Good schools make good neighbors: Human capital spillovers in early 20th century agriculture

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Abstract

Education has an important but often under appreciated role in agricultural productivity. Formal schooling helps a farmer adapt to new developments in agricultural technologies and markets in ways that experience alone cannot. We present evidence from the Midwest at the start of the twentieth century showing that the emerging public schools, particularly secondary schools, were helping farmers successfully adapt to a variety of agricultural innovations. We construct a unique dataset of farmers containing income, educational attainment, and detailed geographical information and use it to estimate both the private returns to education for farmers and human capital spillovers across neighboring farms. The results indicate that public schools contributed substantially to agricultural productivity at the turn of the century and that a large portion of this contribution came through spillovers. These findings shed new light on the forces underlying public school expansion in the United States in the early twentieth century and the role of schools and the agricultural sector in overall economic growth during that period.

1 Introduction

The emergence of the modern American public education system has been studied extensively. The work of Goldin and Katz (2008) and others has removed any doubt of the importance of growth in the educational attainment of the national workforce to growth of the US economy. While there is little dispute about the high returns to schooling in the first half of the twentieth century and the increasing importance of human capital in a wide range of industries, there is one aspect of the expansion of the educational system and human capital investments that has escaped attention, the role of education in the agricultural sector. Despite the Midwest serving

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as the locus of the high school movement, little attention has been paid to the links between education and agriculture. This paper seeks to identify the importance of formal schooling in early twentieth century agriculture by quantifying both the private returns to education for farmers as well as human capital spillovers across farms.

Central to identifying the effects of the emergence of public education on American agriculture is understanding the role of human capital in agriculture. Productivity in agriculture is highly dependent on allocating resources efficiently, adapting to changes in relative prices, assessing and selectively adopting new technologies and successfully incorporating agricultural advances into farming practices. In all of these aspects of farming, the human capital of the farmer will influence his degree of success. Acquiring human capital, then, is an important step in increasing a farmer's productivity.

While the extensive agricultural economics literature acknowledges the importance of human capital in farming, there is little agreement as to how that human capital is acquired in practice, let alone what the most effective method of accumulating human capital is. Various studies identify a variety of channels through which a farmer might accumulate human capital. Among the most commonly discussed are agricultural extension services, private experimentation, social networks and formal schooling. These various channels need not be independent of each other. Additional formal schooling, for example, may make a farmer more likely to incorporate information from extension agents into his own farming practices.

Regardless of how it is acquired, an individual farmer's human capital is not a purely private input in farm production. If human capital is productive because it allows a farmer to choose better farming technologies, better performing seed varieties or more efficient allocations of his land, it also has value to other farmers who can observe both these decisions and their results. In this sense, by acquiring additional human capital, the farmer improves his own output as well as that of his neighbors or members of his social network. Agricultural production, particularly in the context of smaller single-family farms, is conducive to human capital spillovers.

This chapter introduces a new dataset to explore the effects of schooling and human capital spillovers in early twentieth century American agriculture. The early 1900s were a period in which public education was expanding at a rapid pace and a period which, while predating the dramatic biological advances in agriculture of the 1930s and 1940s, witnessed a wide range of important agricultural innovations. Public schools offered a channel to disseminate information on innovations from the growing agriculture programs at land-grant colleges, giving farmers a new way to accumulate productive human capital. We construct a dataset containing income, education and a variety of unique spatial data for a sample of Iowa farmers and use it to estimate significant income gains both from an increase in a farmer's own education and from increases in the educational attainment of his farmer neighbors.

These estimates of the private returns to education and human capital spillovers for farmers reveal that even prior to the major agricultural innovations of the mid-twentieth century, formal schooling played an important role in increasing farm productivity. The significant private and public returns to education suggest that there were tremendous social welfare gains created by the Midwest's aggressive introduction of public graded schools and high schools in the early twentieth century. These findings shed new light on the forces underlying early public school expansion in the United States and on the potential importance of public schooling in modern developing countries with large agricultural sectors.

2 Human Capital, Schooling and Agriculture

The role of human capital in agriculture has received considerable attention but there is little consensus about the magnitude of its importance. Any uncertainty regarding the importance of human capital accumulation to farmer productivity is amplified when looking specifically at the effects of human capital acquired through formal schooling. This can be seen in Figure 1 which shows the distribution of the estimated returns to schooling for farmers from 22 different studies conducted around the world.[1] These studies find a wide range of returns to education, both in magnitude and sign, making it clear that schooling cannot be assumed to be strictly productive in agriculture. Assessing how schooling affects farmer productivity both in modern times and historically requires understanding the complicated role of human capital in agriculture. This section outlines what is known about the returns to formal education and other forms of learning in agriculture and what questions about the relationship between human capital and agricultural

[1] For surveys of these and other studies estimating the return to schooling for farmers, see Jamison and Lau (1982), Huffman (2001) and Huffman and Orazem (2007).

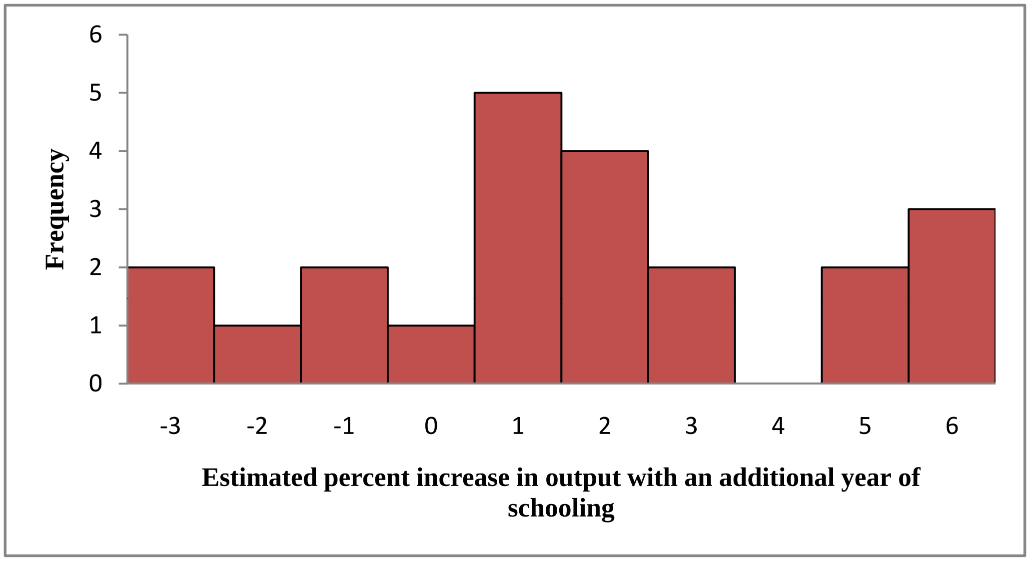


Figure 1: Estimated returns to education for farmers from 22 studies. Estimated returns are the percentage increase in output from one additional year of schooling, rounded to the nearest percent. Estimated returns are taken from Table 2-2 of Jamison and Lau's *Farmer Education and Farm Efficiency*.

productivity remain unresolved.[2]

It is not difficult to envision a role for human capital in farming. Farming is a complex task requiring decisions to be made over a variety of inputs and outputs and a wide and ever-changing set of technologies. Optimal decisions depend on knowledge of prices, local land characteristics, weather and current agricultural science. Successful farming requires not simply physical effort but also a remarkable amount of decision-making akin to that of any firm, only without the support of executives, analysts and consultants. Viewed in this light, it is clear that human capital is a crucial input in successful farming. What is far less obvious is what form that human capital takes and how it is best acquired.

Before considering the acquisition of human capital, it is instructive to be more specific about the types of human capital potentially relevant to farmer productivity. For our purposes, human

[2] In this study we are concerned with human capital as it relates to the knowledge and skills of a farmer that make him more productive. An additional aspect of human capital central to agricultural productivity is health, with a healthier farmer capable of providing more units of effective labor. This role of physiological capital is particularly important given the physical nature of farming. While the health of farmers is not the focus of this paper, it does have an interesting relationship with the sort of public school expansion discussed in the following sections. One feature of the curriculum in these schools was promoting modern views on health and hygiene. This is one more channel through which the introduction of public schools may have increased farm productivity in our period of interest and is worthy of future study.

capital's effects can be divided into two broadly defined aspects of productivity. The first is technical efficiency, the ability of the farm to maximize output given a particular set of inputs. The second is allocative efficiency, the ability of the farmer to properly distribute resources to maximize overall farm profits. These are two very different aspects of efficiency in agriculture and, as the existing literature shows, have very different relationships to the various ways of acquiring human capital.

Technical efficiency can be obtained in a variety of ways. The basic competencies developed through early schooling including literacy, numeracy and general cognitive skills all contribute to technical proficiency. The proper use of fertilizer, use and maintenance of machinery, and a variety of other aspects of agriculture all depend on these basic skills for success. However, while elementary levels of schooling create the invaluable literacy and numeracy needed by farmers, advanced schooling may not necessarily contribute to technical efficiency, particularly when considered relative to the foregone experience associated with additional years of schooling. The ability to use inputs efficiently is likely to be more strongly related to experience in working with those inputs rather than knowledge obtained from the classroom. It comes as no surprise then that studies of the returns to education in agriculture reveal that farmer's schooling has little effect on technical efficiency (Huffman, 1999). This should not be taken as an indication that human capital is not of central importance to technical efficiency but rather that the sort of human capital that contributes to technical efficiency is best acquired through channels other than formal schooling.

The role of schooling in allocative efficiency is much more complex and important. Allocative efficiency is relevant in any context in which there are changes in some dimension of agricultural production, including the relative prices of inputs or outputs, growing conditions, or the set of available technologies. A farmer's overall productivity and profitability will be dependent on his ability to adapt to new conditions through reallocating resources and adopting new practices. This adaptive ability is a function of a farmer's human capital stock. One component of this human capital is a stock of knowledge, information on prices, new technologies and so on. A second component is the ability to adapt, to properly apply new information and successfully experiment with new approaches to farming to improve productivity.[3]

[3]The role of human capital in helping a farmer adapt to a changing environment is raised in Schultz's work on

The first component is relatively straightforward. A farmer's stock of relevant information will grow through exposure to that information, exposure that can occur through a variety of obvious channels including extension agents, trade publications, social networks and formal schooling in which agricultural topics are taught. The role of schooling manifests itself in both direct and indirect ways. Schooling directly impacts the stock of knowledge through a farmer or future farmer learning about new topics in the classroom. Schools provide a setting in which the latest advances in agricultural science can be taught to students. If this were the only way in which formal education added to a farmer's human capital stock, we would expect the returns to education to diminish over his career as the information he was taught becomes outdated. However, schooling has an indirect and lasting impact through making a farmer more likely to seek out information. Several studies have found farmers with higher levels of education are both more receptive to new information and more likely to seek it out. Wozniak (1993) examined innovations in livestock feeding in Iowa and found that more educated farmers were more likely to contact extension agents for information about new technologies. Bindlish & Evensen (1997) find a similar result when looking at extension programs in Kenya and Burkina Faso. In both countries, more educated farmers were more likely to participate in extension services and seek out information from other farmers, leading to educated farmers learning about and adopting new technologies earlier than less educated farmers. Bindlish and Evenson find that the educated farmers had a greater appreciation for the value of information from extension services and higher expectations regarding the returns to that information. Additional formal education makes farmers more likely to continue building their stock of useful knowledge throughout their careers, learning about the latest agricultural advances even if they occur after schooling has been completed.

Production of the second component of human capital relevant to allocative efficiency, the ability to successfully experiment and adopt new information and technology, is far less straightforward. Certainly a portion of this adaptive ability is innate. However, there is evidence that adaptive ability can not only be learned, but learned through formal schooling. Abdulai and Huffman (2005) find that a farmer's likelihood of adopting hybrid cow technology in Tanzania

human capital and the ability to deal with disequilibria (1975). The changing agricultural technologies of the late nineteenth and early twentieth century are consistent with Schultz's notion of disequilibrium and the distinctions he draws between traditional agriculture and agriculture in a modernizing economy.

depended positively on his level of schooling. Lin (1991) finds similar results for the case of hybrid rice in China. Wozniak (1993) shows that higher education for a farmer significantly increased the probability of adopting new technologies.[4] The greater likelihood of adopting new technologies coupled with the greater likelihood of properly utilizing new information are important ways in which additional education translates into higher productivity of farmers.

The magnitude of productivity gains arising from this role of education and from the simpler role of information acquisition discussed earlier will be highly dependent on the level of change and innovation in the agricultural industry. In a period of rapid scientific advance or major fluctuations in prices of outputs, prices of inputs or growing conditions, adaptive ability becomes crucial to productivity and the returns to education for farmers will be at their highest. An example of this phenomenon can be found in the work of Foster & Rosenzweig (1996) in which returns to schooling rose with increases in the rate of technological advances during the Green Revolution in India. In cases where there is a great deal of uncertainty in either the benefits of the new technologies or in the optimal way to use them, the ability to experiment and adapt to technologies takes on added importance. Munshi (2004) studies technology adoption during India's Green Revolution and finds that experimentation by farmers on their own land was quite important for rice growers, where significant heterogeneity in growing conditions existed and unobserved characteristics were important, but less relevant for wheat production where useful information could be obtained through social networks, something that will be discussed in the next section. Formal education, to the extent that it improves the ability to acquire information and experiment, takes on additional importance not simply when technologies are changing but also when the benefits of those technologies depend on very local growing conditions or on farmer characteristics.

An additional component of adaptive ability beyond experimenting with and successfully adopting new technologies when they become available is adapting the set of technologies and inputs used when relative prices of inputs and outputs change, influencing profitability but not necessarily productivity as measured by yields. Even if a farmer is aware of current technologies

[4] The existing literature does not unanimously support this link between schooling and technology adoption. Pitt and Sumodiigrat (1991) study the choice of seed varieties in Indonesia and find that while education affects seed variety specific profit and input demand (aspects of technical efficiency), it does not significantly affect the choice of seed variety.

and methods and understands how to properly use them, his success still depends choosing the most profitable approach to his farm. The empirical literature reveals that this is yet another area influenced by a farmer's level of education. Huffman (1977) examines the responses of farmers in the U.S. Corn Belt to changes in the price of nitrogen fertilizer and finds that more educated farmers adjust fertilizer usage toward the optimal level more rapidly than less educated farmers when prices change. Petzel (1978) finds a similar result when the relative prices of outputs rather than inputs change. Farmers with more education adjusted their mix of crops more quickly to changes in the price of soybeans relative to corn and cotton than less educated farmers did. In these studies it is the rate of adjustment that is influenced by education, reinforcing the argument that the gains from formal education will be greatest for farmers in settings with a great deal of change, whether that change is in the form of new technologies being developed or simply change in market prices for inputs and outputs.

This discussion of human capital and farmer productivity leads to a mixed outlook on the value of schooling to farmers, consistent with the mixed estimates of the returns to education in agriculture captured in Figure 1. Elementary schooling is beneficial, creating the basic literacy, numeracy and cognitive skills required of any occupation. More advanced schooling, while having little impact on technical efficiency, has potentially large effects on a farmer's stock of useful information and on his adaptive ability. The magnitude of these effects will be largest in the presence of rapid innovation in agricultural science. While schooling beyond a basic minimum cannot be considered unconditionally productive in agriculture, it can be exceedingly productive in the proper environment.

3 The Transmission of Agricultural Knowledge

As the previous section outlined, a main source of the returns to human capital in agriculture is the acquisition and incorporation of current information into farming practices and the adoption of new technologies and techniques. The public nature of information and farming practices, due both to the public roots of agricultural research and the observability and easy replication of farming practices, creates important roles for human capital spillovers in agricultural production. The presence and magnitude of these spillovers will influence the social value of schooling in agricultural communities.

Human capital spillovers in agriculture have two important sources: the public nature of innovation and the transmission of information through social networks. The first source of spillovers, innovation, relates to the role of human capital in making individuals more likely to successfully experiment with new technologies. A farmer who experiments with new technologies or techniques and finds success contributes an important piece of information to collective local farming knowledge, potentially raising the productivity of other farmers in the community. To the extent that farming practices and results are highly observable to everyone in the local community, innovation on one farm produces non-excludable, non-rival knowledge for the community as a whole. The returns to schooling take on a public component when that schooling leads to greater levels of successful experimentation with new technologies on farms.[5] With higher educational attainment of any one individual farmer or higher numbers of educated farmers in a community, the stock of useful public agricultural knowledge will grow.

The second source of human capital spillovers relates to the diffusion of information as opposed to the creation of information discussed above. Social networks allow information to flow easily from one farmer to another. In this way, information received by an individual farmer either through own experimentation or from learning through education, publications or extension becomes public as that farmer passes information along to acquaintances through his social network or to neighbors through his publicly observable actions. The productivity gains resulting from a farmer accumulating human capital become shared through social networks, making the social returns to that human capital significantly higher than the farmer's private returns.

Several modern studies have found significant spillovers in agriculture. Foster and Rosenzweig (1995) find that in the case of new seed varieties in India, there were important learning spillovers, with farmers learning effectively from their neighbors who were experimenting with new seed varieties. Bandiera and Rasul (2006) find that the decision of farmers in Mozambique to adopt a new crop depend on the decisions of family and friends in their social network to adopt the

[5]The concept of successful experimentation is used quite broadly in this context. For an individual farmer experimenting with his own land, success may be easily defined as something that improves his productivity or profitability. This definition can be expanded when considering the social returns to individual experimentation. An experiment that is a failure for the experimenter still has positive value to the rest of the community by allowing other farmers to eliminate one unsuccessful experimentation path from their choice set without incurring any costs, increasing their probability of success should they decide to engage in their own experimentation.

new crops. The pineapple industry in Ghana provides another example of this, with farmers learning about successful fertilizer usage from the results of experimentation with fertilizer by other members of their social network (Conley & Udry, 2001). An older study, and one closer to the farmers that are the subject of this study, is a classic sociological study of innovation diffusion by Ryan & Gross (1943). Ryan and Gross surveyed Iowa farmers in 1941 to understand the diffusion of hybrid seed corn. While the most common way for farmers to initially learn of hybrid seed corn was through salesman, farmers cited the most influential source of information as being neighbors (14.6 percent of farmers first heard of hybrid seed from neighbors yet 45.5 percent claimed that neighbors were the most influential information source when choosing to adopt hybrid seed). As Ryan and Gross note, early adopters of hybrid seed corn "provided a community laboratory from which neighbors could gain some vicarious experience with the new seed."

Collectively, these studies demonstrate that learning from others is important in agriculture in the presence of technological innovation. That learning can occur through social networks of friends and families or simply from informal observation of neighbors. However the information is transmitted, the implication is that human capital spillovers exist and that there are positive externalities resulting from a farmer's human capital accumulation.

The importance of these spillovers will depend on the rate of technological change in agriculture, the nature of that technological change and the presence of others channels of disseminating information. In the studies of Foster and Rosenzweig, Conley and Udry and Bandiera and Rasul, new technologies were introduced that required experimentation to adopt profitably. In these cases, own experience accumulated over years of farming did not help with adapting to the new technology but the results of neighbors' experiments were tremendously useful. Spillovers become important because new knowledge is available and requires a certain degree of learning to implement properly. In a state of little innovation, these spillovers decline in importance. They will also decline if there is a channel other than social networks for new knowledge to efficiently spread, for instance a well developed and trusted agricultural extension service. In the case of little to no innovation, the importance of human capital both to the individual and to the community is relatively low. In the case where innovation occurs but can be efficiently transmitted through institutions like extension services, the spillovers from human capital accumulation are reduced but the private returns can still be quite high if additional human capital helps the farmer acquire and implement the new knowledge.

4 Agricultural Innovation at the Turn of the Century

While there is a growing consensus that human capital is critical to productive farming and a small body of evidence suggesting that schooling can be an effective way to accumulate that human capital in modern agriculture with its steady rate of innovation, the role of human capital and schooling historically in agriculture has received little attention.[6] Part of this lack of study has been the absence of reliable data in which farmers' education and productivity are jointly observed. A much more severe barrier has been the widely held and seldom debated belief that education had little bearing on a farmer's productivity prior to the modernization of farming ushered in with the biological innovations of the mid-twentieth century. The consensus view has been that education gained importance with the rise of industry and that while schooling is important to modern farms employing modern technology and engaging in a global economy, farming at the beginning of twentieth century was not an endeavor aided by formal education.

In this section we seek to dispel this view by examining the details of agricultural innovation in the late nineteenth and early twentieth centuries in the American Midwest. A thorough examination of agricultural technology and the details of the emerging public school system reveal that there was much to be gained by individual farmers and the community as whole through formal schooling and that in their formative years, public schools were quite important in the agricultural sector not simply for the invention of new technology as the growth literature emphasizes, but also for the productivity of individual farms. Understanding that the role of education in farming was important prior to the revolutionary agricultural advances of the mid-twentieth century recasts the expansion of public education as a major contributor to economic growth through its effects on farmers at the individual level. A rough appreciation of the sizable correlation between public schools and local productivity can be gained from Figure 2, showing average earnings for Iowa farmers at the turn of the century as a function of distance to the

[6] We refer here specifically to the human capital related to skills and the ability to successfully adapt to advances in agricultural science. For a studies of the health component of human capital and its relationship to agricultural productivity, see Schultz (2001), Deolaliker (1988), Strauss (1986) and Haddad & Bouis (1991).

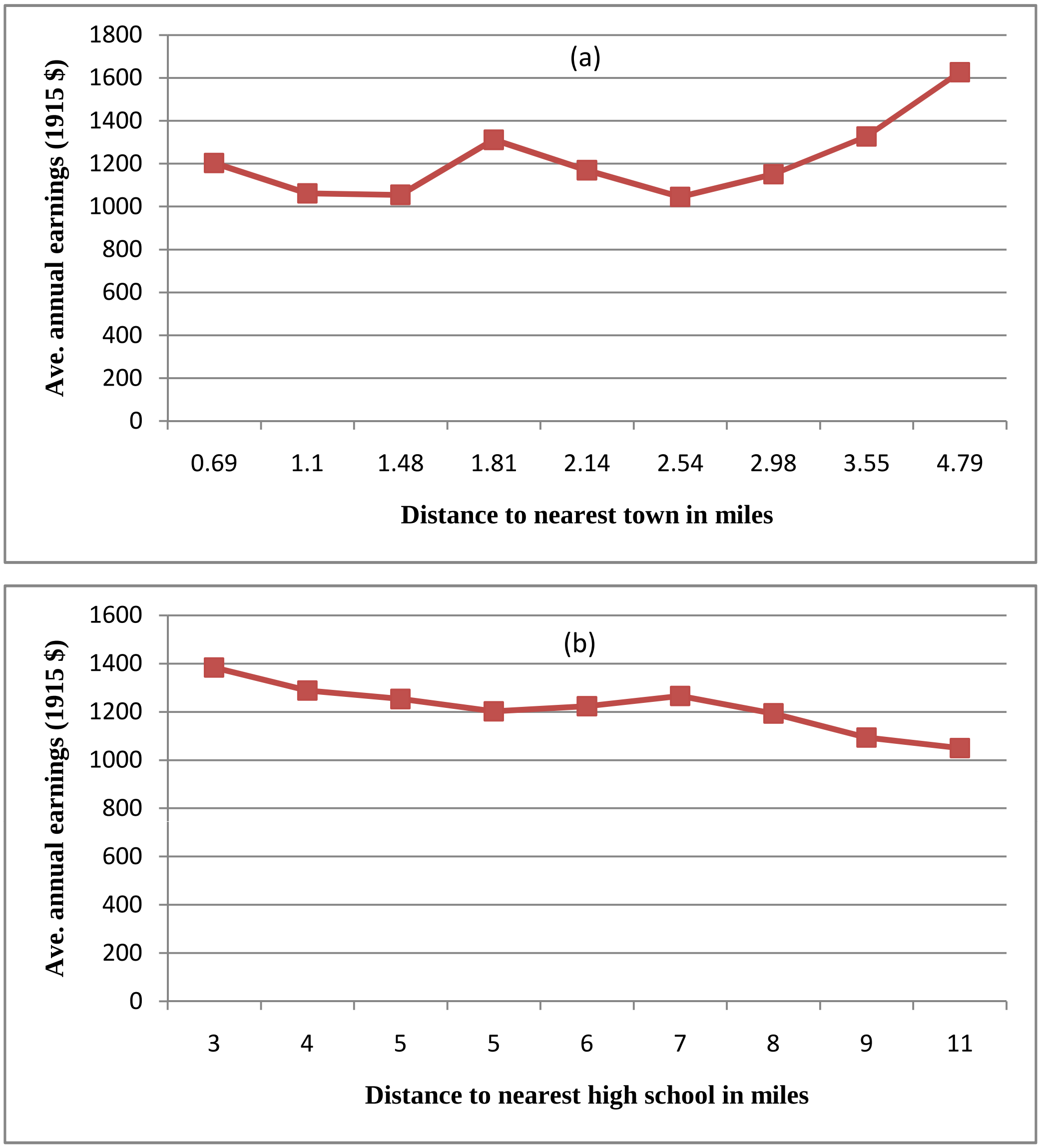


Figure 2: Average annual earnings for farmers by distance to nearest town (panel a) and distance to nearest high school (panel b). Data are for Iowa farmers living in Chickasaw, Poweshiek and Ringgold counties in 1915. Each point represents the mean earnings of single distance decile.

nearest town and distance to the nearest high school. Figure 2 reveals no discernible relationship between a farmer's earnings and how far he lives from a town but a large, negative relationship between earnings and the distance to the nearest high school, with average earnings dropping off by 25 percent as the distance to the nearest high school increased from three to eleven miles. The combination of higher individual educational attainment and higher human capital spillovers resulting from farming near a public high school, factors that will be discussed at length in the remainder of this paper, led to tremendous gains in agricultural productivity at the turn of the century.[7]

The stylized facts about schooling and farmer productivity reviewed in the previous section provide a foundation for understanding which features of the agricultural sector at the turn of the century may have influenced the returns to education. The modern studies surveyed reveal that the returns to formal schooling are at their highest when there is significant innovation and that agricultural advances often require some experimentation to implement effectively. Furthermore, spillovers from formal schooling can exist under these conditions, particularly when alternative channels for disseminating new knowledge are not present. A close examination of agricultural technology in the late nineteenth and early twentieth centuries reveals that these conditions were clearly present and that the potential for formal schooling to offer significant private returns to farmers as well as to create substantial spillovers existed.

Discussion of agricultural innovation prior to the 1930's is often focused on the introduction of new forms of mechanical technology. Mechanization of tedious and strenuous farming tasks led to greater worker productivity but did so in a way that required little additional human capital. The operation of these mechanical devices was not terribly complicated and there were few decisions to be made about how to profitably deploy new mechanical technology. Consequently, while these innovations were important to farm productivity, the productivity gains were not highly dependent on a farmer's human capital stock or level of formal schooling. The traditional view is that these mechanical innovations were responsible for nearly all of the productivity gains in farming prior to 1940. In his study of the development of American agriculture, Cochrane (1993)

[7] Figure 2 in no way demonstrates a causal relationship between the presence of local schools and farmer earnings. While we are interested in whether public schools helped farmers increase earnings, it is certainly possible that wealthy farmers tended to locate near schools or push for their creation. The estimates of the returns to education in the following sections will control for local community fixed effects. The positive effect of education on earnings persists even once local community characteristics are controlled for.

claims that mechanization was "almost the exclusive...form of farm technological advance".[8] He goes farther, claiming that much of the innovation, such as the introduction of the mechanical reaper and thresher, occurred early in the nineteenth century. The latter half of the nineteenth century was a time of refinement and improvement of existing machines but "not a period of innovation".[9] This traditional view, epitomized by Cochrane's observations, has fostered a belief that human capital was not important in agricultural until the biological advances of the 1930s and 1940s.

Only in recent years has this view begun to be challenged. Olmstead & Rhode (1993) demonstrated that settlement patterns and biological advances were important contributors to changes in agricultural productivity well before the 1930s. In their work on American wheat production, they have shown that there was a steady stream of biological advances in the early twentieth century that improved crop yields (Olmstead & Rhode, 2002). They calculate that roughly one half of the labor productivity growth between 1839 and 1909 previously attributed to mechanization was actually due to biological innovations. The specific advances Olmstead and Rhode point to include the introduction of new wheat varieties and an emphasis on farm-level experimentation with various crops and techniques to improve yields and more effectively combat pathogens and insects. Their work raises the possibility that biological advances requiring the sort of experimentation and learning aided by education were as important as mechanization in improving agricultural productivity at the turn of the century. In what follows, we use the specific experience of Iowa to examine how the forces discussed by Olmstead and Rhode as a well as a variety of other innovations were changing the nature of production on farms and the role of schooling for farmers.

The challenges facing Iowa farmers at the end of the nineteenth century were similar to those that other farmers in the emerging agricultural regions of the Midwest and later the West would experience.[10] Farms in Iowa had been settled for a relatively short period of time, with much learning about how to effectively farm the land still taking place. Farmers were faced with the task of experimenting with new technologies and techniques including methods of planting,

[8] Cochrane, p. 200
[9] Cochrane, p. 196
[10] For a much more thorough account of the early history of Iowa farming, see the history published by the staff of the Iowa State College, *A Century of Farming in Iowa, 1846-1948*, from which much of the information in this section is drawn.

drainage systems and new seed varieties to turn Iowa into the highly productive agricultural state it is known as today. These technologies and techniques were neither foolproof nor equally suited to all locations. Human capital played a pivotal role in translating innovation into improved productivity.

One of the first tasks facing farmers of newly settled land in Iowa was exposing the rich soil. Early farming took place on soil that was already well drained by topography allowing the farmer to simply break the sod and begin growing crops. The heavier, more fertile soil required drainage systems to be constructed. Installation of drainage systems began in the late 1800s and continued through the early 1900s. Properly constructing drainage systems was not a trivial task to be carried out by unskilled labor. It took time to determine the best designs for Iowa, with farmers experimenting with European methods and then flat tile systems before ultimately settling on round tile drains. Even once the best type of drainage system was revealed, room for error persisted. Drainage patterns could be poorly designed and a properly designed drainage system could fail given improper maintenance. Learning to properly implement tile drainage systems transformed thousands of acres of wet lands in Iowa into highly productive land.

Properly drained soil does not guarantee that the soil remains fertile. As farmers began to heavily cultivate the Iowa soil, the soil began to lose its fertility. The turn of the century saw several advances in ways to efficiently return essential elements to the soil. One example is lime, needed to reduce the acidity of soil allowing legumes to efficiently fix the nitrogen necessary for fertile soil. At the turn of the century, scientists began testing soils for acidity as a way of identifying lime deficiency. Publications were produced to inform farmers about the need for liming, a subject that was also stressed by agricultural teachers in high schools. Lime is just one example of the improvements in soil science at the turn of the century that had the potential to dramatically improve yields if incorporated properly into farming. Knowledge of how to properly maintain nitrogen, calcium, potassium and phosphorous levels in their soil was crucial to farmers' productivity. The task of passing advances in soil science on to farmers fell primarily to government agencies producing informational publications and to instructors in the growing public school system.

Fertile soil still required proper crop selection to maximize farm productivity. Consistent with Olmstead and Rhode's accounts of the importance of experimentation with wheat varieties to increase yields and combat destructive pests, selection of crops was a central element of agricultural productivity gains in Iowa at the turn of the century. Around 1900 Iowa farmers transitioned from spring wheat to winter wheat as the hardier varieties of winter wheat discussed by Olmstead and Rhode were introduced. Growers of corn engaged in extensive experimentation with varieties. Between 1890 and 1920, experiment stations throughout the farming regions of the United States engaged in extensive corn breeding. Varietal hybridization was first introduced in Michigan in 1880. Ear-to-row breeding was introduced in Illinois in 1896, providing individual farmers and experiment stations with a systematic method to experiment with different corn varieties.[11] P. G. Holden, the first professor of agronomy in the United States, began gathering data on the performance of different corn seed and disseminated his results through teaching courses and his "Seed Corn Gospel Train." Experiments in crossbreeding corn began in the early 1900s. All of these various practices led to major advances in knowledge of corn varieties and improvements in corn yields well before the broad introduction of hybrid corn in the 1930s.

Beyond better selection of crops through experimentation, yields were also improved at the turn of the century through new knowledge of how to fight pests, weeds and disease. At the end of the nineteenth century, Iowa farmers realized that spring wheat planted next to barberry bushes was more susceptible to black stem rust and that oats planted near buckthorn would get crown rust, leading to campaigns to eradicate these bushes. The late 1800's saw the development of chemicals to treat wheat seed to prevent bunt, a fungal disease. A seed law was passed in 1907 requiring that seed offered for sale be labeled with a listing of weeds. Other information on weeds was disseminated through the publication of weed guides for use by agricultural teachers and farmers. Overall, the stock of knowledge of the hindrances to healthy crops and ways to combat them was growing steadily at the turn of the century.

It is clear that much innovation was taking place in Iowa agriculture at the turn of the century beyond simply the mechanization of farming. Advances in drainage techniques, crop selection, soil science and knowledge of pests and disease all had the potential to dramatically increase farm yields but, unlike mechanization, were heavily dependent on the human capital of farmers to implement effectively. For all of these advances, the ability for new information to

[11] Ear-to-row breeding was a technique of choosing a selection of ears and planting them one ear to a row. Detailed records of performance were kept and used to choose the best corn to grow on the basis of both appearance and progeny performance. It essentially provided farmers with a systematic approach to crop experimentation.

find its way to farmers and be successfully integrated into farming practices was crucial. The emerging public school system and extension services were particularly well suited to these tasks. The early history of Iowa agriculture saw the development of agricultural science at Iowa State College and the introduction of high schools and extension services capable of disseminating this knowledge. An examination of the history of these institutions reveals a close relationship between the sources of agricultural innovation and the formal education of farmers.

Systematic agricultural research in Iowa traces back to the foundation of the Iowa Agricultural College and Model Farm in 1858, which would become a land-grant institution in 1864 through the Morrill Act. As a land-grant institution, the college pursued the goals of accessible higher education in practical subjects and applied research. Both of these functions of the college were critical to the creation and implementation of agricultural innovations.

As a center for applied research, the college was engaging in cutting edge experimentation in all aspects of agriculture. Much of the advances in soil science and the development of better varieties of crops would come from the research done at the college and through the Agricultural and Home Economics Experiment Station established in 1888 with the passage of the Hatch Act. The scientific advances occurring at the college were passed on to farmers in two ways. The first was through directly educating the farmers, either through attendance at the college itself or its short courses and demonstrations. The second was through students and graduates of the college teaching other farmers. In biographies of alumni who graduated from the college between 1872 and 1899, nearly ten percent listed occupations of either teacher or educator (Tiernan, 1939, 1952). It was not uncommon to have "teacher and farmer" given as a graduate's occupation. The teachers educating young farmers across the state were themselves educated at the agricultural college, exposed to the latest in agricultural innovation and capable of passing it on to their students. Beyond graduates choosing teaching as a career, enrolled students at the agricultural college often taught at public schools in their time between terms as a source of income while in college (Ross, 1942). The agricultural college had clear ties to the public school system. Knowledge of the agricultural innovations being researched was passed on to farmers through schooling both at the college itself and at public schools throughout the state with college educated teachers.

This role of schooling as a channel through which agricultural innovations could be disseminated was particularly important at the turn of the century given the timing of school expansion in the state. Extensive agricultural research was being undertaken by the last decades of the nineteenth century with the creation of land-grant colleges with the Morrill Act and Hatch Act. However, it would not be until 1914 that the Smith-Lever Act would establish the Cooperative Extension Network and agricultural extension programs would fully mature. Iowa's public school system was already going through rapid expansion two decades prior to this. As common schools improved through consolidation and grammar schools and high schools were introduced, the public education system became a critical and effective means of passing knowledge and skills on to farmers. This role of the schools as a means of diffusing agricultural information was not simply a result of the educators themselves often being trained at the agricultural college but also the curriculum at every level being explicitly tailored to developing better farmers.

There is a wealth of historical sources demonstrating the desire of administrators and legislators to teach skills for agriculture in the public schools. How to better design the curriculum of rural schools to promote farming as a career and improve the productivity of farmers was a matter a much debate at the turn of the century. Rural schools were being designed with a focus on developing critical skills through more practical demonstrations and experiments rather than memorization and recitation of facts. There are a wide variety of ways in which schools tried to develop interest in farming and experimentation. In 1913, Iowa passed legislation providing state funding for consolidated schools to improve the quality of rural schools. This funding was conditional on consolidated schools maintaining an agricultural experiment plot. As L.H. Bailey (1904), a leader in the development of agricultural education, noted, the purpose of these sorts of programs at common schools was not simply to "teach technical agriculture, but to inculcate the habit of observing." Rural schools often promoted the the efforts of local boys' clubs to have school-aged boys experiment with different seeds and approaches to growing crops, share their results and compete in yield contests (Davis, 1912). Survey responses regarding successful curricula in rural schools included references to "experimental plots for plant breeding, soil inoculation, and other soil experiments; ear-to-row method of improving corn, and use of acre plots; [and] seed germinating including tests of viability."[12] There was a strong sense that a key component of rural education was to develop critical skills of observation and experimentation, skills that

[12] Davis p. 118

would help future farmers adapt to changing technologies and new agricultural information.

This emphasis on experimentation in no way implied that the more formal teaching of agriculture in the classroom was ignored. Particularly at the high school level, agricultural science and business topics relevant to managing a farm were common components of the curriculum. The curriculum for an agricultural secondary school in Minnesota included courses in agricultural botany, field agriculture, farm accounts, study of breeds, agricultural physics, dairy chemistry and dairy husbrandry in the first three terms of study alone (The University of Minnesota, 1902). Nearly forty different agriculture textbooks were produced for use in elementary and secondary schools in just the first decade of the twentieth century (Davis, 1912). In addition to these texts, pamphlets and extension bulletins containing the most recent advances in agricultural science and the teaching of agriculture were often distributed by agricultural universities and extension programs to teachers to help them incorporate recent developments into their teaching.

Schools in the Midwest were providing students with current agricultural knowledge while also instilling in them the value of critical reasoning and experimentation. From the teaching of the value of observation and experimentation in the early years of common school to the teaching of current agricultural science and management in the high schools, schools were helping individuals build human capital that would be productive in agriculture. While the value of the specific agricultural science students were learning may have diminished over time as science progressed, schools were still offering a strong base of agricultural knowledge and skills that would help the farmer adapt to innovations occurring even after his school years were well behind him.

Overall, the agricultural sector experienced substantial innovation at the turn of the century. Advances were made in seed selection, drainage techniques, disease and pest prevention and soil science all prior to the major biological advances in the mid-twentieth century. The long list of innovations created a major role for human capital, with productivity gains possible through the accumulation of new information and experimentation with new techniques. The public school system in Iowa was well positioned and in fact deliberately designed to provide that human capital. It functioned as a link between farmers throughout the state and the agricultural research taking place at land-grant colleges and experiment farms, offering a channel for the latest scientific advances to find their way to the farm. The school system also sought to improve the ability of farmers to critically think about agricultural problems and to experiment. In this respect, schools gave farmers not only the latest agricultural information but also the tools to continually take advantage of agricultural innovations.

These potential productivity gains were not necessarily limited to those farmers who attended school. The knowledge and techniques schools taught farmers were, once implemented, easily observed and replicated by neighbors. Seed choice, fertilizer usage and a variety of other decisions made by an educated farmer could be copied by his neighbors. Beyond the spillovers resulting from mimicry, the educated farmers' actions themselves could benefit his neighbors. If an educated farmer learns how to prevent the spread of pests or disease among his crops, his neighbors' crops also become less vulnerable, even with no action on the neighbors' part.[13] Whether by mimicry or more passive means, neighbors could benefit greatly from an educated farmer.

Given the variety of agricultural innovations occurring and curricula designed to promote better farming practices, the emerging public school system in Iowa was well situated to generate both substantial private returns and also significant spillovers in agricultural communities. In the following sections, we will test for both the private returns to and spillovers resulting from the formal education of farmers.

5 Constructing a Spatial Dataset

Estimating the private and public returns to education at the turn of the century is difficult due to the scarcity of historical data on the incomes and educations of farmers. Income was not asked in the federal population census, the most easily accessible source of individual level data at the turn of the century. Proxies for income or farm productivity could be obtained from the federal agricultural census schedules which contained detailed information on farm size, land value, expenditures and output. Unfortunately, the records from the turn of the century have been destroyed, the 1890 schedules destroyed by fire and the 1900 and 1910 schedules by Congressional order. What remains of the agricultural censuses is data aggregated at the county level which does

[13]This also raises the issue of negative spillovers resulting from less educated neighbors. Even if an educated farmer takes measures to eradicate a certain pest, if his less educated neighbor does not take a similar course of action, the educated farmer's crops may still be at risk. Consider the example mentioned earlier of crown rust. Oats planted near buckthorn bushes were more likely to get crown rust, leading to campaigns to remove buckthorn bushes. While an educated farmer may be responsive to these campaigns and remove any buckthorn on his land, if his neighbor does not follow suit everyone's oats remain at risk of getting crown rust.

not allow for separately identifying the private returns to education and spillovers. Educational attainment data is even harder to come by, with the federal census not asking about educational attainment until 1940. As a result, the only proxies for educational attainment traditionally available have been literacy, numeracy and other similarly coarse measures of education. We require a more detailed measure of education.

A solution is to turn to the unprecedented data collected by the state of Iowa. With its 1915 state census, Iowa gathered data on both the annual earnings and the educational attainment of all residents. This census is a unique occurrence of jointly reported income and education data in the United States prior to 1940.[14] The census asked individuals for their annual earnings, farm value, educational attainment by type of school (common, grammar, high school, college) and occupation. These data, coupled with the demographic variables reported in the census (age, birthplace, years in Iowa, years in the United States, religion, parents' birthplaces), provide the information necessary to estimate the returns to education for farmers.

Because we are in part interested in spillovers resulting from farmer education, additional spatial data is required beyond what is available in the 1915 census. Location is provided in the 1915 census through the reporting of the town of residence.[15] By itself, this information will not allow us to disentangle human capital spillovers from other location specific factors such as local land fertility or weather patterns. To properly examine spillovers, finer detail on farm location is needed. For this we turn to historical plat maps showing land ownership. From these maps, we can identify the boundaries of farms and determine the neighbors of any given farmer. As we will discuss in more detail later, these plat maps can provide much more information than simply which farmers are neighbors. Through the use of Geographical Information System (GIS) software, they allow for calculation of farm acreage, distances to town centers and schools, and identification of farmers managing multiple plots of land. The drawback of using plat maps to

[14]While the 1915 census is the only chance to observe both income and educational attainment, it is not the only chance to observe educational attainment by itself. Educational attainment questions in the 1915 Iowa census were included in the 1925 census as well, although the annual earnings question was dropped. South Dakota, perhaps influenced by their neighbor to the southeast, also included educational attainment questions in the state census.

[15]In many censuses, additional locational information can be inferred from the ordering of census records, as the census enumerator would systematically work his way through the community. Neighbors would therefore appear next to each other in the census schedules. Rather than lists of people, with multiple individuals on each page, the 1915 Iowa census manuscripts are in the form of individual index cards, one per person, stored alphabetically by county.While the cards are numbered, a mapping of these numbers reveals that they were not numbered by location or path of the enumerator. Consequently, nothing can be inferred about the location of individuals beyond which town they live in.

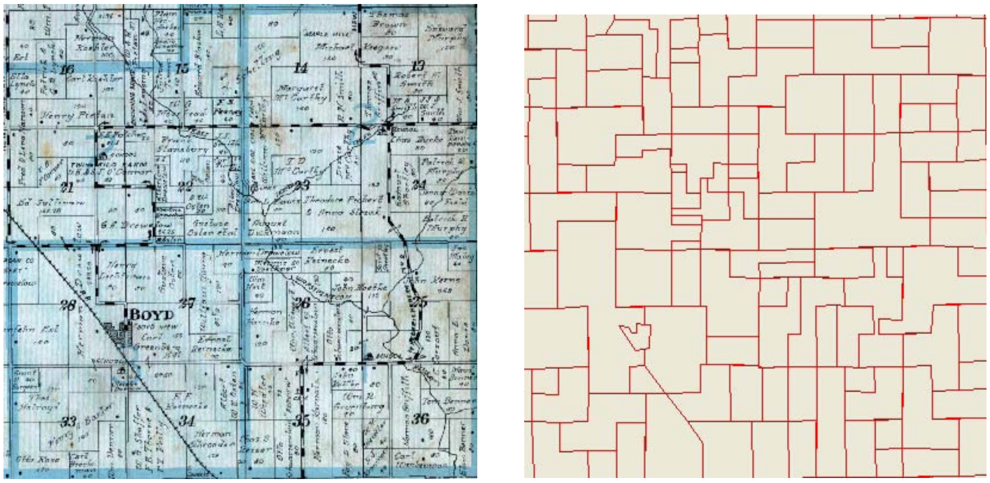
incorporate spatial data is that it restricts us to land owning farmers, eliminating farm laborers, tenants, and managers from our analysis unless they are listed as the owners of the farm.

The process of creating our dataset begins with county plat maps. To create a reasonably large sample of farmers, we focus on complete samples of farmers from three different counties. The counties of Chickasaw, Poweshiek and Ringgold were chosen on the basis of being located in three distinct agricultural regions of Iowa and having well preserved, complete plat maps published within one year of the 1915 Iowa census.[16] In the first stage of dataset construction, digital images of the township plat maps are georeferenced to a digital map file of township boundaries for the county.[17] Through this process, we stitch the individual township plat maps together and create a spatial reference for the data. This allows for automating computations of distances and spatial relationships. By combining the township maps and focusing on the county level, the resulting map file can consider relationships across township borders (this is particularly useful for examining neighbors across township lines and identifying cases where the closest town or other feature of interest is not in a person's own township, something not possible with census data alone).

Once the township plat maps are stitched together and georeferenced, farm boundaries are digitized by tracing them on a computer screen and storing the resulting polygons as a GIS shapefile. Figure 3 provides a detail of the plat map for New Hampton township and the farm boundary polygons created from the plat map. This detail represents approximately .5 percent of the total land area digitized for this project. Finally, the farmer names on the plat maps are transcribed and associated with their respective polygons. The results of this process are three separate GIS datasets, one for each county, containing digitized maps of farm boundaries with a known spatial coordinate system and corresponding tables giving a unique identifier for each farm and the farm owner's name. Added to this data on farm locations are the locations of towns (also identified from the plat maps and represented as polygons). The data stored for the town polygons includes whether the town had graded schools, whether the town had high schools, and the number of graded classrooms in the town's schools. These data are taken from the reports

[16]A map of Iowa showing these counties and the agricultural regions is provided in Figure 7. Agricultural statistics for the counties are given in Table 10 and demonstrate that the chosen counties are fairly representative of the state's agricultural sector.

[17]To georeference the plat maps, we match the one mile by one mile grid shown on the plat maps to the same grid on Public Land Survey System township shapefiles.



(a) (b)

Figure 3: Detail of New Hampton Township, Chickasaw County plat map (a) and the farm polygons created from the plat map (b) to be used for spatial analysis. Neighbors are defined as polygons that share at least one common side or vertex.

of the county superintendents of schools.[18]

Linking these geographical data to the 1915 census data begins by matching the farmer names from the plat maps to lists of adults in the 1915 state census. Given that the only information available from the plat maps is name and the township the farm is in, matching is done on only these two criteria. While we only have these two variables to match on, concerns of mismatches are minimal; knowing township location substantially narrows the set of people to consider making it straightforward to assess the quality of a match. This is distinct from the matching process used to construct intergenerational samples from censuses which requires matching across time and therefore has to allow for changes in location across the entire country, substantially increasing the difficulty of accurate matching.[19] The lists of township residents from the state census come from electronic records of the census in which name, location and age are

[18]Details on these county superintendents of schools records can be found in chapter 1. We include information transcribed from the 1900 school records for use in the mobility studies and well as information transcribed from the 1915 school records specifically for this chapter. Using both sets of records allows for observation of not only where schools were in 1915 but also if those schools were relatively new.

[19]While the accuracy of matches is easier to assess in this case and the set of people to search is much smaller, the actual rate of successful matching is still under 50 percent. The reason stems from the inability to use additional information to determine when people with differently spelled but similar names are actually the same person or which person is the correct match when multiple people have the same name. This is particularly problematic in the matching between plat maps and census records because the plat maps often contain only an initial for the first name, making it hard to narrow the set of potential matches.

all transcribed. Once a match is found, an image of the original census record is downloaded to transcribe information on occupation, earnings, education, religion, years in Iowa, years in the United States, incumberance on farm, and farm value.

Once all of the matching is completed and the information from the 1915 census fully transcribed, the census data is merged into the GIS databases, adding individual farmer characteristics to the farm boundary maps. The final stage in preparing the dataset for analysis involves using GIS software to perform a series of spatial calculations and append the results to the farmer data. These calculations include calculating farm acreage (which allows for converting variables such as farm value into per acre terms), identifying and calculating the distance to the nearest town, graded school and high school and identifying neighbors and neighbor characteristics. To calculate neighbor characteristics, we use an algorithm that identifies all polygons that share a vertex or line segment with the polygon representing the farm of interest. The resulting set of polygons is defined as the set of neighbors of the farm and statistics on the characteristics of these neighbors are computed and written to the record for the farm. These statistics include the number, mean age, mean and maximum education by type, mean and maximum farm value (and value per acre) and the mean and maximum income (and income per acre) of neighboring farmers.

The final product is a sample of roughly 2,600 land owners with a wide range of farm sizes, incomes and educational attainments. Summary statistics for the main variables of interest are included in Table 1. As a result of being limited to property owners, the average age of the sample is relatively high at 47 years old. Mean annual earnings are also high but the variation is large. The mean farm size is close to the traditional 160 acre family farm although the largest land owners in the sample have farms that are several hundred acres in size. Even controlling for size, the reported value of farms varies extensively throughout the sample as shown by the large variation in farm value per acre. The distances to towns and schools are of interest given the role of social networks in disseminating productivity enhancing information discussed in the previous sections. Farmers live on average over two miles from the nearest town, a small distance by modern standards but sufficiently far that daily interaction in the town would likely not be occurring. Schools are even farther away, with the average distance to the nearest high school of over six miles implying that for most farmers, the nearest high school was at least one township

Table 1: Summary statistics for the sample of farm owners, 1915

Variable	Mean	Standard Deviation
Age	46.70	11.68
Annual earnings	1199.62	1175.47
Farm value	17439.32	13079.76
Incumbrance on farm	3357.70	5399.68
Farm acreage	153.03	106.92
Earnings per acre	9.80	10.77
Farm value per acre	126.08	90.98
Incumbrance to farm value ratio	0.20	0.25
Distance to nearest town (miles)	2.25	1.52
Distance to nearest graded school (miles)	3.16	2.06
Distance to nearest high school (miles)	6.51	3.28
Foreign born (yes=1)	0.14	0.35
Mean total schooling for neighbors	8.51	1.92
Max total schooling for neighbors	10.23	2.76
Mean graded schooling for neighbors	0.58	1.33
Max graded schooling for neighbors	1.63	3.09
Mean high school/college for neighbors	0.30	0.68
Max high school/college for neighbors	0.87	1.71
Number of neighbors	7.84	3.26

Notes: All dollar values are in 1915 dollars. Total schooling is defined as the sum of years of common school, grammar school, high school and college.

Table 2: Correlations between land owner and neighbor characteristics

Owner characteristic, neighbor characteristic	Correlation
Total schooling, mean total schooling	0.1656
Total schooling, max total schooling	0.1777
Graded schooling, mean graded schooling	0.1494
Graded schooling, max graded schooling	0.156
Annual earnings, mean annual earnings	0.2274
Annual earnings, max annual earnings	0.1898
Farm value, mean farm value	0.2309
Farm value, max farm value	0.2489
Age, mean age	0.0409

away. These distances suggest that information may have more easily and frequently been shared between adjacent neighbors than through population and schooling centers.

Many of these variables are spatially correlated. Table 2 gives the correlations for various characteristics between farmers and their adjacent neighbors. Along every dimension except age, neighbors exhibit similar characteristics. Highly educated farmers tend to live next to other well educated farmers. Similarly, high earning, wealthy farmers tend to have well off neighbors.

Of particular interest to our study is the heterogeneity in educational attainment in the sample. This heterogeneity includes differences in years of schooling, type of schooling and where schooling was received. This last source of variation in education is particularly interesting in terms of the returns to education. If Iowa schools were teaching skills specific to Iowa agriculture, the returns to schooling received in Iowa would potentially be higher than the returns to schooling received outside of Iowa. However, if schooling provided more general human capital, skills like literacy, numeracy and general principles of scientific experimentation, a farmer's education could be equally productive regardless of where it was received. Table 3 summarizes the various measures of educational attainment, including attainment by school type and by whether schooling took place in Iowa, outside of Iowa but in the United States, or outside of the United States.[20] While the average years of schooling of the farm owners is over eight years,

[20] We determine where education was received from the reported years of education, years in Iowa and years in the United States data. We assume that individuals start school at age five and that schooling was completed with no gaps and that all years of common school were completed before the years of grammar school and then high school and then college. The assumption that schooling begins at age five is made on the basis of the county superintendents of schools records from this period listing the number of school aged children as those children between the ages and five and twenty-one.

Table 3: Years of schooling by schooling type and location

Variable	Mean	Standard Deviation
Total schooling	8.43	2.65
Common school	7.91	2.65
Grammar school	0.23	1.26
High school	0.19	0.72
College	0.10	0.54
Total schooling in Iowa	5.77	4.46
Total schooling in US	6.30	4.31
Total schooling outside US	2.13	3.51
Total schooling outside Iowa	2.66	3.80
Total schooling outside Iowa in US	0.54	2.02
Graded schooling	0.52	1.80
Graded schooling in Iowa	0.41	1.53
Graded schooling in US	0.44	1.63
Graded schooling outside US	0.08	0.72
Graded schooling outside Iowa	0.11	0.91
Graded schooling outside Iowa in US	0.03	0.54

Notes: Total schooling includes years of common school, grammar school, high school and college. Graded schooling includes years of grammar school, high school and college only.

graded schooling is relatively rare. The majority of schooling was completed in Iowa and for those farmers who did receive graded education, nearly all of it was completed within the state. This comes as no surprise given that in 1915 Iowa's high school system was well ahead of most of the rest of the country; a common school education was easy to obtain anywhere in the United States but a high school education was much harder to come by.

6 Private Returns to Education for Farmers

The sample of farm owners offers data on earnings, land value, and educational attainment with which we can estimate the returns to schooling. Information on religion, immigration and farm location offer a variety of controls for important unobservables that could influence earnings. With these data, we can estimate a standard Mincer of the form

$$\ln Y_i = \beta_0 + \beta_1 p(A_i) + \beta_2 E_i + \alpha X_i + \epsilon_i \tag{1}$$

where Y_i is the annual income of farmer i, $p(A_i)$ is a polynomial in his age, E_i is a measure of his education and X_i is a vector of other observable characteristics. Throughout this section, we include controls for religion, the township in which the farm is located, whether an individual is foreign born, years in the United States if foreign born and the quality of local farm land, proxied by land value per acre. These controls are included to ensure that E_i is not picking up the effect of farming in a more productive area or living in a more wealthy area in general.

As any cursory look at the labor literature would point out, the estimation of this relationship and interpretation of the returns to education β_2 are plagued with problems, most significantly the endogeneity of the education variable. Estimating the returns to education with our sample requires consideration of these standard estimation issues as well as some unique problems presented by our data and the details of farming and education at the turn of the century.

A fundamental concern, regardless of the equation to be estimated, is sample selection bias. Our set of farmers is far from a random sample of the Iowa population or even a random sample of Iowa farmers. The largest concern is that they are all farm owners. This distinguishes them from the rest of the population and most importantly from the rest of the population employed in the agricultural sector in a significant way. The fact that these are property owners implies that our farmers have a source of wealth not held by other farmers in the state. Education could play an important role in the probability of land ownership and it is quite possible that the type of person who becomes a land owner differs in important unobservable dimensions that are correlated with educational attainment or that education serves a different role for land owners than for other agricultural workers. This latter point is particularly relevant when considering that some portion of the returns to education comes from making a farmer more likely to adopt innovations. As several studies in the agricultural economics literature point out, the incentives to invest in new technologies depend heavily on whether a farmer owner farms his land himself or rents the land.[21] Any estimates of the returns to education, even if properly estimated for farm owners, may not be generalizable to other types of farmers.[22]

The manner in which farm owners are identified and added to our dataset also clouds the interpretation of the returns to education. To be in our dataset, a farmer's name must be associated with a plot of land on a plat map. We assume that because his name is given on the map and because his occupation is listed as farming in the census, he is farming the land we see on the map.[23] Things are certainly more complicated than this. We cannot tell if the farmer farms his land himself or if he rents out his land. We do not know if decisions are made by him or by managers that he hires. We cannot say with certainty that he is the sole owner of a farm rather than simply a majority owner. His farm may be run by his sons or his father or any of many possible combinations of unobserved partners. Without knowing what role the farm owner has in the farm operations, it is unclear how his education is being applied or even whether it is his education that matters. Estimated returns to education will capture both the returns resulting from improving farming practices and the returns resulting from better management in general (for example, hiring better managers). The problem with conflating these two sources of returns is that it becomes difficult to translate any estimated returns to education into optimal

[21] See Feder et al. (1985) for a survey of papers on tenurial arrangements and technology adoption.

[22] Estimates from the intergenerational Iowa sample do reveal significant private returns to education for farm managers and farm laborers similar to the private returns we estimate for farm owners in this chapter. However, we have no way of estimating the spillovers experienced by these agricultural workers because we have no way of identifying either their precise location or the members of their social network.

[23] There are cases in the sample where an individual owns a large plot of land according to the plat maps but has listed as an occupation something other than farmer. It is uncertain whether, in addition to his listed occupation, the land owner is deriving income from the land and should be considered a farmer. We run all regressions both for the sample of land owners listed as farmers and for the complete sample of land owners. In the latter case, it is important to recognize that the estimated returns to education are due in part to the gains in non-farming income.

school policy regarding what should be taught.

Uncertainty about involvement in non-farming occupations for the land owners is as problematic as the uncertainty over their involvement in the farming operations. In all of the census observations, only a single occupation is reported. For those who list their occupation as farmer, we cannot be certain that they do not have an additional job that accounts for a portion of their reported earnings. Any estimated returns to education may be picking up the returns to education for this additional job rather than for farming. Without knowing anything about the likelihood of farmers having additional jobs or about what individual characteristics are correlated with having an additional job, we can say very little about what portion of the returns to education we estimate is actually specific to farming rather than some other occupation.[24] When we turn to estimating spillovers, this is less of a concern as we would not expect the increased earnings from non-farming jobs to influence the earnings of neighbors.

Having a sample of farmers also presents difficulties when controlling for experience. In equation (1), we include a series of age controls but omit standard controls for experience. Typically, a wage regression of this sort would control for potential experience, defined as years that the individual has been working and calculated by determining the number of years since that individual left school. We have the age and schooling data needed for this calculation but it may be inappropriate in the context of agriculture. A year of additional schooling does not imply one less year of farming experience. Work can take place on the farm over the course of the year even if the farmer is attending school, certainly enough for the farmer to accumulate knowledge relevant to future years of farming. This is particularly true for the majority of the farmers in our sample involved in wheat and corn production which varies over the year in terms of the amount of labor required. Age, rather than an imputation of potential experience, may be a more relevant variable to capture the earnings profile over a farmer's career. While choice of age or potential experience has important implications for the interpretation of earnings over the life cycle, the results we will present for the returns to education are ultimately not sensitive to the choice of experience controls.

[24]One possible assumption is that the likelihood of having additional jobs increases as the distance to the nearest town, and all of the jobs and markets associated with town centers, decreases. In the appendix, we estimate the returns to education for farmers restricting the regression sample by distance to the nearest town. Results are provided in Table 13 and show that the high returns to high school we find actually get larger when we exclude farmers living close to towns who are more likely to have other non-farming jobs.

One last issue raised by focusing on a sample of all farmers concerns the endogeneity of educational attainment. This is a standard issue in any wage regression containing education. Education will be correlated with unobservable characteristics, most notably innate ability or intelligence. One of the few approaches to correcting for this problem is finding a valid instrument for educational attainment. With our limited set of farmer characteristics, this is not an option.[25] We can, however, say something about unique features of this endogeneity problem given our data. First, the traditional issues of education as a screening mechanism are not relevant here as every person in our sample is a self employed farmer with no reason to pursue additional schooling purely to signal ability. Schooling will only be undertaken if farmers either have a strong preference for education as a consumption good or if education is actually productive in agriculture. This former possibility seems highly unlikely given the large opportunity cost to a farming family of having children in school. The latter, however, is a rather appealing reason for farmers going to school and suggests that observed returns to education are actually capturing something about the productive nature of schooling rather than simply abilities or preferences that are correlated with educational attainment. This in no way implies that the returns to education will not pick up aspects of ability; it can certainly be the case that schooling increases productivity only for those with high ability. However, for our purposes this matter can be left unresolved. We want to know whether schooling increased productivity in turn of the century agriculture. We are not concerned with whether the returns to education were uniform across all farmers or not, but simply with whether they existed.

The estimated returns to education coefficients from various specifications of equation (1) are summarized in Table 4 (complete regression results are provided in Table 11). The first column gives the estimated returns to education for all land owners using three different measures of educational attainment: total years of schooling, years of graded schooling (all schooling except common school), and years of schooling broken down into common school, grammar school, high school and college. The second column shows the results when the sample is restricted to those individuals with farmer given as their occupation in the census. For all coefficients, the measure of

[25] In an ongoing project, we use data on the structure of a farmer's household when he was a child to instrument for educational attainment. The instruments we use require intergenerational data. The match rates to construct the intergenerational data coupled with the match rates between the Iowa census and the plat maps prevent us from using similar techniques to instrument for education here where we are concerned with observing neighbors. Preliminary results from these regressions produce large but statistically insignificant estimates for the private returns to education.

Table 4: Returns to education by type of schooling, log annual earnings as dependent variable

Measure of schooling used:	All land owners	Farmers
Total schooling	0.017***	0.013**
	(0.005)	(0.006)
Graded schooling	0.022***	0.010
	(0.008)	(0.010)
Common school	0.010*	0.011*
	(0.006)	(0.006)
Grammar school	0.005	-0.004
	(0.014)	(0.015)
High school	0.046**	0.052**
	(0.020)	(0.022)
College	0.064**	0.009
	(0.025)	(0.029)
Numbers of observations	2410	2219

Standard errors in parentheses. All regressions control for age, religion, land value per acre and township.* significant at 10%; ** significant at 5%; *** significant at 1%

education is in years and the dependent variable is log annual earnings, so the coefficients can be interpreted as the percent change in annual earnings associated with an increase in educational attainment of one year. The coefficients in Table 4 make it clear that there were significant returns to education for land owners and specifically farmers at the turn of the century. For all land owners and farmers, an additional year of common school raised earnings by roughly one percent, a modest but statistically significant increase in earnings. Grammar school had no significant impact on earnings. High school is where large returns to education can be observed. For all land owners as well as for the subset of land owners that were farmers, an additional year of high school led to an increase in earnings of five percent. An additional year of college was associated with a six percent increase in earnings when looking at all land owners but did not have a significant effect on the earnings of farmers.

These returns to education estimates are consistent with the predictions of the previous section, that in a time with technological innovation education would be useful to farmers both in developing basic competencies, evidenced through the returns to common school, and through more advanced studies at the high school level where more specific information can be taught and the ability to experiment and adapt can be developed. These skills can have a large impact on productivity in a period of innovation and it is therefore quite reasonable that we observe such large returns to high school education for farmers. It is unsurprising that there are no significant returns to grammar school while both common school and high school show evidence of significant returns. Most farmers had access to rural common schools early in their educational careers and could then opt to go to a high school later on. Grammar schools were located in towns and cities and were less agriculturally focused than the common schools and high schools attended by the farmers in our sample. The agricultural focus of these common schools and high schools is a compelling explanation for the significant returns to common school and high school but not grammar school for the farmers.

One question that the high returns to high school education raise is whether the human capital acquired through high school is general or whether it may be location specific. If high schools in Iowa are targeting their curricula to Iowa farmers, it is possible that the returns to education completed in Iowa may be different from the returns to education completed outside of Iowa. To explore this possibility, the earnings regressions are also run with multiple education variables capturing not only how many years of education an individual received but also where that education was received. Table 5 presents the returns to education coefficients from these regressions for both the full sample of all land owners and for the farmers only (full regression results are provided in Table 12).

The results from Table 5 suggest that where a person was educated did affect the returns to that education. For the farmers, it is only for education received in Iowa that the returns to education are statistically significant. Both common school and high school received in Iowa are significant and reasonably large, with returns to a year of common school in Iowa of 1.3 percent and returns to a year of high school in Iowa of 5.7 percent. The lack of precision for the estimates of the returns to schooling received outside of Iowa prevents us from concluding that common school or high school received outside of Iowa was not productive for Iowa farmers. The results change when including all land owners. We would expect that the human capital required for non-farming occupations would be less location specific. The results for total years of schooling are consistent with this reasoning, with the returns to schooling received outside of Iowa being statistically significant and similar in magnitude to the returns to schooling received in Iowa. As with the farmer only sample, the large standard errors prevent making meaningful

Table 5: Returns to education by location where schooling was received, log annual earnings as dependent variable

	All land owners	Farmers
Total schooling in Iowa	0.019***	0.015***
	(0.006)	(0.006)
Total schooling outside Iowa	0.013**	0.008
	(0.006)	(0.006)
Total schooling in US	0.019***	0.015***
	(0.005)	(0.006)
Total schooling outside US	0.012*	0.006
	(0.007)	(0.007)
Common school in Iowa	0.012**	0.013**
	(0.006)	(0.006)
Common school outside Iowa	0.006	0.006
	(0.007)	(0.007)
Grammar school in Iowa	-0.002	-0.007
	(0.016)	(0.019)
Grammar school outside Iowa	0.018	0.016
	(0.026)	(0.030)
High school in Iowa	0.059***	0.057**
	(0.022)	(0.023)
High school outside Iowa	-0.002	0.014
	(0.046)	(0.063)
College in Iowa	0.045	-0.013
	(0.029)	(0.032)
College outside Iowa	0.107**	0.089
	(0.052)	(0.064)
Numbers of observations	2410	2219

Standard errors in parentheses. All regressions control for age, religion, land value per acre and township.* significant at 10%; ** significant at 5%; *** significant at 1%

comparisons of the returns to specific types of schooling received in and outside of Iowa. The one striking coefficient when looking at specific schooling types is that of college. The returns to college received outside of Iowa are quite large, implying a 10.7 percent increase in earnings from one additional year of college. An interpretation of this coefficient is that those individuals who are not farmers but still large land owners often have white collar occupations such as lawyer or doctor. These white collar workers tend to have high educational attainments and very high incomes relative to individuals in the farmer only sample.

7 Human Capital Spillovers Across Farms

The returns to education results in the previous section reveal that additional schooling did lead to higher productivity for farmers at the turn of the century. If the ways in which an educated farmer achieved higher productivity were observable we would expect that the neighboring farmers could mimic those practices and achieve higher productivity for their own farms. In this section, we test for the presence of these spillovers from education by including a measure of neighbors' education in the earnings regressions used in the previous section. With the detail of our data, we can estimate spillovers from neighbors' education while controlling for a farmer's own education and the local value of land, allowing us to distinguish human capital spillovers from the effects of own characteristics and local characteristics that are correlated with neighbors' education levels.

Deciding how to measure neighbors' education depends both on how we believe spillovers should occur and on limitations of the data. If education improves productivity purely through giving a farmer the ability to correctly utilize inputs, it may be only the most educated neighbor that matters. An example of this situation would be a farmer learning about a disease resistant seed variety through a short course sponsored by the agricultural college. If there is no uncertainty about how to grow the new variety or about its profitability relative to other varieties, the educated farmer will simply put the information into practice and obtain higher yields. It does not matter whether this information was received by one educated neighbor or several; once the first educated neighbor puts the information into practice everyone else can follow. In this situation, the number of educated neighbors does not matter, simply the level of education of the most educated neighbor.

Adapting to new innovations is rarely as simple as this example. It is more realistic to imagine several new seed varieties to choose from whose performances will depend on local soil conditions, planting techniques and a variety of other factors. An educated farmer may need to experiment to profitably adapt to new innovations. In this situation, multiple educated farmers may be better than one highly educated farmer. There is more communal information created both through knowledge disseminated through schools and knowledge created by experimentation. Several neighbors experimenting with new information are more likely to generate productivity gains than simply the actions of the single most educated neighbor. In this case, the relevant measure of education will be an aggregate statistic capturing the education of all neighbors. In the case where the mean level of education is used as the aggregate statistic, the estimation equation becomes

$$\ln Y_i = \beta_0 + \beta_1 p(A_i) + \beta_2 E_i + \beta_3 \frac{1}{n_{total}} \sum_{j=1}^{n_{total}} E_j + \alpha X_i + \epsilon_i \tag{2}$$

where E_j is the education level of neighbor j and n_{total} is the total number of adjacent neighbors observed for farmer i. The coefficient β_3 captures human capital spillovers.

We will use both the mean education of all adjacent neighbors and the maximum level of education among all adjacent neighbors as measures of neighbors' education. For both measures, we use a variety of different measures for education including years of total schooling, years of graded schooling, years of high school and years of high school and college combined. One problem with these measures is that, due to the difficulties of linking the plat maps to the census records, we do not necessarily observe all of an individual's neighbors. For the mean level of neighbor education, this is not a major problem if we assume that the neighbors are missing at random.[26] However, even if neighbors are missing at random, their absence is problematic for measuring the maximum educational attainment across neighbors. Missing neighbors means that

[26]Unlike many other situations in which linked data is used, this assumption that individuals are missing at random is not unrealistic. Because we are using plat maps and census records from the same year, individuals will not be missing because they have moved. Instead, they will only be missing if their name either did not match between the maps and census records or led to multiple matches. Failure to match an individual is mainly a result of bad handwriting on the part of the census enumerator or the individual having a common last name and only initials given for the first name. It is reasonable to think that the likelihood of bad enumerator handwriting or a common last name is uncorrelated with educational attainment.

the maximum educational attainment across neighbors may be censored. A censored independent variable is a problem in any scenario but is particularly bad here as there is no constant cutoff across observations at which the variable is censored. We cannot say whether a particular observed maximum education is censored regardless of its value as long as some neighbors remain unobserved. The likelihood of the maximum education variable being censored depends on the number of missing neighbors, the magnitude of the observed maximum education and the correlation of education between neighbors. This censoring will tend to bias our results.[27]

Estimates of both the private returns to education and spillovers from neighbors' education are given in Equation 7 (full regression results are provided in Table 14). The private returns to education change very little when including neighbors' education in the regressions. We still find the returns to a year of common school to be roughly one percent, the returns to grammar school to be insignificant and the returns to a year of high school an impressive 5.5 percent. Our estimates of spillovers from neighbors' education reveal that additional schooling for neighbors has a significant impact on a farmer's earnings. An increase in mean total schooling of one year by a farmers' neighbors leads to a 2.3 percent increase in the farmer's own income. When breaking down neighbors' education by schooling type, we find that this result is being driven by increases in high school education by neighbors, with an additional year of mean high school attainment across neighbors associated with an increase of over two percent in a farmer's income. While a farmer's own educational attainment has a larger impact on earnings as one would expect, this contribution of neighbors' education is quite substantial indicating that spillovers from education were sizable in the agricultural sector at the turn of the century.

To this point we have considered only the proximity of two individuals in determining whether spillovers may exist. The argument has been that farmers will be likely to observe and interact with their adjacent neighbors and the similarity of growing conditions across adjacent plots of land will make shared information useful to farmers on adjacent plots. However, our data allow us to explore a more nuanced version of human capital spillovers. The census records contain several pieces of information that allow us to identify potential social networks based on characteristics

[27] In the appendix, we simulate the effects of missing neighbors on the estimated coefficients for the private returns to education and spillovers. These simulations demonstrate that as the number of missing neighbors rises, the spillovers coefficient is biased toward zero while the private returns coefficient is biased upwards. The simulation results suggest that missing neighbors are leading us to underestimate both the absolute magnitude of spillovers and the size of spillovers relative to the private returns to education.

Table 6: Private returns to education and education spillovers for farmers by schooling type

Neighbors' education measure:	Total schooling		All graded schooling		High school		High school and college	
	Mean	Maximum	Mean	Maximum	Mean	Maximum	Mean	Maximum
Neighbors' education	0.023***	0.026***	0.010	0.011**	0.038	0.028***	0.027	0.023***
	(0.008)	(0.006)	(0.011)	(0.005)	(0.029)	(0.011)	(0.020)	(0.008)
Own education:								
Common school	0.009	0.008	0.009	0.009	0.009	0.008	0.009	0.008
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Grammar school	-0.007	-0.008	-0.008	-0.008	-0.007	-0.008	-0.007	-0.007
	(0.016)	(0.015)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
High school	0.055**	0.052**	0.057***	0.057***	0.057***	0.056**	0.056**	0.055**
	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)
College	0.021	0.021	0.023	0.023	0.022	0.023	0.021	0.021
	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)
Number of obs.	2158	2158	2158	2158	2158	2158	2158	2158

Standard errors in parentheses. All regressions control for age, religion, land value per acre and township.* significant at 10%; ** significant at 5%; *** significant at 1%

Table 7: Distribution of farmer sample by church affiliation

Church	Percentage of sample
Baptist	2.45
Brethren	0.51
Catholic	16.98
Congregational	2.92
Evangelical	0.79
Lutheran	11.57
Methodist	15.21
Presbyterian	7.42
Other	4.98
Not reported	37.16

other than simply physical proximity. A farmer may be more inclined to share information with or consider the suggestions from a neighbor within his social network than a neighbor outside of his network. It is plausible that human capital spillovers may be stronger within than across social networks. To test for this effect, we can include two separate measures of neighbors' education in the earnings regressions, one capturing the average education of neighbors within a farmer's social network and one capturing the average education of neighbors outside of that social network. With this modification, the regression equation becomes

$$\ln Y_i = \beta_0 + \beta_1 p(A_i) + \beta_2 E_i + \beta_3 \frac{1}{n_G} \sum_{j \in G} E_j + \beta_4 \frac{1}{n_{total} - n_G} \sum_{k \notin G} E_k + \alpha X_i + \epsilon_i \tag{3}$$

where G is the set of adjacent neighbors in the same social network as farmer i, n_G is the total number of adjacent neighbors in the farmer's social network and n_{total} is the total number of adjacent neighbors for the farmer.

The data offer several ways to identify likely social networks. The first is simply using the information on age. Farmers may be more likely to communicate with other farmers in their cohort compared to farmers that are significantly younger or older. With this in mind, one definition used for a farmer's social group is the set of adjacent farmers who are fewer than five years older or younger than the farmer. A second measure of the social group takes advantage of the church affiliation provided in the Iowa census. Under this measure, two adjacent farmers are considered to be in the same social group if they report the same church affiliation. The

Table 8: Correlations between farmer characteristics by social group membership

Social group defined by:	Church affiliation	Parents' birthplaces	Birth cohort
Percentage of neighbors that are in social group	38.80%	21.8%	17.4%
Correlation of own education with that of similar neighbors	0.258	0.299	0.131
Correlation of own education with that of dissimilar neighbors	0.125	0.155	0.057
Correlation of own years HS/college with that of similar neighbors	0.242	0.103	0.048
Correlation of own years HS/college with that of dissimilar neighbors	0.053	0.078	0.084
Correlation of own log earnings with that of similar neighbors	0.194	0.312	0.270
Correlation of own log earnings with that of dissimilar neighbors	0.254	0.248	0.207

distribution of church affiliations for the sample of farmers is given in Table 7 which shows substantial heterogeneity in terms of Christian denominations reported in the census. The final measure of the social group is based on ancestry; neighbors are considered to be in the same social group if their parents' share the same country or state of birth.[28]

Table 8 gives summary statistics for the sample based on social group membership. Under all three group definitions, on average fewer than half of a farmer's neighbors are in his social group.[29] When looking at the correlation between a farmer's own education and that of his neighbors it is clear that farmers are more similar to neighbors in their social group than neighbors outside of

[28]For both the social group measure based on church affiliation and the measure based on ancestry, any individuals not reporting a specific church affiliation or place of birth for either parent are not included in the regressions. Two neighbors who leave church affiliation or parental place of birth blank are neither considered in the same social group nor in different social groups; they are simply dropped from the sample.

[29]Maps showing the spatial patterns of group membership are provided in an online appendix available at http://www.econ.ucdavis.edu/faculty/jparman/.

that group in terms of educational attainment. Differences in the correlations between a farmer's income and that of his neighbors are much smaller between neighbors in the social group and neighbors outside of it.

The results of the earnings regressions when distinguishing between within group neighbors and neighbors outside of the social group are given in Table 9 (complete regression results are provided in Table 15 in the appendix). The coefficients on the education of similar neighbors and the education of dissimilar neighbors represent the percent increase in a farmer's own earnings from an increase in the average education of his similar or dissimilar neighbors respectively. The results share the same basic patterns as the previous spillover estimates; increases in neighbors' mean education by a year have a positive effect on a farmer's earnings similar in magnitude to an increase in his own education of one year. These positive spillovers are once again being driven largely by increases in high school and college attainment. What is of interest are differences in the spillovers from similar neighbors' education and from dissimilar neighbors' education.

The most noticeable feature of the estimates is that the coefficients when the social group is defined by birth cohort or ancestry are quite similar while the coefficients when the social group is defined by church affiliation are dramatically different. For social groups based on birth cohort or ancestry, spillovers are positive for both similar neighbors and dissimilar neighbors and either similar in magnitude for the two neighbor types or greater for neighbors within a farmer's social network. This finding seems rather intuitive, farmers learn from all of their neighbors but they may learn more from those neighbors they are more likely to interact with. When looking at spillovers for social groups defined by church affiliation, this pattern is reversed. Spillovers resulting from increased education of neighbors within farmer's social group are statistically indistinguishable from zero while the spillovers resulting from an increase in the education of dissimilar neighbors are significant, positive and quite large, with an increase in average high school attainment of one year for dissimilar neighbors leading to a seven percent increase in a farmer's annual earnings. It is only possible to reject the hypothesis that the magnitude of the spillovers is the same for both similar neighbors and dissimilar neighbors in two cases: the spillovers associated with mean graded schooling in the case of social groups based on religion and the spillovers associated with mean high school and college attainment in the case of social groups based on ancestry. These two cases underscore the difference between church based groups

Table 9: Private returns to education and education spillovers for farmers by schooling type and social group membership

Social group measure:		Parents' birthplaces			Birth cohort			Church affiliation	
Neighbors' education measure:	Total schooling	Graded schooling	High school and college	Total schooling	Graded schooling	High school and college	Total schooling	Graded schooling	High school and college
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Neighbors' education:									
Mean education within group	0.010**	0.027*	0.045	0.013***	0.019**	0.037**	0.005	-0.003	0.018
	(0.004)	(0.015)	(0.035)	(0.003)	(0.009)	(0.017)	(0.004)	(0.014)	(0.034)
Mean education outside group	0.012**	0.005	0.018	0.017**	0.004	0.016	0.016**	0.041***	0.070***
	(0.006)	(0.010)	(0.018)	(0.007)	(0.009)	(0.018)	(0.006)	(0.010)	(0.018)
Own education:									
Years of common school	0.008	0.009	0.008	0.008	0.008	0.008	0.014	0.015*	0.014
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.009)	(0.009)	(0.009)
Years of grammar school	-0.007	-0.008	-0.007	-0.006	-0.009	-0.007	0.004	0.001	0.006
	(0.014)	(0.015)	(0.015)	(0.014)	(0.014)	(0.014)	(0.021)	(0.023)	(0.021)
Years of high school	0.053**	0.054**	0.053**	0.051*	0.054**	0.052**	0.049*	0.054**	0.050*
	(0.026)	(0.026)	(0.026)	(0.027)	(0.025)	(0.026)	(0.026)	(0.026)	(0.027)
Years of college	0.023	0.024	0.021	0.025	0.025	0.023	0.014	0.015	0.011
	(0.033)	(0.031)	(0.032)	(0.033)	(0.031)	(0.032)	(0.032)	(0.032)	(0.033)
Observations	2148	2148	2148	2158	2158	2158	1284	1284	1284

Robust standard errors clustered by township in parentheses, all regressions control for age, nativity, years in the United States, religion, land value per acre and township.
* significant at 10%; ** significant at 5%; *** significant at 1%

and ancestry based groups; the spillovers for similar neighbors are significantly larger than for dissimilar neighbors in the case of ancestry while it is the opposite case for church affiliation.

8 Spillovers and Public School Provision

These results on the returns to education and spillovers have important implications for our understanding of the forces behind public education expansion in the United States and the contributions public schools made to economic growth. The high returns to secondary schooling in the agricultural sector challenge notions that public school expansion was driven by an increasing role of human capital in industry. Recognizing that education was productive in agriculture and that spillovers existed helps further our understanding of why the Midwest led the high school movement in the United States and what gains can be expected from education in modern developing countries with large traditional agricultural sectors.[30]

The substantial returns to secondary schooling for farmers suggest that schools were serving an important role in rural communities at the turn of the century. Public subsidization of these schools was potentially important not only as a way of helping farmers overcome credit constraints to obtain education but also because of the large spillovers from secondary education. Given the magnitude of the observed spillovers, individuals would choose socially suboptimal levels of schooling in the absence of public subsidization of schooling even if they were not credit constrained.

Public subsidization of rural education has its share of problems. Typically of greatest concern are the problems arising from brain drain, the migration of the educated individuals from rural to urban areas. Because public education is largely financed at the local level, the spillovers from educated individuals are experienced by a community that does not share the burden of

[30]While they did not have the data and means to precisely estimate the returns to education, public officials in the Midwest were certainly aware of the importance of education in agriculture and this factored into the debate over school expansion. An example of this can be found in legislation passed in Iowa in 1913 regarding the creation of consolidated schools. Among other conditions, a consolidated school was required to maintain an agriculture experiment plot and proper equipment to teach agriculture in order to be eligible to receive state funds. There was even a belief that the cost of improving rural schools would be made up for by the increase in productivity. Rapeer (1920), in a call for hiring the best teachers possible for rural consolidated schools, notes that their high salaries would be covered by the "increased prosperity and wealth that would come to any community with [a consolidated rural school]." Increased agricultural productivity was not simply a fortunate by-product of public school expansion but rather one of its underlying motivations.

the costs of that education if educated individuals migrate upon completion of their educational careers. In situations of this sort, locally decided levels of public education will be too low. The high returns to education within agriculture and the potential for much of the education to be geographically specific (choice of seed varieties, maintenance of soil acidity and fertility, etc.) reduce the expected level of brain drain compared to the traditionally held view where schooling had little value in agriculture relative to other sectors. Proponents of school expansion even suggested that better rural schools were a way of retaining educated individuals. A recurring theme of the report of the Country Life Commission, appointed by President Roosevelt in 1908, was a belief that the quality of rural schools had to be improved and the curriculum more agriculturally focused in order to keep rural individuals from seeking education and employment in the towns and cities. An annual report on agricultural secondary education in Minnesota notes that "the school, then, does not educate students 'away from the farm'...on the contrary it educates them toward the farm...proved by the fact that eighty two per cent of the students return to agricultural occupation."[31] Our evidence of high private and public returns to schooling in agriculture reveals that this view was not unrealistic; rural communities had strong incentives to invest in public schools.

The substantial private returns to high school made schooling attractive to farmers. The large spillovers from secondary education made education a very public good; an agriculturally based community could experience significant gains in productivity though the subsidization of public education. This adds a new dimension to the discussion of the historical evolution of public schools. The importance of education in the agricultural sector well before the Green Revolution suggests that the agricultural sector cannot be ignored when modeling public school expansion. Models like those of Galor & Moav (2006) and Galor et al. (2006) which assume that capital-skill complementarities in industrial sectors drove the desire for public education will not adequately address the American experience. In these models, schooling is assumed to be unproductive in the agricultural sector. Consequently, large land owners resist the public funding of schools and a shift in political power to capitalists, who benefit from an educated workforce, is required to make public schools politically feasible. The American experience is dramatically different from this. The Midwest and areas with low levels of manufacturing led

[31]The University of Minnesota Bulletin, p. 186

the expansion of high schools in the United States (Goldin & Katz, 1997; Goldin, 1998). These patterns can be understood by recognizing the important role education had in the agricultural sector. The significant private returns to education and the public nature of education created by human capital spillovers produced strong incentives to build public schools in rural areas. The decentralized political mechanisms of school creation in the United States, discussed in Go & Lindert (2007) and characterized by school creation being voted on locally by majority vote and funded through property taxes, made rural communities even more likely to adopt public schools. Small farm owners, benefiting from public schools directly through subsidized schooling and indirectly through spillovers yet sharing a small portion of the costs of those schools, would vote for and take advantage of public schools.

The contributions we have identified of formal schooling to American agricultural productivity are key to understanding the patterns of high school introduction in the United States. The wide range of innovations in the agricultural sector in the late nineteenth and early twentieth centuries and the political structure of the United States made the Midwest particularly well suited to introduce and benefit from public schools. Any account of the forces behind public school expansion needs to recognize the important relationship between education and the agricultural sector.

9 Conclusion

The history of agriculture in the American Midwest reveals that there was substantial innovation occurring in the decades before the technological advances of the mid-twentieth century. Human capital played an important role in helping farmers profitably adopt new technologies and the public schools were well suited to producing that human capital. We have used individual level data on Iowa farmers to reveal that schools did indeed have a large impact on farmer productivity. Secondary schooling in particular led to significant increases in earnings. By linking the earnings and educational attainments of farmers to geographic data, we have shown that the benefits from formal schooling extended beyond the private returns to education for a farmer. Significant human capital spillovers existed; an additional year of schooling for a farmer substantially increased the earnings of individuals on neighboring farms.

These significant private returns to education and spillovers demonstrate that public education played a large role in agricultural productivity growth at the turn of the century. Rather than simply allowing educated individuals to escape the farm for white collar occupations in the city, public schools allowed those farmers who stayed in agriculture to increase their productivity and the productivity of other farmers in the community. Our results suggest that a full accounting of the expansion of public schools and of economic growth at the turn of the century must consider the links between education and agriculture.

Identifying human capital spillovers in agriculture at the turn of the century opens up a large set of interesting areas for future study. Knowing the size of the private and public returns to education in agriculture offers a foundation for modeling the expansion of public education throughout the United States and assessing whether there were major efficiency gains from having local control over school expansion rather than the federal control governing the expansion of educational institutions in Europe. Exploration of the role of public schools and human capital spillovers in modern developing nations is also of major importance. The lessons of the United States during a period of steady innovation can be extended to inform education policy in agricultural regions of developing nations adapting to modern agricultural innovations.

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A Missing Neighbors and Biased Returns to Education Estimates

The fact that not all of a farmer's neighbors are observed presents difficulties for our estimation of human capital spillovers, particularly in the context of estimating the effects of the maximum level of education across all neighbors. This section presents a brief discussion of why missing neighbors are problematic and how the level of missing neighbors affects the bias of our estimated coefficients.

Our spillover estimates focus on two main types of measures for neighbors' education, the mean education of all neighbors and the maximum individual education across all neighbors. If we assume that the probability of a neighbor being missing is independent of their education level, the expected value of the mean education level of the observed neighbors is equivalent to the expected value of the mean education level of all neighbors, observed and unobserved.[32] A greater number of missing neighbors simply increases the level of classical measurement error in our mean neighbor education variable, a common measurement problem that will introduce a downward bias in the estimated spillover coefficient.

When using the maximum level of education across all neighbors, the effects of missing neighbors are more complicated. This is no longer a case of classical measurement error. With any number of missing neighbors, the observed maximum education level provides a lower bound on the true maximum across all neighbors. Our measure of maximum neighbor education is potentially censored. A small amount of work has been done on the problems of censored independent variables showing that censoring biases the estimated coefficient for the censored variable as well as the coefficients for other independent variable (see Austin & Hoch (2004) and Austin & Brunner (2003)). Our case is even more problematic than those considered in the literature, as the level at which maximum neighbor education is censored varies across observations. The likelihood of the variable being censored depends on the observed maximum education, the correlation of education levels between neighbors and the number of missing neighbors.

[32]The assumption that neighbors are missing at random is not as implausible as it may at first seem. The primary reason for missing neighbors is that their names were given on the plat maps with only an initial for the first name leaving multiple possible matches with the census. Whether or not this occurs has nothing to do with the education level of the individual.

To get a sense of how this censoring of the maximum neighbor education variable may influence our spillover estimates, we can use Monte Carlo simulations that estimate coefficients for varying levels of missing neighbors. Our simulations estimate income as a function of own education and neighbors' maximum education. We populate a grid with individuals whose education is a function of their location on the grid and a mean zero stochastic term. Making educating dependent on grid location allows us to generate the positive correlation between adjacent individuals' education levels observed in our Iowa sample. We then generate an income for each individual that is a linear function of own education, the maximum education level of all adjacent neighbors (the eight surrounding points on the grid) and a stochastic term that is a random draw from a standard normal distribution. We then choose a level of missing neighbors. The proper number of missing neighbors are randomly selected from the grid and their education levels are set to missing.[33] New maximum neighbor education levels are then calculated and income is regressed on own education and maximum neighbor education. All data is reset to the original state and a new set of missing neighbors is drawn and a new set of coefficients estimated. This process is repeated 1000 times for each level of missing neighbors.

The results of these simulations are shown in Figure 4 and Figure 5. It is clear that as the number of missing neighbors increases, it creates a downward bias for the estimated spillover coefficient. As the estimated coefficient on spillovers is biased toward zero, the estimated coefficient for the private returns to education rises. These simulations reinforce our findings that spillovers in agriculture were substantial relative to the private returns to education for farmers. Given that our sample has a substantial number of missing neighbors, the estimated spillovers are likely to be smaller than the true spillover and the estimated gap between the private returns to education and the spillovers from neighbor education is larger than the true gap. In the presence of ideal data with no missing neighbors, we would expect even larger estimates of human capital spillovers.

[33] Education levels that are set to missing are missing only relative to the neighbors. Own education is always known and is used in the regressions. An individual only drops out of our regressions when all of their neighbors are set to missing.

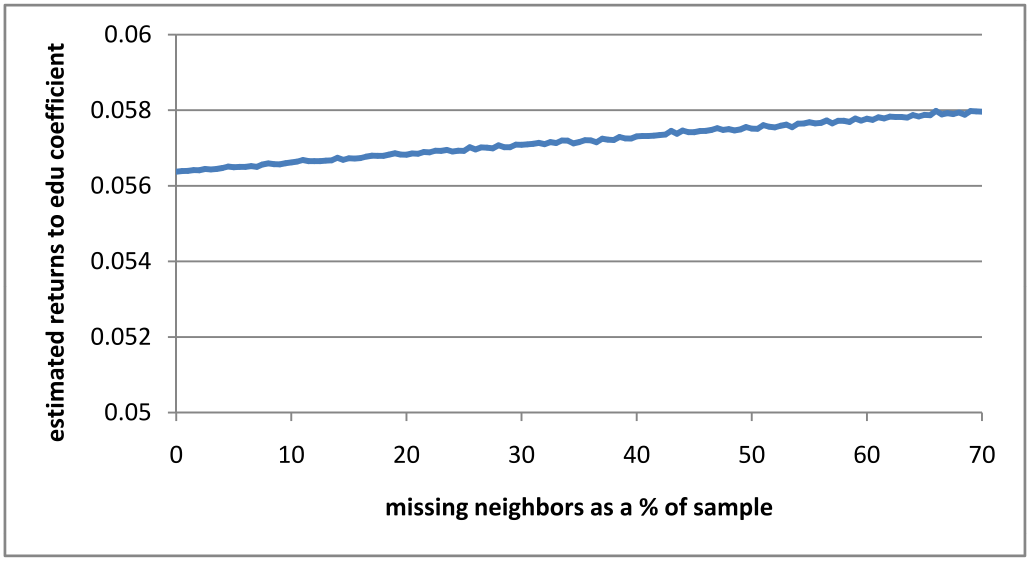


Figure 4: Estimated private returns to education coefficient by number of missing neighbors

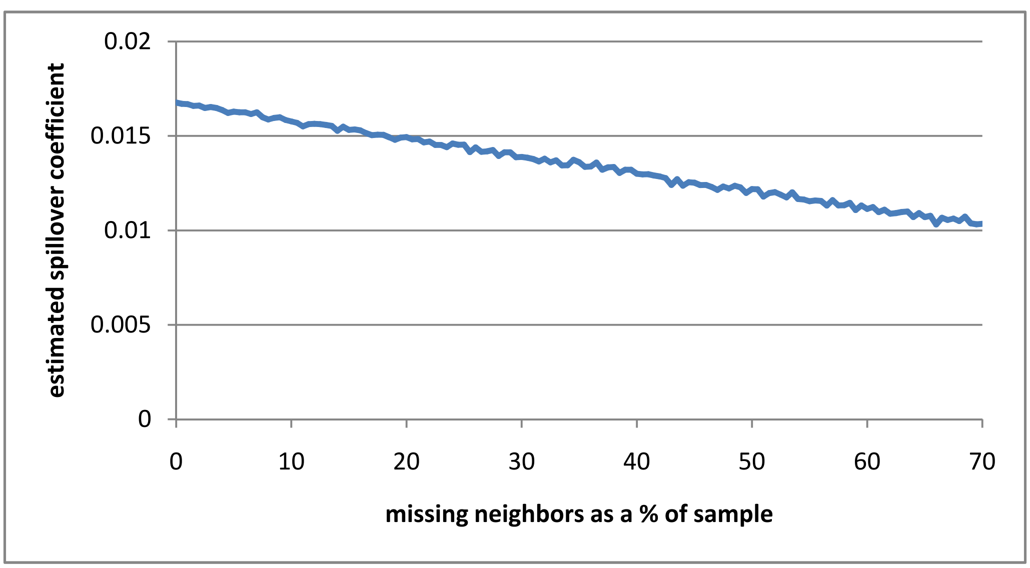


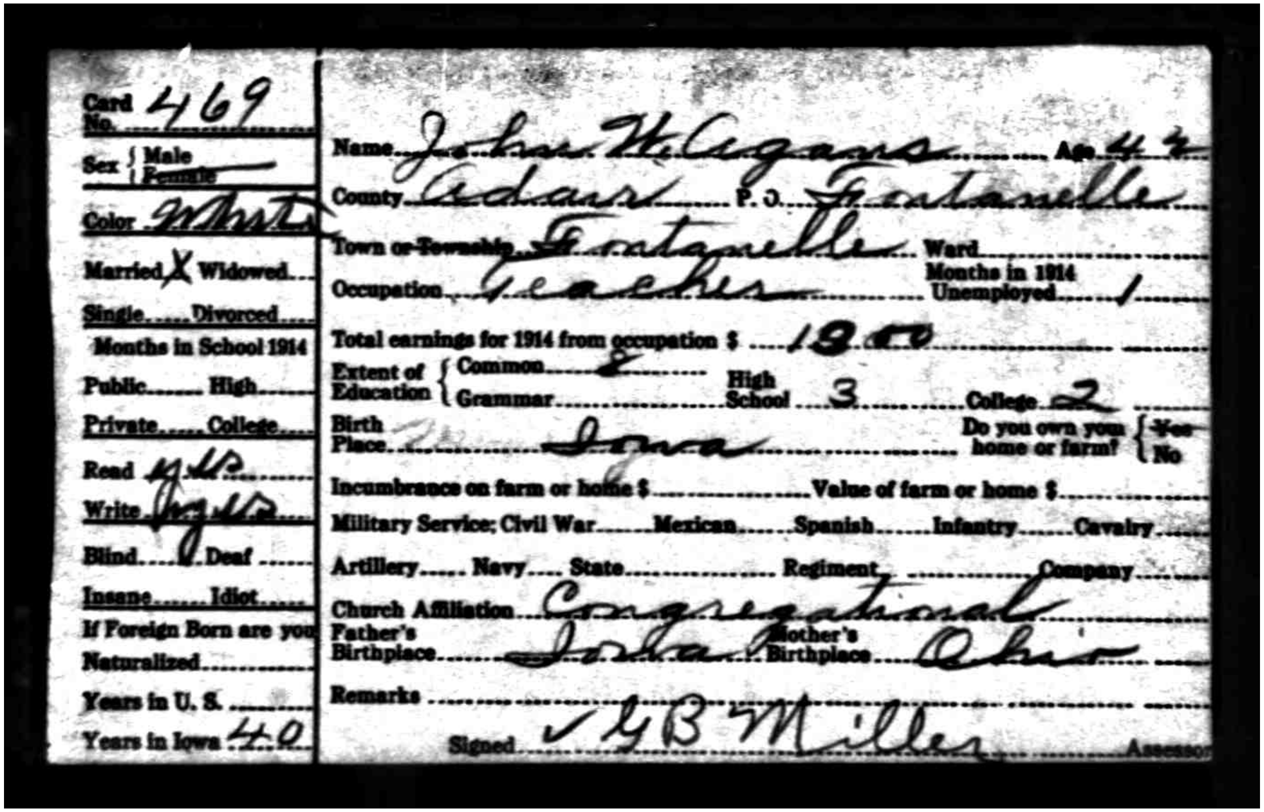
Figure 5: Estimated spillovers from maximum of neighbors' education by number of missing neighbors

B Appendix Tables and Figures

Table 10: Agricultural statistics for Chickasaw, Poweshiek and Ringgold counties, 1915

	Chickasaw	Poweshiek	Ringgold	State average
Number of farms	1905	2142	1854	1996
Average size of farms	152	160	168	160.7
Total acreage of farms	289658	342489	311814	320711
Acreage in pasture	90488	115002	117683	97601
Ave. monthly wage paid farm help, summer months	30.8	33	28.43	32.7
Ave. monthly wage paid farm help, winter months	20.69	25.72	28.77	24.61
Corn, acres	63194	110557	69328	98463
Corn, bushels per acre	3	38	23	27.5
Oats, acres	64068	42748	24330	50354
Oats, bushels per acre	25	37	19	37.8
Winter wheat, acres	179	860	13245	5929
Winter wheat, bushels per acre	16	23	9	18.5
Spring wheat, acres	1607	780	6	1495
Spring wheat, bushels per acre	12	14	7	13.8
Barley, acres	4043	608	55	2049
Barley, bushels per acre	9	39	13	31.3
Horses (all ages)	12819	18228	13703	14484
Swine	78547	124161	59604	94564
Cattle, Cows and heifers kept for milk	17367	9877	7987	11053

Statistics are complied from the 1915 *Annual Iowa Yearbook of Agriculture* .



Card No. 469
Sex { Male / Female
Color White
Married X Widowed
Single Divorced
Months in School 1914
Public High
Private College
Read yes
Write yes
Blind Deaf
Insane Idiot
If Foreign Born are you Naturalized
Years in U. S.
Years in Iowa 40

Name John W. Cagans Age 47
County Adair P. O. Fontanelle
Town or Township Fontanelle Ward
Occupation Teacher Months in 1914 Unemployed 1
Total earnings for 1914 from occupation $ 1200
Extent of Education { Common 8 / Grammar High School 3 College 2
Birth Place Iowa Do you own your home or farm? { Yes / No
Incumbrance on farm or home $ Value of farm or home $
Military Service; Civil War Mexican Spanish Infantry Cavalry
Artillery Navy State Regiment Company
Church Affiliation Congregational
Father's Birthplace Iowa Mother's Birthplace Ohio
Remarks
Signed J. G. B. Miller Assessor

Figure 6: An example of a single 1915 Iowa census card. Images of the cards are available online for the entire enumerated population and are searchable by name, age, place of bith and parents' places of birth.

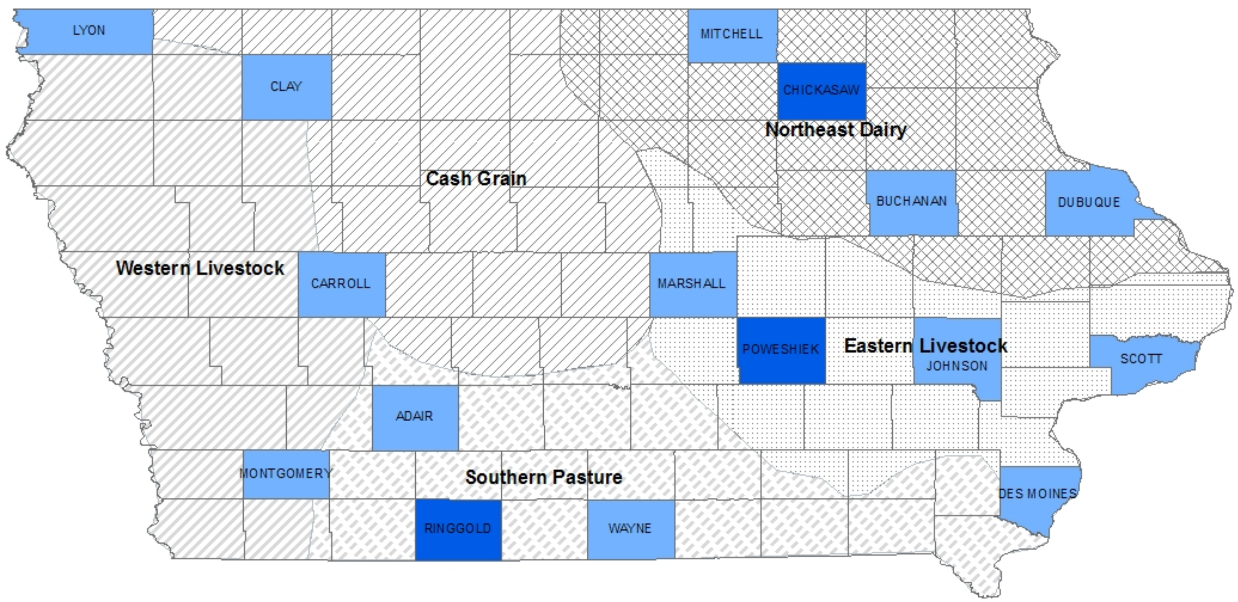


Figure 7: Map of Iowa with county borders and agricultural regions shown. Counties in the Goldin-Katz sample used for their esimates of the returns to education and in the farm owner sample are shaded (the farm owner sample counties are shaded in the darker color). The borders for the agricultural regions are from Latta (1952).

Table 11: Private returns to education estimates, log annual earnings as dependent variable

	All land owners				Farmers			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Foreign born (yes=1)	-0.075	-0.098	-0.081	-0.080	-0.122	-0.136	-0.119	-0.121
	(0.114)	(0.114)	(0.114)	(0.114)	(0.112)	(0.112)	(0.112)	(0.112)
Years in US x	0.004	0.004	0.004	0.004	0.005*	0.005*	0.005*	0.005*
foreign born	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Ln(farm value per acre)	0.099***	0.100***	0.100***	0.100***	0.121***	0.122***	0.121***	0.122***
	(0.022)	(0.022)	(0.022)	(0.022)	(0.026)	(0.026)	(0.026)	(0.026)
Total schooling	0.017***				0.013**			
	(0.005)				(0.006)			
Graded schooling		0.022***				0.010		
		(0.008)				(0.010)		
Common school			0.011*	0.010*			0.010*	0.011*
			(0.006)	(0.006)			(0.006)	(0.006)
Grammar school			0.005	0.005			-0.004	-0.004
			(0.014)	(0.014)			(0.015)	(0.015)
High school				0.046**				0.052**
				(0.020)				(0.022)
College				0.064**				0.009
				(0.025)				(0.029)
High school and college			0.053***				0.035**	
			(0.014)				(0.016)	
Constant	5.533***	5.624***	5.565***	5.565***	7.385***	7.444***	7.391***	7.382***
	(0.750)	(0.750)	(0.749)	(0.750)	(0.748)	(0.748)	(0.748)	(0.748)
Observations	2410	2410	2410	2410	2219	2219	2219	2219
R-squared	0.32	0.32	0.32	0.32	0.35	0.35	0.35	0.35

Standard errors in parentheses. All regressions include controls for age, religion and township.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 12: Returns to education by location where education was received, log annual earnings as dependent variable

	All land owners				Farmers			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Foreign born (yes=1)	-0.024	-0.011	-0.009	-0.030	-0.063	-0.030	-0.030	-0.068
	(0.119)	(0.124)	(0.123)	(0.119)	(0.118)	(0.123)	(0.123)	(0.119)
Years in US x	0.003	0.003	0.003	0.003	0.004	0.003	0.003	0.004
foreign born	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Ln(farm value per acre)	0.099***	0.100***	0.100***	0.100***	0.015***	0.015***		
	(0.022)	(0.022)	(0.022)	(0.022)	(0.006)	(0.006)		
Total schooling (Iowa)	0.019***	0.019***			0.122***	0.123***	0.123***	0.122***
	(0.006)	(0.006)			(0.026)	(0.026)	(0.026)	(0.026)
Total schooling (non-Iowa)	0.013**				0.122***	0.123***	0.123***	0.122***
	(0.006)				(0.026)	(0.026)	(0.026)	(0.026)
Total schooling (non-US)		0.015*				0.014		
		(0.008)				(0.009)		
Total schooling (non-Iowa, US)		0.012*	0.012*			0.006	0.006	
		(0.007)	(0.007)			(0.007)	(0.007)	
Total schooling (US)			0.019***				0.015***	
			(0.005)				(0.006)	
Common (Iowa)				0.012**				0.013**
				(0.006)				(0.006)
Common (non-Iowa)				0.006				0.006
				(0.007)				(0.007)
Grammar (Iowa)				-0.002				-0.007
				(0.016)				(0.019)
Grammar (non-Iowa)				0.018				0.016
				(0.026)				(0.030)
HS (Iowa)				0.059***				0.057**
				(0.022)				(0.023)
HS (non-Iowa)				-0.002				0.014
				(0.046)				(0.063)
College (Iowa)				0.045				-0.013
				(0.029)				(0.032)
College (non-Iowa)				0.107**				0.089
				(0.052)				(0.064)
Observations	2410	2410	2410	2410	2219	2219	2219	2219
R-squared	0.32	0.32	0.32	0.32	0.35	0.35	0.35	0.35

Standard errors in parentheses. Control included for age, religion and township.* significant at 10%; ** significant at 5%; *** significant at 1%

Table 13: Private returns to education for farmers by distance to nearest town, log annual earnings as dependent variable

	Distance to nearest town is at least:					
	0 miles	1 mile	2 miles	3 miles	4 miles	5 miles
Common school	0.011*	0.008	0.016*	0.014	-0.021	-0.012
	(0.006)	(0.007)	(0.009)	(0.014)	(0.025)	(0.045)
Grammar school	-0.004	-0.011	0.000	0.002	-0.033	-0.015
	(0.015)	(0.017)	(0.022)	(0.031)	(0.041)	(0.060)
High school	0.052**	0.052**	0.078**	0.126**	0.117	0.056
	(0.022)	(0.026)	(0.033)	(0.057)	(0.082)	(0.122)
College	0.009	-0.015	-0.050	-0.041	-0.012	0.273
	(0.029)	(0.034)	(0.040)	(0.060)	(0.083)	(0.294)
Observations	2219	1764	1159	647	287	126

Standard errors in parentheses. All regressions control for age, religion land value per acre and township.* significant at 10%; ** significant at 5%; *** significant at 1%

Table 14: Private returns to education and spillovers for farmers, log annual earnings as dependent variable

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Foreign born (yes=1)	-0.110	-0.092	-0.115	-0.116	-0.114	-0.112	-0.115	-0.115
	(0.113)	(0.113)	(0.113)	(0.113)	(0.113)	(0.113)	(0.113)	(0.113)
Years in US x	0.005*	0.005	0.005*	0.005*	0.005*	0.005*	0.005*	0.005*
foreign born	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)	(0.003)
Ln(farm value/acre)	0.119***	0.124***	0.122***	0.124***	0.122***	0.125***	0.122***	0.124***
	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)	(0.026)
Own schooling:								
Common school	0.009	0.008	0.009	0.009	0.009	0.008	0.009	0.008
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)
Grammar school	-0.007	-0.008	-0.008	-0.008	-0.007	-0.007	-0.007	-0.008
	(0.016)	(0.015)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)	(0.016)
High school	0.055**	0.052**	0.057***	0.057***	0.056**	0.055**	0.057***	0.056**
	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)	(0.022)
College	0.021	0.021	0.023	0.023	0.021	0.021	0.022	0.023
	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)	(0.031)
Neighbors' schooling:								
Mean total years	0.023***							
	(0.008)							
Max total years		0.026***						
		(0.006)						
Mean graded years			0.010					
			(0.011)					
Max graded years				0.011**				
				(0.005)				
Mean HS/college					0.027			
					(0.020)			
Max HS/college						0.023***		
						(0.008)		
Mean high school							0.038	
							(0.029)	
Max high school								0.028***
								(0.011)
Constant	6.682***	6.610***	6.966***	6.943***	6.957***	6.936***	6.961***	6.945***
	(0.734)	(0.728)	(0.728)	(0.727)	(0.728)	(0.727)	(0.728)	(0.727)
Observations	2158	2158	2158	2158	2158	2158	2158	2158
R-squared	0.35	0.36	0.35	0.35	0.35	0.35	0.35	0.35

Standard errors in parentheses. All regressions control for age, religion and township.
* significant at 10%; ** significant at 5%; *** significant at 1%

Table 15: Private returns to education and spillovers by social group membership for farmers, log annual earnings as dependent variable

Social group definition:	Parents' birthplaces			Birth cohort			Church affiliation		
Neighbors' schooling measure:	Mean total schooling	Mean graded schooling	Mean HS/college	Mean total schooling	Mean graded schooling	Mean HS/college	Mean total schooling	Mean graded schooling	Mean HS/college
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
Age	0.022***	0.022***	0.022***	0.017***	0.021***	0.022***	0.032***	0.032***	0.033***
	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.008)	(0.008)	(0.008)
Age^2	-0.000***	-0.000***	-0.000***	-0.000**	-0.000***	-0.000***	-0.000***	-0.000***	-0.000***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Foreign born	0.069	0.065	0.065	0.078	0.066	0.067	0.035	0.028	0.025
(foreign born = 1)	(0.051)	(0.051)	(0.051)	(0.052)	(0.052)	(0.052)	(0.055)	(0.053)	(0.053)
Ln(farm value	0.128***	0.127***	0.126***	0.130***	0.127***	0.128***	0.123***	0.114***	0.119***
per acre)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)	(0.027)
Years of common	0.008	0.009	0.008	0.008	0.008	0.008	0.014	0.015*	0.014
school	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.006)	(0.009)	(0.009)	(0.009)
Years of grammar	-0.007	-0.008	-0.007	-0.006	-0.009	-0.007	0.004	0.001	0.006
school	(0.014)	(0.015)	(0.015)	(0.014)	(0.014)	(0.014)	(0.021)	(0.023)	(0.021)
Years of high school	0.053**	0.054**	0.053**	0.051*	0.054**	0.052**	0.049*	0.054**	0.050*
	(0.026)	(0.026)	(0.026)	(0.027)	(0.025)	(0.026)	(0.026)	(0.026)	(0.027)
Years of college	0.023	0.024	0.021	0.025	0.025	0.023	0.014	0.015	0.011
	(0.033)	(0.031)	(0.032)	(0.033)	(0.031)	(0.032)	(0.032)	(0.032)	(0.033)
Neighbors' schooling,	0.010**	0.027*	0.045	0.013***	0.019**	0.037**	0.005	-0.003	0.018
within group	(0.004)	(0.015)	(0.035)	(0.003)	(0.009)	(0.017)	(0.004)	(0.014)	(0.034)
Neighbors' schooling,	0.012**	0.005	0.018	0.017**	0.004	0.016	0.016**	0.041***	0.070***
outside group	(0.006)	(0.010)	(0.018)	(0.007)	(0.009)	(0.018)	(0.006)	(0.010)	(0.018)
Constant	6.040***	6.249***	6.259***	6.019***	6.143***	6.143***	5.720***	6.007***	5.993***
	(0.253)	(0.247)	(0.246)	(0.237)	(0.209)	(0.207)	(0.247)	(0.242)	(0.244)
Observations	2148	2148	2148	2158	2158	2158	1284	1284	1284
R-squared	0.35	0.35	0.35	0.35	0.35	0.35	0.37	0.37	0.37

Robust standard errors in parentheses and clustered by township. Regressors include a set of religion dummies and a set of township dummies.
* significant at 10%; ** significant at 5%; *** significant at 1%