The Evolution of Rural Farming in the Scottish Highlands and the Arkansas Delta: Investments and Inequalities

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ABSTRACT

The development and evolution of an agricultural system is influenced by many factors including binding constraints (limiting factors), choice of investments, and historic presence of land and income inequality. In this study, we analyzed the development of two farming systems: expansive, mechanized farming in the Arkansas Delta and crofting in the Scottish Highlands. We hypothesized that the current farm size in each region can be partially attributed to the binding constraints of either land or labor. The Induced Innovation Model and the Gini coefficient were employed in the analysis of data pertaining to the respective regions' agricultural constraints, investments, and economic inequalities. In Scotland, it was found that the continuous binding constraint was the availability of arable land. In Arkansas, the binding constraint began as land, but experienced points of inflection where the constraint became labor (first as a result of the end of slavery and then sustained by mechanization). Each region's respective inelastic supplies contributed to the investments that were used to maximize the output per binding constraint. We also explored the idea that those investments related to binding constraints have influenced the levels of land and income inequality in the Highlands and the Delta today. The historic presence of slavery in the south has contributed to the Arkansas Delta's relatively high level of income and land inequality today.

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I am from Van Buren, Ark., and lived there throughout my life until I came to school at the University of Arkansas in Fayetteville. I graduated in May 2012 with a Bachelor of Science in Environmental, Soil, and Water Science. I chose to participate in the honors program while I was in school and I found many opportunities to explore my interest through the generosity and support of the faculty and administration of the Dale Bumpers College. During my time at the University I was able to travel to France to study language, to Belize with a community development project, and to Scotland to study ecology and environmental policy. I will move to Scotland in the summer of 2012 to pursue professional experience in forestry and environmental education.

I would like to thank Lanier Nalley as well as Frank Farmer and Curt Rom for advising and supporting me during my honors thesis construction, research, and defense. This experience will be beneficial when conducting further research and applying to graduate school in the future.

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INTRODUCTION

The historic selection of appropriate farming systems involved a complicated set of decisions based on a variety of factors which characterized the community that they supported. In order to realize maximum efficiency (high yields, caloric sufficiency, and profit) and environmental health (sustainability and degree of biodiversity) in food production and distribution, the proper farm size, number of farms, crop choice, and management practices are among the factors affecting communities when developing an appropriate farming system (Spencer and Stewart, 1973). Spatially and temporally analyzing empirical farming differences can assist in the identification of the factors that most directly affect the efficiency, sustainability and suitability of these systems and, therefore, can reveal connections to the nature of a farming system's progression and development. Agricultural constraints (natural resources, labor, and technology) also have played a historic role in shaping farming communities both in Europe and the United States. Historic constraints from over 100 years ago still affect farming size and output today. Two such specific examples are the current farm systems in use today in the Arkansas Delta in the United States and in the Highlands and Isles of Scotland.

In the Scottish Highlands the farming system currently in place is known as crofting. Crofting is a small-scale food production system that is largely unique to the Highlands and Isles of Scotland. Typically, crofters are tenants of their strips of land, meaning they rent land from a landowner in exchange for money or crops they produce on the land. Crofters use the land as a means to supplement their family and income while they are also typically employed by industries or the public sector, making most crofters semi-subsistence farmers (Hawkins, 2011). The average croft size is 4.86 hectares (Logie, 2007). In contrast, the farming system in the Arkansas Delta in the United States is predominantly large-scale cotton, rice, and soybean production (USDA, 2012). These farmers are tenants as well, in the sense that approximately 50% of the land is rented, but also serve as suppliers to large agricultural and food corporations. The average farm size in the Delta is 113.72 hectares (USDA, 2012).

We hypothesized that certain factors such as binding constraints, investments, and land and income inequality have greatly affected the formation of current rural farming systems in the Scottish Highlands and Arkansas Delta. The objective of this comparative study was to analyze the historical setting during the time of agricultural development in each area. The objective was also to explain the limiting factors in each system and in turn analyze how each region evolved in their distinctive ways. We hypothesized that farm size in both areas has evolved as a result of the inelastic supply of land or labor. In Scotland's case, the binding constraint is land while in the Arkansas, the binding constraint is labor. These limitations have stimulated the investment in particular agricultural technologies that maximize the output per elastic supply. We also hypothesized that these investments relating to constraints have affected land and

income inequality trends that persist today, particularly in the United States. Our final hypothesis is that the development of large, mechanized farms, as well as the historical presence of slavery, has contributed to the southern United States' (which includes the Arkansas Delta) level of inequality while the smaller, more frequent crofts and the grassroots efforts for crofters' rights has served to combat the same levels of inequality in Scotland today.

MATERIALS AND METHODS

The sources in this study include a range of readings and data involving the agricultural development of the Arkansas Delta and the Scottish Highlands as well as studies done on the historical evolution of the regions. Two methods were implemented to better understand how agriculture evolved and the level of inequality in each region: the Induced Innovation Model and the Gini coefficient, respectively.

Statistical Analysis. The Gini coefficient is one of the primary quantifiers of inequality in research and is a summary statistic of the Lorenz curve (Xu, 2004). The index is used to measure the dispersal of data points of a distribution (income, land, consumption, etc.). This study used the index to measure income inequality in the Arkansas Delta and the Scottish Highlands. It should be noted that the Gini coefficient does not speak to the wealth of a country only how that wealth is divided amongst its citizens. The Lorenz curve is represented in the following equation:

$$L(p) = L(F(y))$$

where $L(p)$ represents the proportion of total income of the area that is obtained by the lowest p^{th} fraction of the population and $F(y)$ is the cumulative distribution function of income when the distribution is continuous (Xu, 2004). The Lorenz curve includes the entire income distribution of a population instead of excluding those incomes above a certain value. When income distribution is equal (e.g. 50% of the population makes 50% of the income) the Lorenz curve is represented by an angle of 45 degrees (the diagonal line of equality). Since income in a population is rarely equal, Lorenz curves lie below the line of equality (Fig. 1) (Grainger and Stewart, 2007).

The area between the diagonal line of equality and the Lorenz curve for a population is the value of the Gini Coefficient and is a ratio. This can be represented by (Xu, 2004):

$$G = \frac{A}{A+B}$$

where A is the area between the line of equality and the Lorenz curve and B is the area below the Lorenz curve. If all the available income in a group is held by one person then the Gini coefficient would be equivalent to one. As income distribution approaches equality, the ratio approaches 0. The ratio is often multiplied by 100 and noted on a scale from 0 to 100 (Leathers and Foster, 2004). The Gini coefficient does not simply illustrate the amount of wealth a country possesses, but instead the equality of the distribution of total income in that country (Xu, 2004). While certain criticisms exist on the validity of the Gini coefficient (presence of an informal market, age and wage differences, etc.) it is a widely used and cited inequality indicator.

Induced Innovation Model. First developed by Vernon Ruttan and Yujiro Hayami in the 1960s, the Induced Innovation Model includes technical change as an internal factor in agricultural development (Ruttan and Hayami, 1998). The model seeks to explain the historical trends that affect how technology (e.g. labor-saving or yield-enhancing) evolves in an agricultural system to balance abundant resources with binding constraints (Ruttan and Hayami, 1998). For this study, the specific constraints (inelastic supply) of both land and labor were considered in the mechanization and farm size of the Arkansas Delta and the Scottish Highlands. The Induced Innovation Model indicates where money should be invested in an agricultural system based on the limiting factor. Different paths of agricultural development have evolved out of the aspiration to increase output per limiting factor.

RESULTS AND DISCUSSION

The Induced Innovation model for agricultural development helps explain how binding constraints (land or labor) have affected investments in agricultural technology in both the Delta and the Highlands. The first hypothesis of this study was that farm size in both agricultural regions has evolved because of different binding constraints resulting in differing technological investments. We hypothesized that the investments would strive to maximize the output per the factor with the highest inelastic supply. By graphically representing the evolution of each farm system, the historic trends in labor and capital investments and constraints that helped shape the agricultural development in the Delta and the Highlands over time can be examined (Fig. 2).

In the Scottish Highlands, land is currently and always has been the binding constraint given the small amount of arable land. The runrig system in the early 1700s was largely inhibited by land limitations (Fig. 2, S1) and thus the tenants had to extract the most productivity out of their small holding in order to maximize the output per hectare. A typical runrig farm included a group of small families that each rented a portion of a larger piece of land (Gray, 1952). Individuals in the runrig system did not rent a fixed area of arable land, but instead rented a fixed share of the total land on the farm. These shares were annually re-allotted to the tenants on the

farm in a rotational farming system. The terrain in Scotland served to break up most of the larger sections of arable land because of hills, bracken, and moorland. The Induced Innovation Model would indicate that the productivity of the land had to be maximized which led to the investment in increased land management techniques like drainage, re-seeding, liming, and bracken control (Scottish Natural Heritage, 2002).

During the Highland Clearances (Fig. 2, S2) farms were consolidated in the inner Highlands for sheep pasture and tenants were removed from the land; most emigrated or moved to the islands (Catto, 1973). The Clearances occurred during the 18th and 19th centuries. The term "Clearances" refers to the mass, forced emigration that was enacted upon the farming population in the Highlands by landlords. Sheep farming, above all other factors, was the main catalyst for the Clearances. The sharp population decrease, however, was not enough to change the limitation to labor as the amount of land suitable for pasture and arable crops in the Highlands is dramatically sparse. Only around 1.62 million hectares of the 6.68 million hectares of classified farmland in Scotland is actually considered arable and grassland (Catto, 1973).

The main agricultural investments after the Clearances continued to be technologies and crops that maximized output per unit of land (Fig. 2, S3). Potatoes, barley, turnips, and oats were the main arable crops grown (Hance, 1952) and lime was a major soil input to combat soil acidity (Scottish Natural Heritage, 2002). The investments resulting from this land constraint have encouraged small farm sizes in Highlands as the current average farm size is about 4.86 hectares (Logie, 2007). The geography of the Highlands also still serves to inhibit connection of arable land, making it nearly impossible to attain consolidation of separate farms.

The Induced Innovation Model can assist in understanding why Scotland today has more income equality in comparison to Arkansas farming communities.[1] We hypothesized that the development of large, mechanized farms and the historical presence of slavery have contributed to high levels of land and income disparity in Arkansas today and furthermore that the small, frequent crofts in the Highlands coupled with a strong initiative for crofters' rights has served to combat inequalities in Scotland today. In the late 2000s, Scotland had a Gini value of 0.34 and Arkansas had a value of 0.46, meaning Scotland was closer to income equality (Burkey, 2010; Grainger and Stewart, 2007).

The investments and constraints that Scotland has experienced, and the resulting farm size, have contributed to levels of income equality today. Smaller farm sizes allow for greater farm frequency and more opportunity for a larger portion of the population to own or rent land. In June 2010 the Northwest region of Scotland (Shetland, Orkney, the Outer Hebrides, and Highlands) was home to 45,024 agricultural holdings with crops and grass (Scottish Government, 2011). Grassroots movements that exist to preserve the crofting way of life have also been successful in maintaining a more equal distribution of land and income through the campaign for crofters' rights. In 1976, as a result of the outcry by the Scottish Crofting Federation and other individual crofters, the Crofting Reform (Scotland) Act granted crofters the right to purchase the full title to their crofts, allowing for a higher percentage of total land to be distributed more evenly (Doughty, 1999).

In contrast, the Arkansas Delta has experienced two distinct inflection points which varied its binding constraints due to the end of slavery and the advent of relatively expensive labor and relatively cheap mechanization. Land was the binding constraint in the early 1800s before the Civil War when slavery was becoming more prominent (Fig. 2, US1). As the total percent population of slaves in Arkansas rose from 11% in 1820 to 20% in 1840, the supply of cheap labor increased (Bolton, 1982). This allowed plantation owners to devote more of their income to buying/ consolidating land which led to the loosening of the constraint on land (Fig. 2, US2). Neither land nor labor was a binding constraint in this time due to increases in productivity from artificially cheap labor, leading to increased profits which allowed for more land purchases (Fig. 2, US2). That being said, after the end of the Confederacy which freed thousands of slaves in the south, the price of labor increased due to mass migration and an increasingly expensive labor supply. This resulted in a shortage of cheap labor and thus a move towards mechanization on the larger farms (Fig. 2, US3).

The effects of binding constraints are evident when comparing lines labeled US2 and US3 (Fig. 2). Movement in US2 is vertical and horizontal (improving output *per person* and *per hectare*) while US3 is moving primarily in the horizontal direction of increasing output *per person*, implying a labor constraint. The decrease in cheap labor (freed slaves) was further exacerbated by the mass emigrations (reduced supply) from Arkansas as a result of the Great Migration. Since the Great Migration ended farms have continued to grow in size (land is not the binding constraint) and decrease in frequency due to the labor constraint.

The small, family farm is being replaced by mechanized, monoculture farms in the Delta today. The current average farm size for Arkansas is 114 hectares (USDA, 2012). In 1999, the Arkansas Public Policy Panel released a report on the evolution of farming communities in Arkansas from

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[1] It should be noted that more income equality is not equivalent to more wealth per farmer, only that the wealth that does
    exist (which could be more or less) has a more even distribution.

1987 to 1997. According to the report, 60% of the total farm sales in 1997 in the state were made by 7% of the largest farms (Arkansas Public Policy Panel, 1999).[2] Nearly every agricultural sector in Arkansas followed the same trend of a decrease in frequency and an increase in average size from 1987 to 1997. The number of poultry farmers decreased by 12%, but rose by 58% in average size. Rice farms decreased by 25%, but have seen a 78% average size increase. Cotton farms are down by 30%, but size has increased by 160%. There is fewer than half the amount of hog farms existing, but the size of an average hog operation has increased by 385%. There has been a 31% increase in corporate farms, but a 9% drop in privately owned farms (Arkansas Public Policy Panel, 1999).

These percentages are driven largely by several factors including mechanization and farm subsidies which contribute to mechanization. In 1997 the federal government distributed nearly 1.5 billion dollars to farms, most of it going to the largest operations. Farms of 2,000 acres or more received almost 14% of their annual income in subsidies that year (Arkansas Public Policy Panel, 1999). The policy of the Government's agricultural subsidies has contributed to centralized, large-scale farming operations that now are prevalent in the Delta. Mechanization has become the chosen route for most Delta farmers *and labor* continues to be an inelastic supply.

The historical constraints and their evolution have contributed to land and income inequalities that still affect Arkansas today. These large farms are concentrated in the Delta as it is the primary row and cash crop agricultural region in Arkansas. Of the 15 highest Gini values for income distribution in Arkansas in 2000, 8 are located in Delta counties (Burkey, 2010). A high level of income inequality exists in the Delta region which can be partially attributed to large, mechanized farms resulting from how agriculture evolved in Arkansas. Given the evolution of Arkansas agriculture, the large farm size is ideal for mechanization because of relatively high labor costs. Mechanization has reduced the labor needed to produce goods, contributing to higher unemployment (and more income inequality), *ceteris paribus*. This is illustrated by the fact that agriculture represented 10.4 percent of the total state GDP in 2009 with a large portion of that going to the production of commodities which benefits the land owners (McGraw, et. al., 2009). This means a majority of the income is held by a few, wealthy farmers.

Another factor that has influenced inequalities in Arkansas, and in the southern U.S. as a whole today, is the historic presence of slavery. There is a relationship between income inequality in the U.S. in 2000 and percent of total population made up of slaves in 1860 (Nunn, 2007). Southern states (Mississippi, South Carolina, Alabama, Louisiana, Arkansas, Georgia, etc.), those with a higher slave proportion in 1860, had the highest level of income inequality in the country in 2000, suggesting that slavery has contributed to the inequalities that permeate southern society today (Nunn, 2007). This assertion is further supported by the fact that in 1860 the southern states, the states with the highest numbers of slaves, had the highest level of land inequality during that time. The relationship between land inequality in 1860 and income inequality in 2000 also points to the continuation of inequalities in the south. Southern states with the most unequal land distribution in 1860 also had the most unequal income in 2000 (Nunn, 2007). Although slavery, and the inequality that comes with it, is not the only factor that contributed to the continuation of inequalities in Arkansas and the rest of the south, it is a significant factor in the unequal distribution of income and land in the Delta today.

CONCLUSION

As a result of analyzing both the Scottish Highlands and the Arkansas Delta with the Induced Innovation Model, it can be seen that the binding constraint for Scotland today remains land and in the Delta, labor. The hypothesis that farm size in both regions evolved as a result of the technological investments made to combat these constraints is supported by the chain of historical events depicted in Fig. 2. Scotland's inelastic supply of land contributed to smaller farm sizes because more focus was placed on maximizing output per unit of land rather than output per worker. Land management technologies dominated investments in the Scottish Highlands. In the Arkansas Delta the binding constraint is currently labor. Historical setting again contributed to this outcome as investments in the 20th century were mainly related to mechanization. This type of investment, however, was found to have come to prominence after the loss of the cheap labor (slaves) that occurred in the south. The variance in binding constraints in Arkansas was an unanticipated discovery in this study. It is also important to note that geography, population distribution, and government policy also had an effect on farm size evolution.

The hypothesis that the investments which resulted from binding agricultural restraints were found to contribute to the level of land and income inequality was supported when comparing Scotland's and Arkansas' current Gini values and the correlation between the historical presence of slavery and land and income inequality in the southern United States

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[2] Given the loose definition of a farm and the fact that the state average includes many smaller farms in the northwest portion of the state, the average Delta farm is inevitably much larger.

today. The relatively small size and high frequency of crofts contributed to lower levels of inequality today in comparison with Arkansas. It was also found that the crofters' rights initiatives that have occurred in the 20th century served to aid in combatting higher values of inequality in the Highlands today. This does not comment on the relative wealth of the average Scottish citizen in farming communities in comparison to their Arkansas counterparts, only that the wealth amongst them is more evenly distributed. In contrast, the large, mechanized farms that developed in the Arkansas Delta were found to be a contributing factor in the current high levels of land and income inequality today. Mechanization reduces the need for labor inputs, which in turn can increase unemployment in the affected area. The study also found that the greater the historical presence of slaves in a state, the greater the income inequality of that state today.

Although it is undeniable that other factors have influenced the development of the agricultural systems in the Arkansas Delta and the Scottish Highlands, it is clear that historic binding agricultural constraints, the choice of investments, and economic inequalities have contributed to the current agricultural systems in place today, particularly in terms of farm size.

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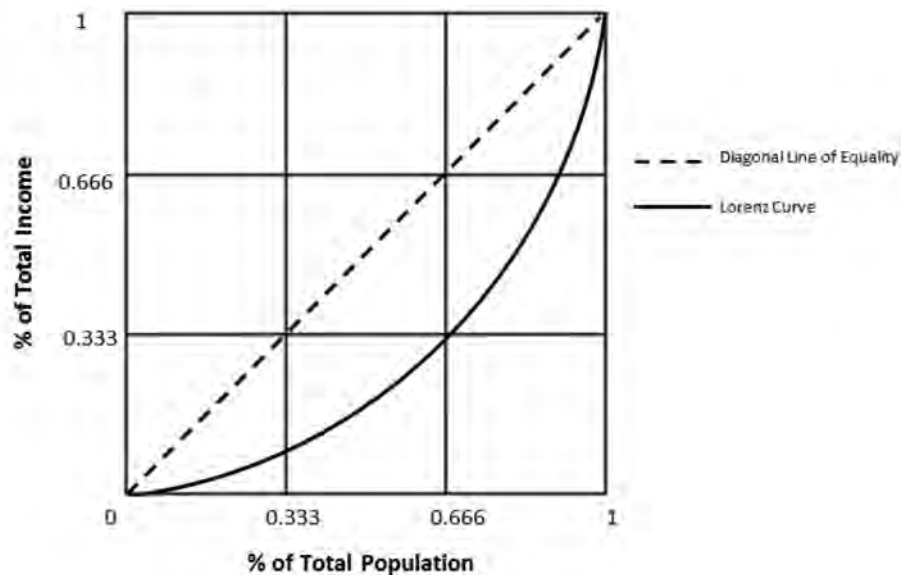
Fig. 1. The relationship between the 45 degree line of equality and the Lorenz curve.
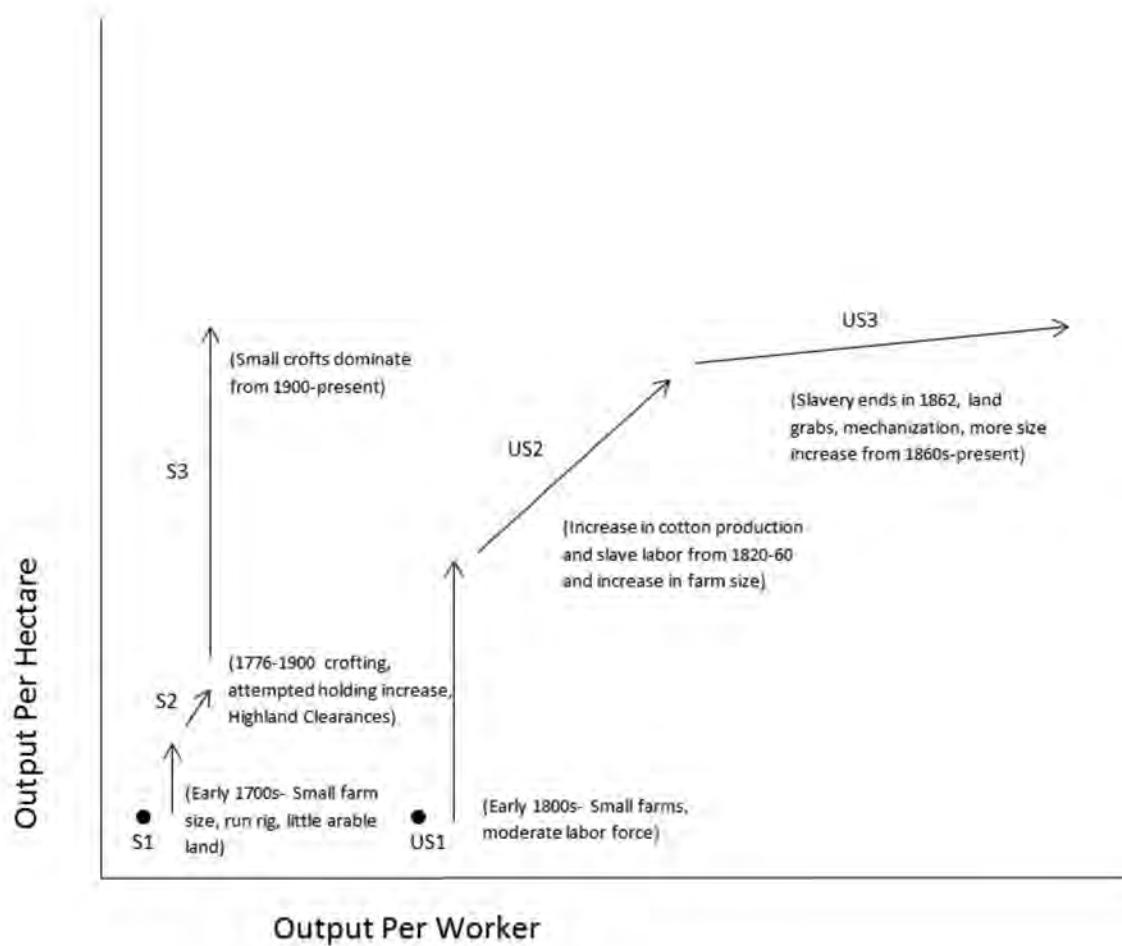
Fig. 2. Trends of agricultural development in the Arkansas Delta (US) and the Scottish Highlands (S) to illustrate the relationship between output per hectare and output per worker in an agricultural system and exhibit the degree of limitation by land and labor.