overall U.S. economic recovery of the 1990s that remain troubling, notably increasing income inequality and reduced income of low-income households relative to mean incomes, the farm economy has performed relatively well. Inequality and poverty in the rural farm population has declined over the last 40 years, and in fact has changed the rural-farm population from an exceptionally poverty-ridden group to one in the economic mainstream. (I've reviewed evidence and causes in Gardner 2000).

Theories of Growth

Many theories both formal and informal have been advanced. The basis for several formal ones is neoclassical growth theory, developed to explain growth in an economy-wide context, but adaptable to explain sectoral growth. The fundamental ideas are that an economy's (or a sector's) output is a function of its labor and capital, that its GDP or income per worker is a function of its capital stock per worker, and that technology limits the GDP growth that can be attained. GDP per worker grows because of investment or because of technological change. Investment funds are obtained by abstaining from current consumption, i.e., savings, which are a function of the rate of interest, and at equilibrium in each period, the rate of interest equals the marginal rate of return to investment. In this context, the growth rate of GDP per worker, and hence income per capita, can be increased by (1) technological change that increases output per given inputs (i.e., productivity), (2) tax or other policy changes that increase the incentives to investment, or (3) quality improvements in inputs (e.g., improved worker skills).

There are several controversial issues in the interlinked causes and effects of growth. Notable ones are: (a) understanding the sources of improvements in technology, (b) explaining the adoption of new technology, (c) understanding the reasons for changes in the economic organization of farm enterprises, (d) the economic consequences of technological and organizational change, particularly the effects on agricultural productivity, farm size, and income distribution, (e) the role of market integration between the farm and nonfarm economies, particularly with respect to labor markets -- both migration off farms and nonfarm sources of income for people who remain on farms, and (f) the role of government, and more generally, economic incentives, in fostering the creation and adoption of new technology and the development of changes in the economic organization of agriculture.

Recent work on "idea-based growth" emphasizes the development of new scientific, technological, and organizational knowledge as the source of technical change that increases the marginal return to investment, and improvements in human capital as a source of increased returns to labor as well as new ideas and their effective economic application (Jones 1995). In the case of agricultural growth, it is widely accepted that agricultural research and the associated infrastructure that results in the resulting new knowledge being commercialized and adopted by farmers is a key cause of agricultural productivity growth.

Two related but distinct analytical frameworks are helpful in understanding the evolution of U.S. agriculture in this context of the whole economy. First is the two-sector model of general equilibrium. Secondly, many authors, notably T.W. Schultz and D. Gale Johnson, have emphasized the importance of labor mobility in solving the problem of low farm income. Unfortunately, general equilibrium models have not provided useful empirical insights into the key questions of the sources of technological change, the role of economic institutions in fostering the development and adoption of new technology, or

the role of investment in agricultural growth. Most importantly, the general equilibrium approach has fallen short as a theory of why returns to labor and other inputs in agriculture can be different in the two sectors, and how and whether such differences will tend to be erased over time.

The analytical remedy is to model disequilibrium in factor markets and the resolution of disequilibria, i.e., dynamics in an empirically applicable two-sector growth model. A possibly helpful approach to organizing our thoughts about dynamics and disequilibrium in an empirically applicable way arises from recent literature on economic growth, as elaborations of neoclassical growth models. For my purposes today, these models contribute simple but important suggestions: paying close attention to the initial conditions in explaining subsequent growth experience, and indicating some particular initial conditions that are likely to be important. My interest here is in transferring some ideas from their economy-wide approach to the two-sector context of economic integration between the farm and nonfarm sectors.

Empirical Evidence: Narrative Assessments

Agricultural economists and historians for many years have been explaining events U.S. agriculture, mainly without the guidance of formal quantitative modeling. Writers have focused mainly on the acceleration of productivity growth that occurred after 1935. This change, called a revolution in U.S. farming by some scholars, only became quantifiable as the data on inputs and outputs in agriculture were developed and refined in the late 1940s.³

One hypothesis is that the key factor was the availability of a continuing stream of better and more applicable new technology after 1935. An acceleration in productivity growth at that time could be explained by the acceleration of agricultural research that took place between 1910 and 1930, with long lags for developing commercially viable new technology from this research. Public spending on agricultural research tripled between the decade of 1900-1909 and the 1910s, and tripled again between the 1910s and the 1920s, and agricultural extension efforts under both Federal and State support also grew rapidly (Alston and Pardey, 1996, pp.34 and 54). Ronald Mighell (1955) presents the considered view of U.S. government analysts based primarily on 1950 Agriculture Census data. He clearly sees an acceleration of productivity growth in the mid-1930s (p. 5), and links this event to agricultural research and education. Spending on agricultural research had been growing for many years but is not so easy to link statistically with a change of trend in the mid-1930s.

³ The issue of whether technological change in U.S. agriculture was revolutionary or evolutionary was debated by economic historians in 1940-60. Only in retrospect has it become clear how sharp and lasting was the break in productivity growth that occurred during the 1930s. One who saw this early was T.W. Schultz: "With knowledge already at hand, it would appear that the recent surge forward is still in its early stages because it will take years, perhaps decades, to put into practice in all parts of agriculture what is already known." (Schultz, 1953, p. 112).

A more promising idea is that what changed after 1935 was not so much the availability of and knowledge about technological innovations as the economic environment in which they would be used. A classic study of the adoption of hybrid corn by Zvi Griliches (1957) established the connection between the profitability of a technological innovation and the extent of its use by farmers.

In agricultural commodity markets a notable long-lasting change intended to influence the overall profitability of farming was the set of commodity support policies introduced with the New Deal farm programs. Willard Cochrane and Mary Ryan put the case thus:

What did the price and income support programs have to do with these gains in agricultural productivity? They had a lot to do with it. They provided the stable prices, hence price insurance, to induce the alert and aggressive farmers to invest in new and improved technologies and capital items, and the reasonably acceptable farm incomes and asset positions to induce lenders to assume the risk of making farm production loans. (Cochrane and Ryan, p. 373)

Sally Clarke (1994) made a variant of this hypothesis the focus of her book. She concentrates mainly on farmers' investments in tractors in the Midwest in the 1930s, concluding that "farmers' willingness to invest turned in large part on the long-term changes initiated by the New Deal farm policy" (p. 200). However, the New Deal also introduced a variety of regulatory requirements and action-specific subsidies that arguably retarded adoption of new technology, and while market sources of instability were reduced, uncertainties associated with the policies themselves were increased.

Another long-term economic change at about 1940 was the rise in real farm wage rates as the general economy emerged from the Depression, and especially as labor markets tightened during World War II. One of the sharpest changes of trend in relative prices was the rise in farm relative to nonfarm wage rates that began in 1941. A possible reason is that the economic development of agriculture was fostered by economic progress in the nonfarm industries of the United States, which was reflected in rising real wage rates throughout the economy. The key developments in the farm sector in this view were those which resulted in closer, more rapid and cheaper connections between rural and urban America – improved roads, electronic communications, consolidated schooling and better education. T.W. Schultz (1953) gave oxygen to this view with his reasoning based on the relatively rapid economic progress in the 1930s and 1940s of rural areas that were located near cities as compared to more remote areas.

Investment in Agriculture

Facts and data relevant to the issue of technology adoption are farmers' investments in capital equipment, which often embodies new technology. Clarke's discussion especially, concentrating as it does on tractors and mechanization, makes farmers' ability and willingness to invest in their farms a crucial element in the sector's productivity growth. Data relevant to capital in agriculture is not as well grounded in surveys as other output and input statistics. We have Census data on farm inventories of certain items of equipment. But these data do not cover a great many investments, notably in new types of

equipment. Moreover, Census inventory data do not provide enough information about the age, condition, and features of the equipment to construct a total capital stock estimate. Independently of the Census, the Economic Research Service of USDA collects a broader range of data from equipment manufacturers, dealers, and other sources. Using this information together with farm buildings and other fixed capital such as irrigation equipment, the Bureau of Economic Analysis (BEA) of the Department of Commerce constructs a measure of "net reproducible capital" (to distinguish this form of wealth from natural resources and financial capital). The increase in this measure from year to year provides an indicator of net investment in agriculture. A time series of the BEA investment indicator is shown in Figure 3.

The data indicate the ill effects of the long period of unfavorable economic conditions in agriculture, with net investment by farmers being negative throughout the 1920s and 1930s. The economic meaning is that the farm community was to some extent living off its capital stock, or "eating the seed corn," by letting its capital stock depreciate. In this context, the increase in investment at the end of the 1930s and early 1940s is really quite modest. The take-off in net investment doesn't occur until 1946, after which the rise is spectacular. The timing is suggestive in two important ways. First, since overall productivity growth began to accelerate at about 1940, and had definitely begun its permanently faster growth before 1945, it is a mistake to tie the acceleration of productivity growth to farmers' investment in capital equipment. Second, while the New Deal programs undoubtedly gave farmers reasons for less pessimism, the investment data do not indicate a real switch to ebullient willingness to invest any time in the 1930s and early 1940s. Wartime restrictions helped keep a lid on some investment until 1945, but even so the facts of overall investment limited the extent to which underlying optimism could be converted into productivity-increasing new equipment. Moreover, to make a big difference requires more than just a year or two of investment, especially after years of depreciation of the capital stock as occurred in the 1930s. Even in 1947 after two years of accelerated investment, the capital stock had only just recovered to its level of 1930. But by 1980 the capital stock had tripled. These considerations cast doubt on the Cochrane-Clarke hypothesis at least as it pertains to the New Deal programs fostering productivity growth by stimulating investment during the late 1930s.

Consequences of Productivity Growth: Farm Income

While farmers have seen the benefits of technological progress in their individual operations, some farm organizations as well as agricultural economists have been skeptical about the benefits to farmers as a group when a large number or all of them adopt new technology. Economists have provided analytical support for such skepticism. There are two kinds of concern: a distributional worry and one about aggregate farm income. The distributional worry is that only the early adopters of new technology would gain. The idea is that the aggressive, low cost farmers expand output and this drives down prices so that farmers who stay with previous technology can no longer cover costs. Their incomes fall and income equality with agriculture increases. The concern about aggregate farm income is a longer-run consequence. As the high-cost producers are squeezed out, and their farms

“cannibalized” (Cochrane’s term) by the aggressive, growing farm enterprises, the whole sector finds itself with output increasing and prices falling so far as to just cover the new, lower costs (or with overshooting of output, not covering costs for the sector as a whole). Thus only buyers of farm products are sure to gain.

A large literature by agricultural economists has attempted to work out in analytical detail the circumstances under which farmers as a whole can be expected to gain or lose from cost-reducing technical progress. There is no strong a priori prediction, for two main reasons. Farm income is the returns to the factors of production that farmers own, principally their land and labor, and whether technical change increases their income depends on how technical change affects the net returns to land and the farmer’s labor (the wage rate of self-employment). Technical change may be biased in such a way as to reduce labor requirements (e.g., mechanization), land requirements (e.g., improved irrigation methods), or the use of purchased inputs (e.g., seeds engineered to be pest resistant). It is possible that the set of technological changes that occur during a given time period may be factor-neutral in the sense of reducing the need for all inputs proportionally. The first reason why there is no sure forecast of whether farmers will gain or lose is that we cannot be sure whether any factor bias in technical change will increase or decrease the use of farm-owned inputs.

The second reason for uncertainty is that even if technical change is factor neutral we cannot be sure what the effects on factor returns will be. Factor neutrality results in the demand for both farm-owned and purchased inputs moving in the same direction, but we don’t know if that direction is up or down. The key variable in determining that direction is the elasticity of demand for farm products. If a technology generates a 10% decline in all input requirements and hence in the cost of a product, and that induces a less than 10% decline in demand for the product (inelastic demand), then there will be a net reduction in the demand for inputs and aggregate farm income will decline. But if product demand is elastic, then more of both farm-owned and purchased inputs will be used, tending to increase their returns, and farm income will rise. This last scenario is most likely when farm products are exported.

It remains an empirical question how productivity growth in U.S. agriculture has affected aggregate net farm income.

Agricultural Sector Growth: State Comparisons

The data that we have been discussing are national, and the attempts to sort out the causes of productivity and income growth that were cited use national time series data. There is however reason to doubt that time series econometrics will ever be able to provide convincing tests of hypotheses because there is too little independent variation in the causal forces – history simply has not performed enough enlightening experiments. But disaggregated data may hold out more hope.

Recent research on economic growth has revisited the question of economic growth and convergence in more austere theoretical contexts (see for example Robert

Barro and Xavier Sala-I-Martin, 1992; Aghion and Howitt, 1996). Regions with GDP below average in per capita GDP at an initial date will tend to catch up according to neoclassical growth models because low output per person in such regions indicates a high marginal return to savings and investment. With a well functioning capital market, investment will occur at a higher rate in the low-income area and its per capita income will grow faster than in high-income areas (from which capital flows may be coming). Even in the absence of capital flows, people will move out of low-income areas into high-income areas and this will also cause convergence in per capita incomes. The initial state is one of economic disequilibrium, in the sense that the initial state is not sustainable. The initial state itself generates actions which move the economy out of that state.

One may ask why, if the disequilibrium state is observed at one point in time, it should not continue? Indeed, may we not be observing an area moving away from rather than toward a long-run equilibrium? Theodore Schultz (1950) argued that U.S. agriculture was in just that situation. From an initial situation at the time of rural settlement in which disparities in income between communities were not large, big income differences arose not because some areas became poorer, but rather because others became richer for reasons unavailable to communities that were economically left behind. In this context, convergence may or may not occur, and the reasons involve labor and capital mobility and cultural factors which either foster or hinder adjustments to disequilibrium. Richard Easterlin (1960) also gives reasons why convergence between regional income levels might fail to occur, as it does for a sub-period he analyzed when already high agricultural incomes in the Mountain states increased at a rapid rate while a slower rate of growth was observed in the low-income South.

To quantify convergence, an approach used in Barro and Sala-i-Martin as well as other recent studies is helpful. Convergence can be estimated from the following equation:

$$(1) \quad g_{t,0} = a + b y_0$$

where g is the rate of growth of real GDP per worker between 1900 and a later time, t , y_0 is the log of the level of real GDP per worker in 1900, and a and b are parameters to be estimated. The rate of convergence, c , is found from

$$(2) \quad b = (1 - e^{-ct})/t.$$

An estimate of b indicates the change in the annual growth rate resulting from a 1% higher level of Y_0 , while c indicates the rate at which the differences between states are eliminated. The idea of a common rate of convergence across states means that even though they each start out very differently from the common value they will all arrive at when convergence is complete, all states will arrive at that common level at the same time. In what follows we focus on estimates of b . Estimating equation 1 using annual rates of change from 1900 to 1950, in a weighted ordinary least squares regression, the

estimated values of a and b are .061 (6.4) and -.005 (3.7) respectively.⁴ The b value means a state that had about a 30% lower GDP per worker in 1900 than the national average is predicted by the regression equation to grow at a rate 1.5% faster than the national average of 2.2% annually between 1900 and 1950.

Several recent authors have warned against bias that would cause acceptance of the hypothesis of convergence when it is false, or alternatively rejection of the hypothesis when it is true. For assessments of these arguments see Nerlove (1998) or Bliss (1999). The practical point for purposes of the preceding regression result, finding convergence across states, is that this finding might be a statistical artifact. One reason for downward bias in the estimated b is that variables are omitted from the equation that are positively correlated with growth but negatively correlated with initial income. This would be a serious problem if the conclusion of convergence were taken to provide for a particular model of convergence, as for example the studies which motivate convergence through a neoclassical growth model and then take a negative b as confirmation that the model applies. But the present purpose is not to test a model. States that have initially low GDP per worker may grow faster because the marginal return to investment is higher in them, or because low income workers leave those states for richer states, or because public policies invested more in infrastructure or human capital in those states. The issue at present is only whether some forces of income convergence have been at work, or not.

A second line of criticism is potentially more damaging for simple convergence econometrics. If initial GDP levels are temporarily low just by chance, then we are liable to observe convergence according to equation 1 even if in fact there is no convergence in underlying or permanent income. Bliss (1999) relates this phenomenon to “Galton’s fallacy,” the conclusion that because tall fathers tend to have sons shorter than the fathers, and short fathers, taller sons, then we should expect the variance of men’s height to decline over time. We can test for the applicability of this problem in the GDP data by estimating whether the variance of GDP per worker across states is declining over time.⁵ Figure 4 suggests that in fact variation across states, at least the percentage difference between the highest and lowest income states, did not decline between 1900 and 1950. However, the coefficient of variation (standard deviation/mean) of real GDP per worker across states declined from 0.402 in 1900 to 0.373 in 1950. Suppose the estimates of $a=.061$ and $b=-.005$ were the true parameter values indicating the extent of convergence.

⁴ The numbers in parentheses are absolute values of “ t ” ratios. They indicate statistical significance at the 95% confidence level (against the null hypothesis of a zero coefficient, or no convergence in the sense of the b coefficient). Weighted regression is used because of the substantial variation in the size of the agricultural sector in the states. Unweighted regression gives too much influence to the smaller states, and may create heteroskedasticity in the equation’s errors. The observations are weighted by the agricultural labor force of 1950, which varies from 39 thousand (Rhode Island) to 4.5 million (Texas). An unweighted regression was also estimated gave the same value of b as the weighted regression.

⁵ Trends in variance across states are not a conclusive test, however. It could be for example that convergence is really occurring in the sense of economic adjustments working, but that new sources of variance are introduced over time, such a state differences in an influx of immigrants, or relatively poor retirees heading south for noneconomic reasons.

The predicted values of income by state can then be calculated from the actual 1950 GDP values. The resulting predicted coefficient of variation of GDP per worker across states in 1950 is 0.307. That is, if there had truly been as much convergence as the estimated parameters say, the reduction in GDP variability across states would have been about 3 times the reduction that actually occurred between 1900 and 1950; that is about two-thirds of the estimated convergence appears to be spurious.

For the period since 1929 a more complete USDA data set is available for farm sector income, with state-level annual statistics that follow the approach used in the National Income and Products Accounts to measure sectoral value added, which is equivalent to GDP. This measure includes value added by all labor, land, and capital committed to agriculture. Table 1 summarizes the state-level data and shows estimated convergence statistics, b of equation 1, for net farm income. It turns out that there is no clear tendency for convergence. This is borne out not only by the lack of significance of the estimated b coefficients, but more directly by the observation from the means and variances shown in table 1 that net farm income per farm becomes substantially more variable across states, with a coefficient of variation (standard deviation/mean) of 0.73 in 1989 compared to .36 in 1929 and .58 in 1949.

Causes of State Differences. It is apparent that the reason some states have grown faster than others is not that some started later and have been catching up. What does explain the differences? Growth models typically focus on growth of the capital stock and technical progress as determinants of the rate of growth of per capita income. Supplementing the basic equation of table 1 with variables indicating the growth of capital per farm and the rate of productivity increase, the following regression results are obtained explaining the percentage change in real net farm income per farm over the 40-year period 1949-89, using the same data as in table 1 with the addition of two explanatory variables:

Variable:	coefficient	t ratio
Growth of capital	0.827	2.80
Growth of productivity	1.254	2.79
1949 net income per farm	0.017	2.93

The dependent variable is the annual rate of growth of real net income per farm, measured the same as in the regressions in the top half of table 1. Growth of capital is measured as the percentage change in USDA's estimate of capital consumption per farm, in 1992 dollars, between 1949 and 1989.⁶ The coefficient of 0.827 is statistically significant, with a positive sign as expected from standard growth theory. The economic meaning is that a 1% increase in capital per farm is associated with a 0.83% increase in real farm income

⁶ This is an indirect measure, but is an accurate proxy for the capital stock if depreciation is the same fraction of the capital stock in all states in 1949 and 1989. (There are undoubtedly differences between states in this fraction, but since we use only changes over time as the regressor, this will not matter so long as the fraction remains the same over time in each state.)

per farm. Productivity growth is the rate of growth of total factor productivity, which measures how well the farm operators of a state are able to put their labor, land, and capital inputs to productive use. This variable too is positive as expected, with higher statistical significance. Since all variables are measured in annual percentage changes, the coefficient of 1.66 means that a 1% increase in TFP growth is associated with a 1.66% growth of real net income per farm, other things equal.

The variable measuring the level of 1949 net income is the same variable as used in the table 1 regressions to indicate convergence. The most surprising result of the coefficient of 0.017 is that it indicates statistically significant divergence, i.e., that the highest-income states in 1949 grew fastest over the next 40 years, holding capital and productivity constant. Why should this occur? It must be that the higher net income states in 1949 had some characteristics other than capital investment and productivity that fostered their economic growth. To narrow down the possibilities, consider some additional factors whose levels in 1949 may have influenced the subsequent growth farm income: the educational level of farmers, the state's public infrastructure, and the importance of government farm programs, all of which vary substantially from state to state. For statistical purposes I measure the first by the percentage of each state's farm males over 25 years of age who have completed high school. Infrastructure is a more difficult variable even to conceptualize, much less to measure. I use the state's property tax rate on agricultural land in 1949. This indicates the intensity of local government activity in rural areas, and is assumed to be related to spending on infrastructure to the extent that property tax revenues are used to provide local services in rural areas. The importance of farm programs is measured by government payments received per farm in a state in 1949. Levels in 1949-50 are used to minimize the chance that these variables are caused by rather than causing income growth after 1950.

A regression augmented to include these three variables is:

Variable	Coefficient	t statistic
Growth of capital	1.102	3.09
Growth of productivity	0.981	2.05
1949 Net income per farm	0.009	1.54
% completing high school, 1949	-0.001	0.03
tax rate on farm real estate, 1949	0.0044	1.64
government payments, 1949	0.013	2.50

The only added variable that is statistically significant is government payments, indicating that states growing the commodities that received the most support in 1949 saw their net farm income grow the most in 1949-89. The Cochrane-Clarke hypothesis discussed earlier would explain the role of government commodity support as encouragement of investment and innovation which raised productivity growth. But variables representing investment and productivity growth are already in the equation. And, estimating separate regressions in which the growth of capital and TFP growth are

dependent variables, I find that 1949 government payments do not have a positive association with either growth of capital or TFP growth. Moreover, in the analysis of data from 315 counties, described more fully later, government payments does not have a significant effect. Finally, note that the 1950 income level is no longer significant, so that we have eliminated most if not all of the unexplained divergence of net farm income per farm during 1949-89.

Farm Household Incomes

The data we have been considering to this point are narrowly agricultural. This is a serious limitation in studying farm households' incomes because so much of their income is earned at nonfarm activities, and that percentage has been increasing over time. To obtain a fuller picture, we now turn to farm household income data at the state level, which are available decennially since 1950 from the *U.S. Census of Population*.

Estimating equation 1 using the 1950 to 1990 growth rates of median real farm household income indicates significant convergence, substantially different from the results with the agricultural GDP and net income measures, with a estimated at $-.021$ and b at $.22$.⁷ The mean annual real income growth rate is 3.2% annually, with a convergence coefficient that causes the growth rate to slow by .02 for every doubling of base-period income. This means that after 40 years about 80% of 1950 relative income differences have disappeared. Thus, taking two states that fit the regression equation well, Arkansas had real income (in 1992 dollars) of \$5,200 in 1949 and Michigan had \$11,900. By 1990 Arkansas' real income had risen to \$28,000 while Michigan's rose only to \$32,400. The results of this convergence are seen in Figure 6. Compare Figure 7, which shows net farm income. The comparison could hardly be more stark with respect to convergence versus divergence among states over time. The forces at work in the evolution of farm household income must be substantially distinct from the factors influencing income from farming.

Explaining State Differences in Farmers' Income Growth. The role of factors that might underlie convergence is investigated by means of regression analysis like that done earlier for net farm income growth. The dependent variable now is the average annual growth rate of median incomes of rural-farm households between 1950 and 1990, using data from the State Reports of the decennial *Census of Population*. The coefficients and t ratios for the independent variables are as follows:

Variable	coefficient	"t"
Log of 1950 median farm household income	-0.021	14.10

⁷ The t statistics for the null hypotheses of a and b equal to zero are 23.3 and 20.0, respectively, indicating both are statistically significant at the 99% confidence level. The regression was estimated by weighted ordinary least squares, with each state observations weighted by farm numbers in the state. An unweighted regression gives essentially the same parameter values but lower t ratios of 12 and 10 respectively.

Median schooling, rural farm males, 1950	0.075	1.32
Total Factor Productivity, 1950	0.0022	0.61
Farm Capital Stock, 1950	0.00019	0.29
Growth of Median Urban family income	0.331	2.41
Percentage of state population rural	-0.024	7.28
Percentage of rural population nonwhite	0.0084	2.16
Property tax rate (per \$100 land value)	0.050	0.91

This equation explains 97% of the variation across states in the rate of income growth, but 1950 median farm household income itself explained 89% of that variation in the earlier convergence equation. We now find that the farm-related variables that were important in explaining net farm income growth are not significant in explaining farm household incomes. Total factor productivity, farm capital, and the property tax rate are none of them significant. The added variable that is most significant is the percentage of the state's population that is rural. This finding supports the hypothesis of Schultz that a larger presence of nonfarm people in a state is good for the growth of farmers' incomes, because it increases their off-farm earnings opportunities and increases the demand for the goods and services that farmers produce. The third significant variable is the percentage of the state's population that is nonwhite. Since nonwhites migrated out of the rural-farm population at a high rate between 1950 and 1990, and had lower incomes than whites, it is unsurprising that rural incomes grow more when nonwhites leave the rural population; but the 1950 income level is already included as a separate variable so something further may be going on.

The preceding regression explains the rate of change of family income between 1950 and 1990 using the levels of explanatory variables in 1950, except for urban income levels where the rate of change is the explanatory variable. Using the rate of change rather than the initial level for this variable and not the other explanatory variables requires justification. To see how it makes sense, it helps to recognize explicitly that we are dealing with time series as well as a cross-sectional data, even if the time series observations are only of two point in time. The limited dynamics that we have in the decennial observations of states can be thought of as a cross-sectional variant of an error-correction model (ECM) in time series analysis. The economic foundation of an ECM is a cointegrating equation that specifies a long-run equilibrium relation among the variables analyzed. That relation in the state income convergence context says that equilibrated incomes of rural and urban people should be the same. Therefore, the urban income variable requires special treatment as the argument in a cointegrating equation, which in a cross-sectional regression across states is estimated as:

$$(3) \quad yf_i = \alpha + \beta yu_i + v_i$$

With perfect integration we should find $\alpha=0$ and $\beta=1$, where yf_i is the i th state's farm family income and yu_i is each state's urban family income (all variables measured in logs), and v_i is a random error term that incorporates state idiosyncracies or measurement errors. Moreover, in a fully equilibrated long-run situation, urban income levels should

be the same in all states (apart from the y_i) so the regression could not be estimated as in (3) with a constant term because $y_{i,t}$ would also be constant across states. The ECM-like estimating equation for (3) is

$$(4) \quad (y_{f,i,t+1} - y_{f,i,t}) = \alpha + \beta (y_{f,i,t} - y_{u,i,t}) + \gamma (y_{u,i,t+1} - y_{u,i,t}) + u_{i,t}$$

where t is an initial date, and $t+1$ a subsequent date. Using $t=1950$ and $t+1=1990$, we obtain $\beta = -0.027$ and $\gamma = .774$, with t statistics of 16.0 and 4.3 respectively. The interpretation of β is analogous to that of the coefficient of initial income in equation (1). The negative sign indicates that 1950 income differences between farm and urban incomes were eliminated at a rate of β per year between 1950 and 1990. The interpretation of γ is that a 1% rate of growth in urban incomes generates a rate of growth of 0.77% in farm family incomes. The standard error of the estimate of γ is 0.18, indicating that we cannot, with 95% confidence, reject the null hypothesis that a 1% rise in urban incomes cause rural-farm incomes to rise by 1%.

There is an important ambiguity in the analogy between the ECM and the cross-sectional convergence model. The ECM's integrating equation relates each state's farm income to urban incomes in that state. The convergence model relates each state's farm income to a long run equilibrium income level that is the same in all states. We can conveniently investigate both aspects of integration jointly with a slight elaboration of the cross-sectional ECM. To investigate integration with respect to a nationwide common income level as well as integration between farm and urban incomes within each state, we add to equation (4) the right-hand side variable, $y_{f,i,t}$ (the same as in the earlier convergence equation). In terms of the cointegration framework, this is equivalent to the right-hand side of equation (3) with $y_{u,t}$ (the nationwide urban median income at time t , which is common to all states). The estimating equation is:

$$(5) \quad (y_{f,i,t+1} - y_{f,i,t}) = \alpha' + \beta' (y_{f,i,t} - y_{u,i,t}) + \gamma' (y_{u,i,t+1} - y_{u,i,t}) + \delta' y_{f,i,t} + w_t$$

The resulting estimated coefficients (with t statistics) for several sub-periods in 1950-1990 are:

dependent variable	coefficients of independent variables (with t statistic)			
growth rate of median farm family income:	initial year log of farm family income ($y_{f,i,t}$) (δ')	growth rate of urban family income ($y_{u,i,t+1} - y_{u,i,t}$) (γ')	initial year difference between urban and rural incomes ($y_{u,i,t} - y_{f,i,t}$) (β')	R^2
1950-1960	-0.025 (0.83)	-0.051 (0.19)	0.012 (0.27)	.32

1960-1970	0.012 (1.19)	0.84 (5.04)	0.074 (5.74)	.79
1950-1970	-0.006 (0.84)	1.32 (4.50)	0.021 (1.84)	.86
1970-1990	-.029 (6.64)	0.827 (4.64)	-0.006 (0.83)	.80
1960-1990	-0.016 (4.49)	0.559 (4.26)	0.013 (3.02)	.91
1950-1990	-0.013 (3.40)	0.677 (4.15)	0.009 (1.69)	.94

The bottom equation is equation (5) as estimated above, adding the initial-year (1950) farm income level to equation (4). This variable turns out to be statistically significant ($t=3.40$), and its inclusion reduces the coefficients and significance of the other two variables, most notably the initial-year urban/rural income difference in the state. The economic interpretation is that rural-farm family income grows with urban incomes, and that farm family incomes are converging toward a nationwide common income level, not just toward urban income levels in the state in which the farm family lives. The same is true even more strongly for the twenty-year period 1970-1990. However, for income growth in earlier periods the story is different. During 1950-1970, we still see farm family income growing roughly proportionally with urban incomes, but in that period we see convergence towards the state's urban income but not toward a nationwide common income level (coefficient on 1950 income level is zero). During 1950-1960 we find no evidence of any significant convergence nor of farm family income growing with urban family income.

The expanded ECM model is like the earlier convergence equations in not attempting to determine the economic causes of income growth, beyond convergence to urban incomes from an initial state of disequilibrium. Adding the explanatory variables that were statistically significant or nearly so in the earlier regression explaining the growth of farm family income during 1950-1990, we find the following:

Variable	coefficient	"t"
1950 median farm household income (d')	-0.018	5.68
1950 urban-farm income difference (b')	0.004	0.95
Growth of median urban family income (c')	0.419	3.78
Median schooling, rural farm males, 1950	0.095	1.59
Percentage of state population rural, 1950	-0.023	7.28
Percentage of rural population nonwhite, 1950	0.0072	2.10
Growth of Farm Productivity	0.0431	0.77

In the expanded equation, the state's rurality and percentage of farm people nonwhite have significant effects, and schooling is almost significant, as in the earlier estimated equation that excluded the initial urban-farm income difference. That coefficient (β') turns out not significant, so it is not surprising that it made little difference in other coefficient estimates. The equation explains 97.5% of the observed state-to-state variance in rate of income growth between 1950 and 1990.

Summary Discussion

County data permit further analyses of factors behind the economic history of U.S. agriculture. They provide a larger number of observations than states, and constitute a more diverse sample, while being more homogeneous within each observation. A sample of 315 counties is chosen to represent a variety of agricultural areas to the extent possible, by following the classification of "state economic areas," for use in the Censuses of Agriculture, Population, and Housing in 1950 (see U.S. Bureau of the Census, 1950). The results of similar analyses to those reported above for state data generate roughly similar results: no convergence in farm-related economic variables but strong convergence for farm household incomes, with labor market adjustment the predominant cause of income gains over the 1960 to 1990 period.

Overall, the growth of agriculture as a sector of a state's or county's economy is promoted by investment, farm productivity improvement, and governmental support of agricultural research. These variables are of course not independent of one another, and it is not claimed that any one of them is more important than another as a separable cause of growth. Other variables that were thought likely candidates as causes of agricultural growth, notably farmers' schooling, regional and commodity specialization measures, and government commodity support programs, turn out not to be consistently significant factors.

The growth of real farm family incomes, from farm and off-farm sources together, is more directly important from the viewpoint of peoples' welfare. The surprising finding with respect to causes of family income growth is how little any agriculturally specific variables contribute to explaining differences among counties. This is true even for the counties in our sample that are most heavily dependent on agriculture. Instead, farm family income growth is explained, to the extent it is explainable, mainly by the relationship of farm to nonfarm family earnings. This relationship is taken to be attributable principally to labor market adjustments. Counties where farm family income was relatively low as a fraction of nonfarm incomes in 1960 rose significantly faster than in counties where farm and nonfarm incomes were close, and farm incomes consistently rose together with nonfarm incomes. These results indicate strongly that the economic story is one of integration of factor markets, with adjustment to an initial state of disequilibrium.

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Figure 1 Net Real Farm Income per U.S. Farm (1992 \$)

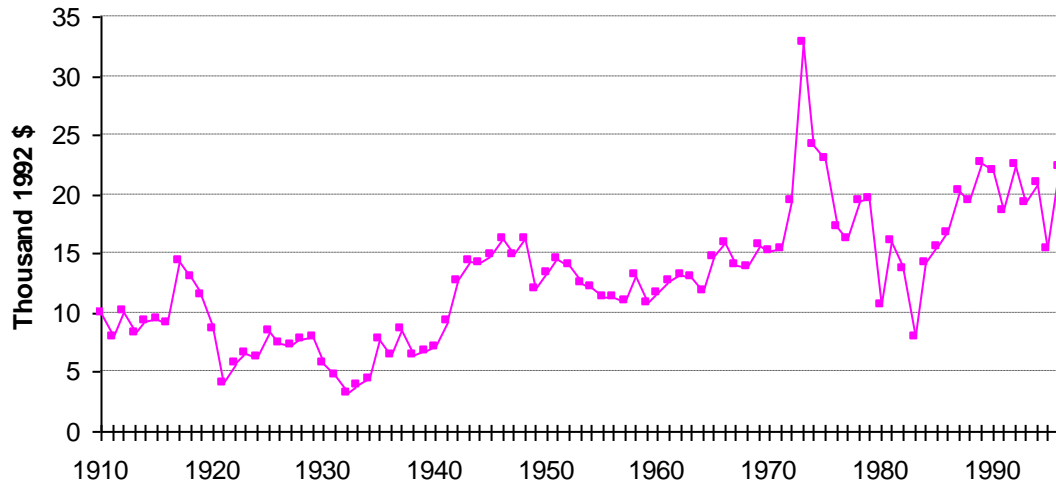


Figure 2. Income of U.S. Farm Households as Percentage of Nonfarm Households

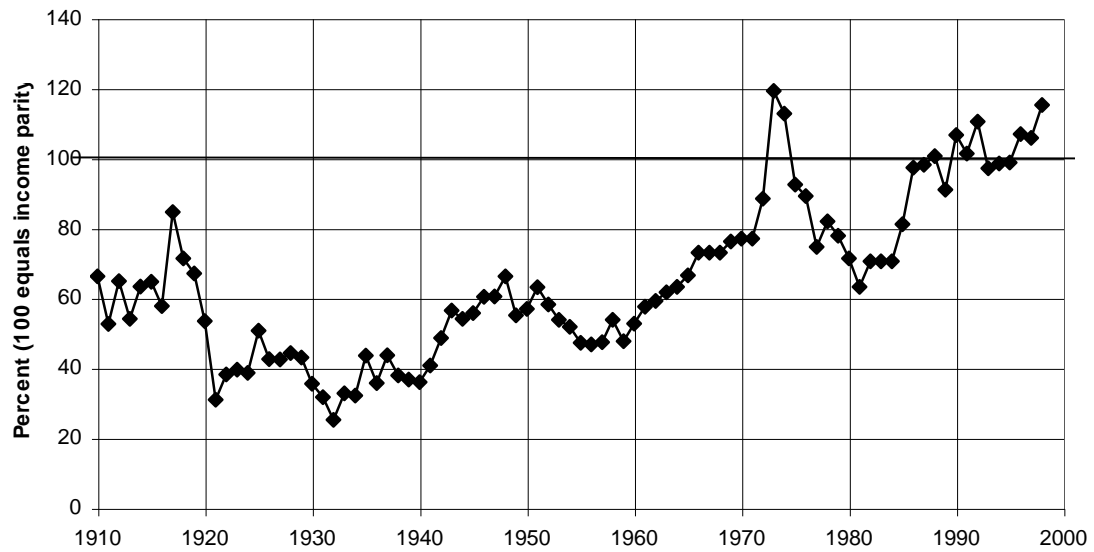


Figure 3 Real Net Investment on Farms

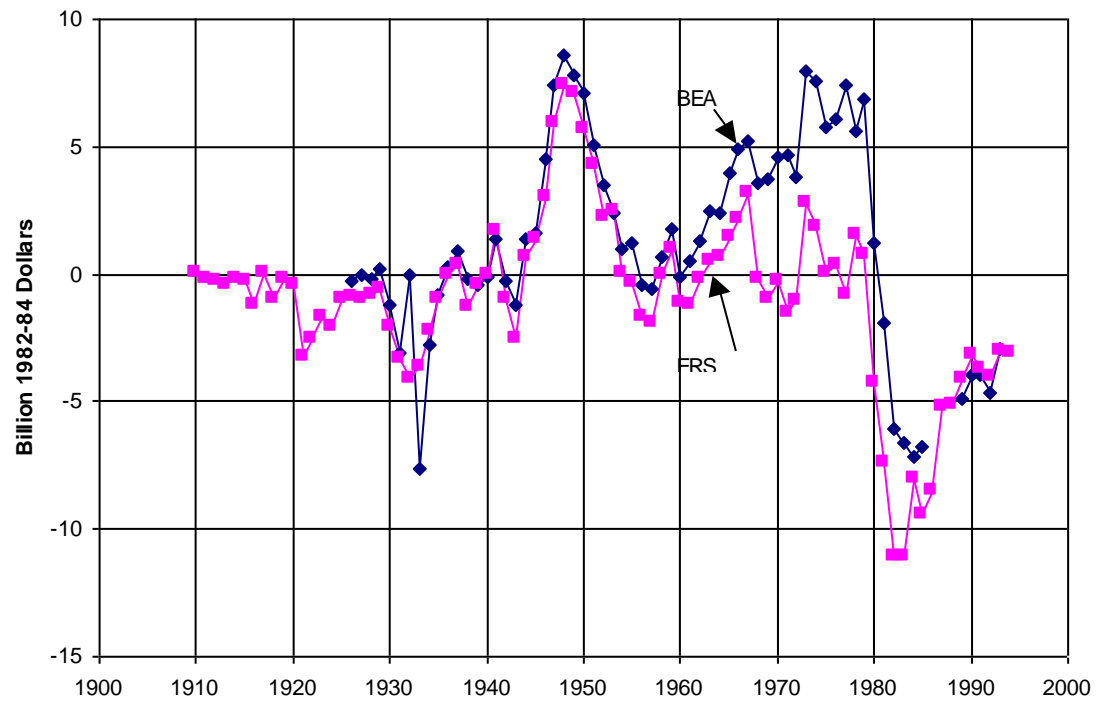


Figure 4. State Growth in Real Agricultural Labor Returns per Person Employed

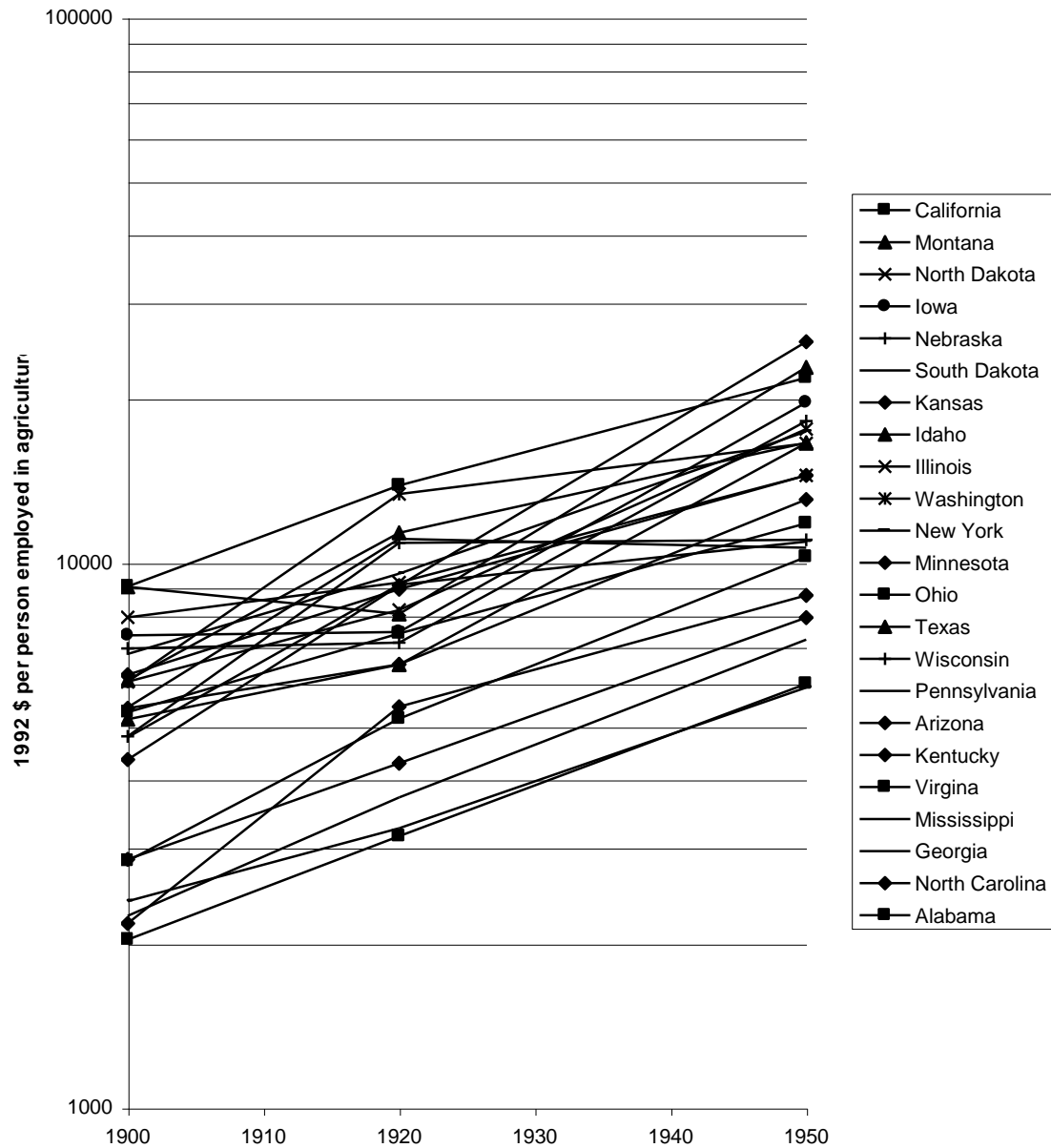


Table 1. Statistics of Convergence and Economic Variation Among States

Net farm income per farm, in 1992\$						
	48-State Mean	Standard Deviation	Coefficient of Variation	Average in Lowest State	Average in Highest State	Ratio Max./Min
1929	9691	3468	0.358	5297	20738	3.92
1939	8679	3039	0.35	4423	17007	3.85
1949	14982	8642	0.577	5414	55566	10.26
1969	20767	13655	0.658	2728	81303	29.8
1989	27361	19910	0.728	1870	93345	49.92

Net farm income convergence					
period	Parameter h	t statistic	Estimate excluding regional effect		
	coefficient		coefficient	t statistic	
1929-89	-0.004	1.04	.013	2.56	
1929-49	0.003	0.67	.008	1.18	
1949-89	-0.007	1.60	.007	1.45	
1929-39	-0.019	2.69	-.021	1.84	
1939-49	0.013	1.31	.006	0.99	
1949-69	-0.006	0.94	.006	1.00	
1969-89	-0.002	0.57	.007	1.41	