Agricultural Change in the United States: Evidence from the Golden Age of Radio *

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Abstract

I use the early twentieth-century establishment of commercial radio in the United States to quantify the impact of locally relevant farm programming on productivity growth. Using variation in exposure to radio due to topography, my analysis shows that the broadcasting of local farm programming led to an increase in the productivity of land used in agriculture that persisted for at least two decades. This positive effect was not limited to a certain region, and was felt in a variety of important crops grown across the country. Consistent with radio reducing information barriers, the productivity gains were more pronounced for farmers on areas with lower literacy rates and economic status, lower media saturation, and reduced transport connectivity via railroads.

Keywords: Agricultural Productivity, Information Access, Technology Adoption
JEL Classification: N52, N72, O33.

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1 Introduction

One of the biggest questions in economics is: why cross-country differences in productivity are so large? It is a well-known and persistent empirical fact that poor countries have large agricultural sectors with disproportionately low productivity when compared to rich countries (Gollin et al., 2014). One often cited explanation for this fact is the slow adoption of new technologies in developing countries, possibly in part due to limited access to information. Because the agricultural sector thrives on information that is specific to geography, climate, and other local factors, understanding the role of different sources of information can offer important policy implications.

This paper investigates the role of mass media on the provision of localized information that enhances agricultural production. Many studies suggest learning and information frictions as key determinants of agricultural productivity (Foster and Rosenzweig, 1995; Conley and Udry, 2010). Yet, empirical work unpacking the effect of mass media on agricultural productivity is limited. Here, I examine the role of radio broadcasting on agricultural change in America during the 1920s to 1950s. This period in time, known as the "Golden Age" of radio, offers a unique setting as it coincides with a dramatic transformation in agriculture with the developments of high yield crop varieties, chemical fertilizers, soil conservation practices, and innovations in farm machinery. I analyze the impact of exposure to local farm educational programming from radio on agricultural productivity on the short and medium run and seek to understand the mechanisms through which this information channel influenced agricultural growth.

I compile a novel data set of digitized records with technical information on all commercial radio AM radio stations in operation between the 1920s to 1950. I also gather from historical sources a list of educational radio stations with an emphasis on broadcasting locally relevant farm programming. Using an engineering model of sound propagation, these data allow me to predict across space and over time the degree of a county's exposure to farm radio, proxied by radio signal strength. I pair the radio data with county-level panel data from the U.S. agricultural census covering this time period (Haines et al., 2014), measuring various agricultural outcomes such as the value of agricultural land, the aggregate value of crops, and the production of major cash crops.

Distinguishing the informational effects of radio from other amenity effects is a difficult task. One econometric challenge concerns the endogenous location of radio stations. As an urban phenomenon, commercial radio stations face a problem of maximizing advertising revenue which is tantamount to maximizing listenership in cities.[1] On the other hand, educational radio stations broadcasting local farm programming are often associated with and co-locating at universities. I address this endogenous location concern by exploiting spatial exogenous variation in signal strength. The identification comes from (1) the opening and closing of radio stations over time, (2) changes over time in broadcasting technology resulting typically in increased radiated power from a station's transmitters, and (3) an empirical strategy first used by Olken (2009) to exploit residual spatial variation in the strength of AM radio signals due to topographic factors.

Another challenge concerns the bundling of all other forms of radio programming not related to the agricultural sector, but which may nonetheless impact the livelihood of agricultural workers. I explore this issue by examining the effects of exposure to farm-focused radio stations versus all other (non-farm-focused) radio stations in an attempt to isolate the effect of the provision via radio of information that is relevant to local farmers.

I start by documenting that counties with higher exposure to farm radio displayed higher overall agricultural productivity. Specifically, a one standard deviation increase in the signal strength of farm radio increased the per acre value of farm land by 2.1%. I find suggestive evidence that this effect was larger in counties with less access to alternative sources of information through other radio stations, in counties with decreased transportation connectivity measured by proximity to railroads, and in counties with lower literacy rates and lower economic status measured by averaged occupational income scores.

To ensure that these first findings did not conflate productivity with other amenity effects

[1] While half of American urban homes had a receiver by 1930, only 27 percent of rural homes did. (Craig, 2006)

of radio that could influence land prices, I show the effect is robust to quantifying agricultural productivity with a revenue-based measure of the per acre value of all crops combined. Using this alternative productivity measure, a one standard deviation increase in farm radio signal led to a 4.4% increase in crop value per acre. I also conduct a falsification test using exposure to other radio stations that did not place an emphasis on farm content. This test shows that the main results were not driven by any radio exposure *per se*, suggesting instead the effects were unique to farm radio programming. I finally unpack the effects of farm radio on the productivity of five of the largest cash crops grown across the entire U.S. during the time, finding significant positive results for all but one crop, ranging from 3.9% in oat yields to almost 10% on cotton yields.

In a related empirical strategy, I exploit the residual variation over time and space in signal strength to estimate the dynamic effects of farm radio with an event study design. I find the effect on overall agricultural productivity measured by the per acre value of farm land persisted throughout the decades of radio's Golden Age and amounted to approximately 8% over the 1920s to 1940s for the counties that received farm radio signal early on, but the effect on the per acre value of crops is short-lived. Taken together, all the findings show that mass media can lead to persistent growth on the agricultural sector.

This paper contributes to the literature on the effects of information access and learning on agricultural productivity (for survey papers related to this literature, see Aker (2011), Bridle et al. (2020), and Suri and Udry (2022)). In particular, my paper is closely related to recent ongoing work by Gupta et al. (2020), who study the role of mobile phones on technology adoption and productivity in agriculture, though our papers differ in my emphasis on a one-way and affordable form of mass communication through radio. My paper is also related to a variety of social projects and randomized trials conducted in the developing world seeking experimental evidence of the impact of radio on farmers' knowledge and welfare. My work complements this body of research with a historical lens from the perspective on a developed country during a time when alternative sources of information were scarce in rural communities. Lastly, recent work by Kantor and Whalley (2019) emphasize the local nature of spillovers from universities on agricultural productivity in the late nineteenth century. As their estimated spillover effects dissipate within 20 years, their findings suggest a reduction in the value of information diffusion that occurred through interactions in close proximity between farmers and researchers early in the twentieth century, as these interactions were supplanted by new technologies allowing for long distance communication such as the telephone and radio.

I also contribute to a growing body of work employing electromagnetic signal propagation models to study the effects of mass media. Social science researchers have used these models to study mass media's impact on a variety of contexts such as public spending (Strömberg, 2004), social capital (Olken, 2009), and political persuasion (Enikolopov et al., 2011; DellaVigna et al., 2014; Adena et al., 2015; Gagliarducci et al., 2020; Wang, 2021).

2 Historical Background

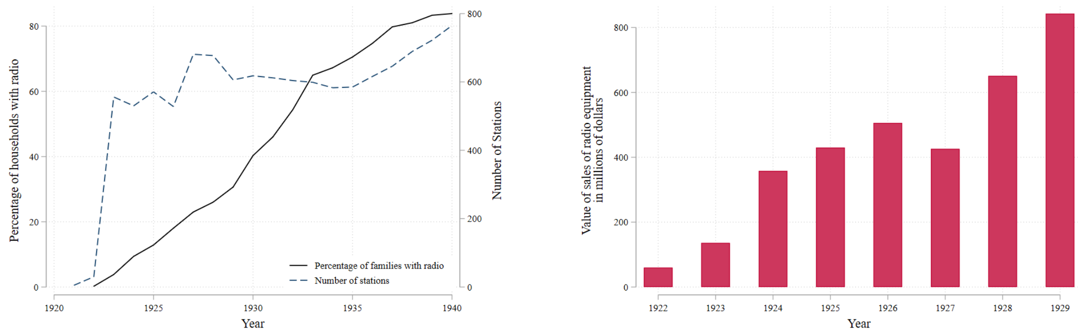
2.1 The Expansion of Radio in the US

The origins of broadcasts from commercial radio stations trace back to the start of the 1920s. As a new medium for entertainment and educational information, radio quickly became a household favorite throughout the US. The immediate popularity of radio is evidenced by its rapid expansion. Panel (a) of Figure 1 shows the share of American families owning a radio increased steadily from zero to 4o% at the end of the decade and 80% by 1940. The number of commercial stations climbed sharply from zero in 1920 to roughly 600 by the end of the decade. Sales of radio equipment increased fourteenfold during the same time period (panel (b)) and an estimated fourteen million US homes owned radios by 1930.

On a radio conference in 1922, recognizing the value of radio for farmers, then secretary of commerce Herbert Hoover stated that "no single use of radio should take precedence over its use for agriculture..." In fact, farmers knew to tune in at specific stations for weather forecasts and crop reports, as well as educational talks on agricultural technologies (Wik, 1981). The US Department of Agriculture (USDA) was heavily involved in the production

Figure 1: Growth of radio, 1920 to 1940

(a) Radio penetration **(b) Sales of radio equipment**



Notes: Data for panel (a) is from the 1940 *Broadcasting Yearbook* (Broadcasting Publications, Inc., 1959). Sales data for panel (b) is from (Douglas, 1987).

of farm programs targeting the dissemination of frontier technologies of relevance to farmers. These included nationwide programs providing general advice to farmers, such as the famous *National Farm and Home Hour*, *Farm Flashes*, and *Housekeeper Chats*. Appendix Exhibit 1 shows selected excerpts of radio programming compiled from transcripts of the National Farm and Home Hour.

On a local level, farming information was delivered by state agricultural radio programs associated with land-grant colleges, state universities, and state agricultural extension services. Land grants often had strong agricultural programs and a close relationship with the USDA and state and local agricultural organizations, so the match-up was natural. By the end of 1922, "stations such as the University of Wisconsin's WHA, WOI at Iowa State College, WKAR at Michigan State, and Texas A&M's WTAW were all carrying a regular schedule of locally-produced agricultural broadcasts" (Craig, 2001). The typical educational radio station dedicated approximately one-fifth of airtime to market and technical information for farmers (Tyler, 1933). Radio played an important role in diffusing innovations stemming from research performed at state agricultural experiment stations.

While the societal value of radio for farmers was widely recognized, the preferences of rural audiences were not a focus of most commercial radio stations. Even though rural listenership increased substantially over time, few advertisers were willing to pay to reach an audience they considered to be made up of relatively unimportant consumers. Anecdotally, farmers sought entertainment on the evenings in commercial radio stations but agricultural information during daytime, highlighting the importance of government-sponsored educational radio service.

2.2 Radio and the Modernization of Rural Life

At the beginning of the 20th century, rural America was being left behind in technological and social evolution. Concerned with the economic consequences of the increasing gap between urban and rural areas, many reformers suggested closing the gap through innovations with the potential of integrating farmers, such as the telephone, the automobile, electricity, and radio. By the 1920s these four technologies had been introduced in rural areas, and by 1930 half of farms in the US had automobiles. The radio boom of the 1920s was largely an urban phenomenon, and adoption at farms was initially slower due to lack of electrification[2] and to the high cost of radio equipment. As the radio industry matured, manufacturers began marketing battery-powered "farm radios" and by 1940 more farms owned radios than had telephones, automobiles, or electricity (Craig, 2006).

3 Data and Empirical Strategy

The empirical strategy seeks to quantify the effect of exposure to local farm content broadcast in AM radio on agricultural productivity and understand how provision of information impacted farmers' productivity decisions.

A key strength of this analysis is the ability to leverage exogenous variation in exposure to radio due to the impact of local topography on the propagation of radio waves.[3] I

[2]Only 10% of farm homes had electricity by 1930.

[3]The path of AM signal propagation varies throughout the day. While at nighttime the AM signal travels long distances through "skywave" propagation, signals in daytime travel by conduction over the surface of the Earth. Importantly, most farm programming occurs during morning hours and at noon, where topography plays a role on how far the signal travels.

first calculate for each radio station-county pair the "free space" signal strength where the Earth is assumed to be a smooth surface, devoid of any features which may act as barriers to the propagation of radio waves. The free space signal strength at any point is inversely proportional to the square distance from a radio transmitter and also a function of the electrical conductivity of the ground and the broadcasting technology. Next, using the method developed by Olken (2009), I attenuate the free space signal strength by the propagation loss due to geographical features on the path from the radio transmitter to the receiving county. This is done with an off-the-shelf implementation of the Irregular Terrain Model (ITM), developed by the U.S. government and considered an industry standard for predicting broadcasting signal strength (Oughton et al., 2020). Below, I describe the radio data used to measure point-to-point signal strength of AM radio stations at the centroid of each county.

3.1 Data

This paper utilizes novel data on radio availability during the first half of the 20$^{\text{th}}$ century. Data for estimating the signal strength of radio stations is drawn from multiple sources. From the World Radio History Project, I collect information about all commercial radio stations' transmitter power, antenna height relative to ground level [4], and broadcast frequency starting in 1922. These data are cross-checked in different years through various sources (Radio Age, 1927; Radio Digest, 1933; USDA, 1933; Radio Annual, 1950; Broadcasting Publications, Inc., 1959) for completeness. Data on ground conductivity – also utilized for the signal strength calculations – comes from the Media Bureau of the Federal Communications Commission. The topographic profile between a transmitting and receiving points comes from a digital elevation model with 1/3 arc-second (10 meters) spatial resolution.[5]

I classify a station as a farm radio station if it is listed in the State Agricultural Radio

[4] Antenna height is known only in 1940 (Broadcasting Publications, Inc., 1959), and when missing it is predicted through a regression of height on the log of the transmitter power for other years. See Appendix Figure B2 for the linear fit of this regression.

[5] Sourced from the National Elevation Database developed by the U.S. Geological Survey (USGS, 2017).

Programs section of Brunner (1936), compiled in a symposium with inputs from program directors, managers of land-grant college radio stations, heads of agricultural colleges, farm group executives, editors of agricultural publications, and members of State Departments of Agriculture and State Extension Services. Importantly, this classification implies the location of farm radio stations is closely related to the location of land-grant colleges and State-run extension services.[6]

Using these data, I calculate the point-to-point signal strengths between county centroids and the city coordinates of each radio station and assign to each county the maximal signal strength. This operation is done separately for farm radio stations and for other (non-farm) radio stations, resulting in a panel data set measuring county-level radio predicted signal strength on five year intervals ranging from 1925 to 1950.[7]

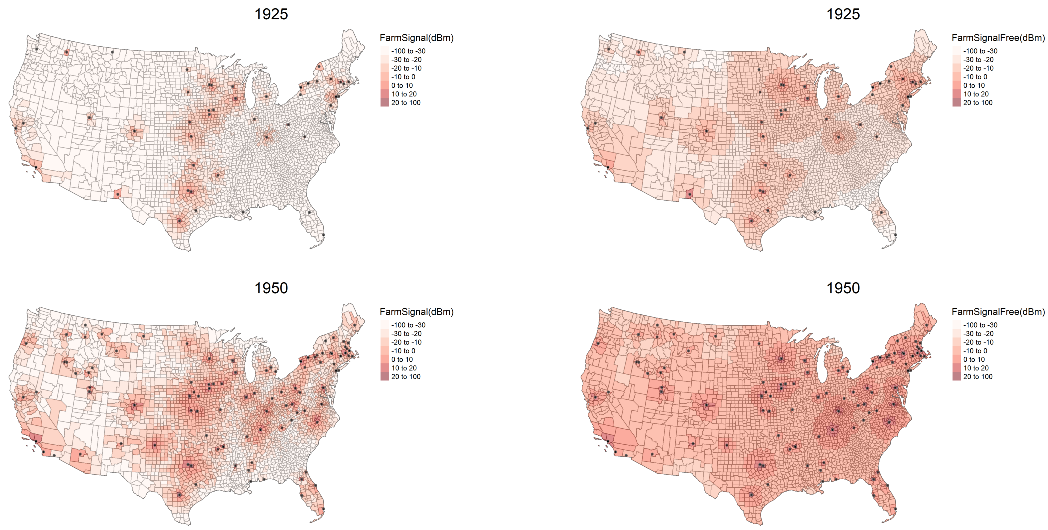
Radio Signal Strength. Figure 2 shows the predicted signal strength of farm radio stations– measured in decibel-milliwatts (dBm) – from the free space ($FarmSignalFree$) and irregular terrain models ($FarmSignal$). The dBm metric is commonly used in radio communication to express absolute power levels. It here serves as a proxy for the quality of radio reception within each county. For ease of interpretation in the analysis, signal strength will be expressed in standard deviations from the mean, with one standard deviation in 1925 corresponding to 20.8dBm for farm radio stations and 14.2dBm for other radio stations.

The panel data set measuring county-level radio signal strength is linked with the following data: time-invariant county-level environmental data on soil quality from Fishback et al. (2005); gridded terrain elevation (USGS, 2017) from which a county-averaged terrain ruggedness index is constructed following Nunn and Puga (2012); time-invariant gridded crop suitability from the Global Agro-Ecological Zones (Fischer et al., 2021) project of the Food and Agricultural Organization (FAO), from which county-level average suitability indices are computed for various crops; and time-varying gridded historical climate data from the

[6]Historically, the location of these land-grant colleges in the 19$^{\text{th}}$ century depended on a variety of political, environmental, and geographical factors. Moretti (2004) supports the idea that "the geographical location of land-grant colleges seems close to random" from the perspective of later developments.

[7]I use radio stations available on the rollout years of agricultural censuses (e.g., 1924 for the 1925 agricultural census). Due to this factor, and availability constraints, the final data draws from published lists of commercial US radio stations in the years 1924, 1929, 1934, 1938, 1945, and 1950.

Figure 2: Signal strength of radio stations broadcasting farm content



Notes: The left figures show the strongest predicted (computed using the ITM) signal strength of farm radio stations in each county, and the right figures similarly show the signal strength in free space, all measured in dBm. Data for 1925 (the top figures) comes from various published lists of radio stations in 1924, and data for 1950 (the bottom figures) from published lists in 1950 as described in the data section.

PRISM Climate Group (PRISM, 2011), used to construct annual cumulative precipitation and mean temperature at the county level.

Lastly, the panel data set includes agricultural census records from Haines et al. (2014) and population census records from Haines (2005). These data contain key agricultural and socioeconomic information used in the analysis and are described in the subsection below.

Census Data. I obtain historical county-level agriculture panel data by combining all waves of the decennial and quinquennial editions of the census of agriculture between 1910 and 1950. Additional socioeconomic data is included from the population census covering the same time period. Linear interpolation is used for some key agricultural and socioeconomic variables in years in which data is not reported in the census.[8] The first two census periods in the sample (1910 and 1920) predate the first commercial radio station and are used mainly for covariates balance checks assuming a counterfactual distribution of radio stations available in 1925.

[8]Detailed variable construction and definitions are available upon request and will soon be included in an online data appendix.

Sample selection. While I collect census data starting from 1910, the first time period in the analysis is 1925 and the sample selection steps below consider the time periods included in the analysis when restricting the sample. I take the following steps to create the balanced panel of counties used in the analysis. Firstly, I map the historical data from all different years and sources into modern county boundaries utilizing the crosswalk developed by Eckert et al. (2020). Then, I drop counties in the top and bottom 1% (pooling data from 1925 to 1950) of the per acre value of farm land and per harvested acre value of all crops. I also drop counties with reported acres of land in farms that exceeds the county's total land area. These observations are dropped due to measurement error in the agricultural census and measurement error introduced by the weights in the county boundaries crosswalk. Lastly, I drop counties with less than 1,000 acres of land and counties that report less than 20% of land in farms in any census year between 1925 and 1950, which for the most part are highly urbanized counties or regions with a topography unfavourable for farming. The resulting balanced panel comprises 2,230 counties within the continental U.S. with modern-day (2010) boundaries, observed over six agricultural census 5-year periods from 1925 to 1950. Panel (a) of Appendix Figure B1 depicts the counties featured in the "baseline" main sample.

Descriptive Statistics. Table 1 shows descriptive statistics of key variables for the year of 1925, the year of the first census of agriculture since the establishment of commercial radio stations in the US. Column (1) presents the mean and standard deviation of relevant variables for the baseline full sample of 2,230 counties remaining after sample selection. Columns (2) and (3) present similar statistics for the subsamples of counties above and below the median predicted signal strength of farm-focused radio stations. Column (4) shows the p-value associated with a test for difference in means between the subsamples from columns (2) and (3).

The Statistics presented in Table 1 illustrate how the distribution of farm radio exposure was far from random. Counties with above median signal strength in 1925 had significantly higher agricultural productivity (panel A) – as measured by farm and crop value per acre – and were more populated (panel B), having on average 1.3 times the population of those below the median signal strength. Panel B also confirms that counties with above median signal strength had a relatively larger agricultural sector. Panel C shows that, as expected, counties with a farm radio station by 1925 will have higher radio penetration in the near future, as proxied by the percentage of farm families with radio by 1930. The panel also confirms the mechanical relationship between predicted signal strength and fixed county factors such as terrain ruggedness and ground conductivity. The results from this table highlight the importance of a well-designed empirical strategy for dealing with endogeneity of radio from its early days.

3.2 Empirical strategy

To examine the short-run impact of farm radio, I use the following two-way fixed-effects estimation equation:

$$Y_{ct} = \beta_1 FarmSignal_{ct} + \beta_2 FarmSignalFree_{ct} + \delta X_{ct} + \gamma_c + \theta_t + \varepsilon_{ct}. \tag{1}$$

In this equation, the variable Y_{ct} is an agricultural productivity outcome of county c in year t, such as farm value per acre. $FarmSignal_{ct}$ represents the maximum predicted signal strength received at the centroid of the county by a radio station broadcasting farm content (hereon "farm radio") in that year and $FarmSignalFree_{ct}$ represents the maximum signal strength assuming unobstructed signal propagation. X_{ct} is a vector of controls for socioeconomic characteristics, climate, and in the richest specification includes an interaction of soil characteristics and year dummies. The baseline specification also includes year (θ_t) and county (γ_c) fixed effects that absorb national trends and time-invariant characteristics across counties. Errors are corrected for clustering at the county level.[9]

The coefficient of interest is β_1, measuring the effect of exposure to farm radio on a given agricultural outcome variable. Far from being randomly placed, radio stations typically locate in areas that maximize listenership and consequently advertising revenue.

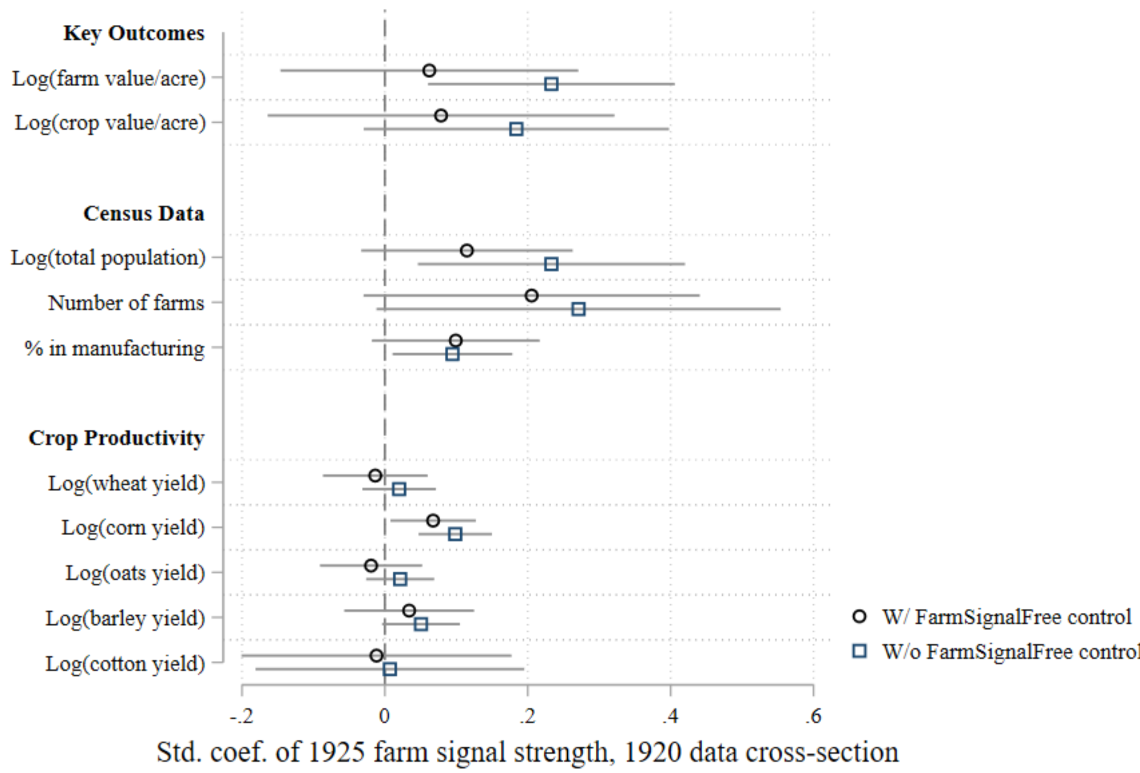
[9] I test the robustness of my main estimates to an alternative method that accounts for spatial correlation in the error terms (Conley, 1999) in Appendix Table A1.

$FarmSignalFree$ alleviates this endogeneity concern as it partials out the decision to locate in densely populated areas, leaving us with residual variation in exposure to farm radio due to topography.

Identification requires this residual variation in signal strength to be unrelated to unaccounted changes in determinants of agricultural productivity. While this assumption requirement cannot be directly tested, Figure 3 presents standardized estimated regression coefficients of farm radio predicted signal strength in 1925 on key outcomes, various predictors of agricultural productivity from census data, and crop productivity in 1920, prior to the establishment of commercial radio stations. These estimates essentially allow us to test for effects of farm radio exposure *prior* to exposure, at a time where no effect would be expected.

Without controlling for $SignalFree$, the test shows that the measure of farm radio signal strength does predict agricultural outcomes and relevant demographic characteristics, confirming what was shown using 1925 data in Table 1. The predictive power of signal strength is expected since the location of radio stations five years later was not random. Upon accounting for this source of endogeneity by controlling for $SignalFree$, the estimated coefficients become smaller in magnitude and in most cases statistically insignificant at the 5% significance level. More is done for the sake of identification in the main analysis, where I can rely on the advantages of the panel setting by including controls and county and year fixed effects. Nonetheless, the results from Figure 3 illustrate the need for controlling for free space radio signal to mitigate threats to identification.

Figure 3: Balance tests



Notes: Plotted standardized coefficients are for the $FarmSignal_c$ variable in a regression on 1920 cross-sectional data of the form $Y_c = \beta_1 FarmSignal_c \; [+\beta_2 FarmSignalFree] + \delta_s + \varepsilon_c$. Regressions includes state fixed effects (δ_s), and errors are clustered at the state level. The grey lines represent 95% confidence intervals. Predicted farm radio signal strength is a 5-year lead (i.e., the 1925 computed signals), as there were no commercial radio stations by 1920, and regressors are constructed from the 1920 population and agricultural censuses.

Table 1: Descriptive statistics, main sample of US counties in 1925

	(1) All	(2) Above median farm signal	(3) Below median farm signal	(4) Diff. p-value
Panel A: Key Outcomes				
Farm value $/acre	60.83	77.14	44.52	0.00
	(44.19)	(50.01)	(29.57)	
Crop value $/acre	10.20	10.47	9.93	0.03
	(5.963)	(4.941)	(6.825)	
Panel B: Crop Productivity				
Wheat yield (bushels/acre)	15.01	17.24	12.62	0.00
	(6.062)	(6.282)	(4.775)	
Corn yield (bushels/acre)	21.31	24.53	18.09	0.00
	(9.223)	(9.072)	(8.192)	
Oats yield (bushels/acre)	24.78	28.93	20.57	0.00
	(10.38)	(10.18)	(8.763)	
Barley yield (bushels/acre)	21.74	23.55	18.80	0.00
	(8.051)	(7.577)	(7.935)	
Cotton yield (bales/acre)	0.36	0.32	0.38	0.00
	(0.128)	(0.167)	(0.0987)	
Panel C: Census Data				
Population (000s)	32.90	37.42	28.38	0.00
	(55.65)	(68.96)	(37.41)	
Number of farms (000s)	2.40	2.45	2.34	0.06
	(1.332)	(1.201)	(1.450)	
% employed in manufacturing	6.26	5.80	6.72	0.01
	(7.858)	(7.696)	(7.994)	
Panel D: Radio Penetration				
% farm families with radio (1930)	22.21	30.63	13.78	0.00
	(19.81)	(19.86)	(15.77)	
Strongest farm radio signal (dBm)	-47.86	-30.06	-65.66	0.00
	(21.95)	(11.24)	(14.28)	
Mean Terrain Ruggedness Index	41.51	35.09	47.94	0.00
	(50.46)	(39.10)	(59.02)	
Ground conductivity	9.39	11.56	7.21	0.00
	(8.254)	(8.172)	(7.754)	
Number of counties	2230	1115	1115	2230

Standard deviations in parentheses.

Notes: This table shows the mean of 1925 county characteristics (except for the % of farm families with radio in panel D, which is sourced from 1930 data). Column (1) shows the means over all counties in the main sample as described in the data. Columns (2) and (3) show the means over the subgroups of counties with predicted farm signal strength above and below median in 1925, respectively. Column (4) shows the p-value of a t test for the difference in the means in columns (2) and (3).

4 Results

Short-run effects of farm radio. The first result presented sheds light on how exposure to farm radio affected overall agricultural productivity on the short run. My main outcome of interest for overall productivity is the per acre value of farm land and buildings (hereon "farm value per acre") as it may capture various dimensions in which farm radio can improve agricultural practices of farmers. The drawback of this measure is it may correlate with other determinants of farm land value unrelated to agricultural productivity, and as such it may conflate any utility derived from listening to radio with changes in productivity due to provision of farming content. I address this concern by investigating the effect of farm radio on additional outcomes that provide narrower measurements of farm productivity. Later in the analysis, I also attempt to isolate any possible effect unrelated to productivity by incorporating to the regression model other radio stations which provide arguably the same utility to households, minus the farming content.

The results of estimating equation 1 with this outcome are reported in Table 2. Moving rightward across the table, we go from sparsest to richest specification. Column (1) contains only county and year fixed effects, and controls are added for farm signal in free space in column (2) and for various socioeconomic and environmental factors in column (3). Column (4), the preferred specification, allows time-invariant county soil characteristics – which may factor on ground propagation of radio waves – to have different marginal effects over time through the inclusion of soil characteristics interacted with year dummy variables. Across all specifications, predicted farm radio signal strength has a positive coefficient significant at better than 1%. Consecutively adding covariates attenuate the estimated coefficients, but do not affect statistical significance. The estimated effect from the preferred specification implies a one standard deviation increase in signal strength leads to 2.1% higher farm value per acre.

The initial results from Table 2 could be attributed to channels unrelated to agricultural productivity, such as other utility value derived from radio exposure. I unpack these initial results firstly by examining more directed measures of agricultural productivity, related to

Table 2: Farm Radio Exposure and Farm Value per Acre

Dependent variable:	Log(farm value/acre)			
	(1)	(2)	(3)	(4)
$FarmSignal$	0.049***	0.034***	0.031***	0.021***
	(0.004)	(0.006)	(0.005)	(0.005)
County fixed effects	✓	✓	✓	✓
Year fixed effects	✓	✓	✓	✓
$FarmSignalFree$		✓	✓	✓
Baseline controls			✓	✓
Soil characteristics × year controls				✓
Observations	13,380	13,380	13,380	13,380
Number of Clusters	2,230	2,230	2,230	2,230
Adjusted R-Squared	0.945	0.945	0.951	0.958

Standard errors clustered at the county level in parentheses

Notes: $FarmSignal$ is a standardized measure (mean zero and variance one) of the predicted signal strength of farm radio resulting from the Irregular Terrain Model. $FarmSignalFree$ in contrast is the predicted signal strength assuming a smooth and featureless earth. Baseline controls include log of total population and farm population, percentage of farms with tenancy regime, and percentage of males, Black individuals, and manufacturing workers. Soil characteristics include soil water capacity, % of soil consisting of clay, soil erodibility (K) factor, soil drainage quality, liquid limit of the soil layer, and soil annual flood frequency. Farm value per acre is the ratio of the combined value of all farms and buildings over the acres of farm land. Standard errors are corrected for clustering at the county level.

crop revenue and crop quantities, as outcome variables. These narrower measures may not be individually relevant to farm radio listeners in the entire US, as crop mix varies largely across the country. Taken together, they offer a more complete picture of the initial results on farm value per acre.

Table 3 presents estimates of the preferred specification of equation 1 with these additional outcomes. Column (1) of the table shows the estimated coefficients using the value of all crops combined (hereon “crop value per acre”) as dependent variable. This outcome quantifies the revenue productivity of cropland. As a revenue-based measure, the overall value of crops may not only capture increases in crop output, but also price differences due to crop quality or due to price dispersion resulting from frictions in the crops market (Kantor and Whalley, 2019). The estimated effect implies a one standard deviation increase in signal strength leads to 4.4% higher crop value per acre, a result that is quantitatively larger than the overall productivity effect using farm value per acre.

Columns (2) to (6) of Table 3 zoom into five of the largest crops grown in the first half of the 20$^{\text{th}}$ century U.S.: wheat, corn, barley, oats, and cotton. These are crops that experienced drastic changes in yields during this time period, both losses due mainly to soil erosion during the Dust Bowl in the 1930s and gains due to technological progress such as advances in plant breeding and chemical fertilizers. With the exception of corn, exposure to farm radio appears to have increased the yield of the examined crops, with the estimated effect ranging between 3.9% for oats and 9.9% for cotton with one standard deviation increase in signal strength. Throughout the country, corn experienced arguably the steepest increase in yield among the examined crops, due partly to developments in corn hybridization. Perhaps word of corn innovations spread fast regardless of radio, as evidenced by the quick adoption of hybrid corn in Griliches (1957) [10].

Event study design. The evidence presented so far offers insights on the short-run effects of farm radio on agriculture. I now turn to a different specification seeking to understand the dynamic cumulative effect of farm radio on agricultural productivity. I do so with a research design that considers exposure to farm radio as treatment events of identical intensity that occurs at the county level, potentially on multiple time periods, following the estimation notation laid out in Schmidheiny and Siegloch (2019).

Treatment assignment occurs when the farm radio signal strength of a county exceeds a threshold, here defined as the median predicted signal strength at 1925, the first period since the opening of commercial radio stations. With multiple events of identical intensity, this implies that treatment $T_{c,t}$ is a dummy variable equaling 1 in any period where the county's farm radio signal exceeds the threshold, and 0 otherwise. I estimate the following equation

[10] Estimates in Griliches imply it took between 4 and 12 years for hybrid corn diffusion to go from 10 percent to 90 percent (Manuelli and Seshadri, 2014).

Table 3: Farm Radio Exposure and Agricultural Productivity – Crop Value and Yields

	Overall crop value	Crop productivity				
	(1)	(2)	(3)	(4)	(5)	(6)
	Log(crop value/acre)	Log(wheat yield)	Log(corn yield)	Log(barley yield)	Log(oat yield)	Log(cotton yield)
$FarmSignal$	0.044***	0.051***	-0.002	0.062***	0.039***	0.099***
	(0.009)	(0.008)	(0.008)	(0.012)	(0.008)	(0.011)
Year fixed effects	✓	✓	✓	✓	✓	✓
County fixed effects	✓	✓	✓	✓	✓	✓
$FarmSignalFree$	✓	✓	✓	✓	✓	✓
Baseline controls	✓	✓	✓	✓	✓	✓
Soil characteristics × year controls	✓	✓	✓	✓	✓	✓
Observations	13,380	11,859	13,257	9,872	12,907	5,109
Number of Clusters	2,230	2,091	2,226	1,894	2,218	878
Adjusted R-Squared	0.829	0.615	0.792	0.485	0.597	0.684

Standard errors clustered at the county level in parentheses

Notes: $FarmSignal$ is a standardized measure (mean zero and variance one) of the predicted signal strength of farm radio stations resulting from the Irregular Terrain Model. $FarmSignalFree$ in contrast is the predicted signal strength assuming a smooth and featureless earth. Baseline controls include log of total population and farm population, percentage of farms with tenancy regime, and percentage of males, Black individuals, and manufacturing workers. Soil characteristics are time-invariant, and include soil water capacity, % of soil consisting of clay, soil erodibility (K) factor, soil drainage quality, liquid limit of the soil layer, and soil annual flood frequency. Crop value per acre is the ratio of the aggregate value of all crops over the acres of harvested cropland. Sample size varies by crop due to differences in which counties have a positive planted area for specific crops, as yields are otherwise undefined. Standard errors are corrected for clustering at the county level.

of levels on changes in treatment:

$$Y_{c,t} = \sum_{\ell=-3}^{4} \beta_\ell D_{c,t-\ell} + \delta X_{c,t} + \gamma_c + \theta_t + \varepsilon_{c,t}, \tag{2}$$

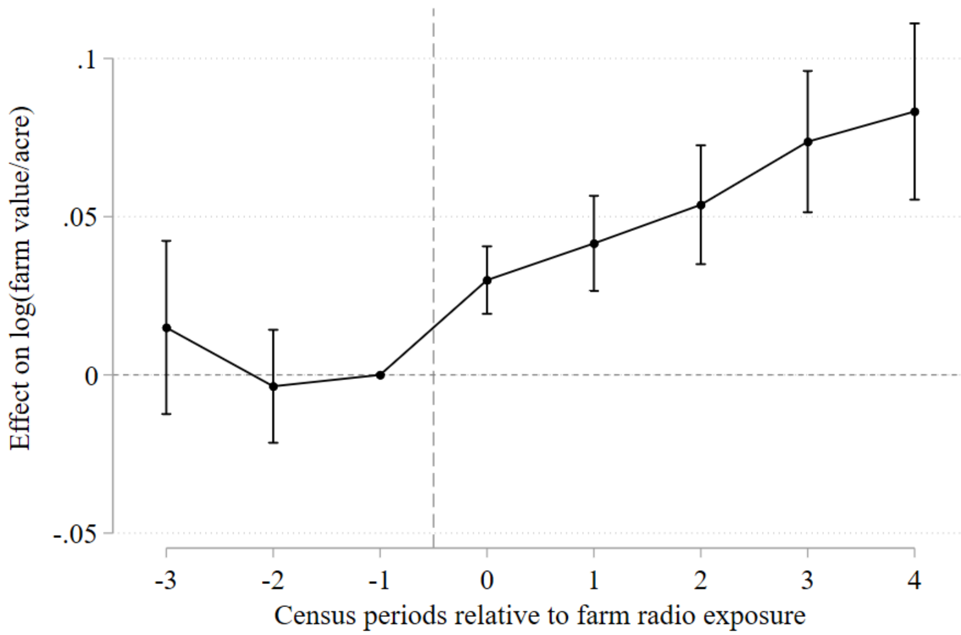
where $Y_{c,t}$, $X_{c,t}$, γ_c, and θ_t are defined as in equation 1. Treatment $D_{c,t-\ell} = \Delta T_{c,t-\ell}$ is the first difference of the treatment status and is assumed to remain constant beyond the endpoints of the event window. The dynamic treatment effects parameters are $[\beta_{-3}, \beta_{-2}, 0, \beta_0, ..., \beta_4]$, normalized to one period prior to the treatment assignment, i.e., $\beta_{-1} = 0$. The periods described in the horizontal axis between each agricultural census are five-year gaps, with the exception of the 1910 to 1920 census, which has a ten year gap.

Figure 4 shows the cumulative effect of farm radio on the two main agriculture productivity measures under the dynamic model with slightly different treatment assignment given by equation 2 where counties are treated if the ITM-predicted signal strengths exceeds the median signal in 1925. While I find no evidence of a pre-treatment effect for farm value per acre on panel (a), the estimated coefficient on one of the pre periods for crop value per acre in panel (b) is significantly different from zero. To interpret these results, the cumulative effect on farm value per acre would imply counties where farmers were exposed to farm radio programming early on would have experienced a growth of approximately 8% on farm land value per acre over after two decades relative to a similar county without farm radio by the end of this same period. The effects on crop value per acre are also positive on the short run but dissipate by the end of the event window.

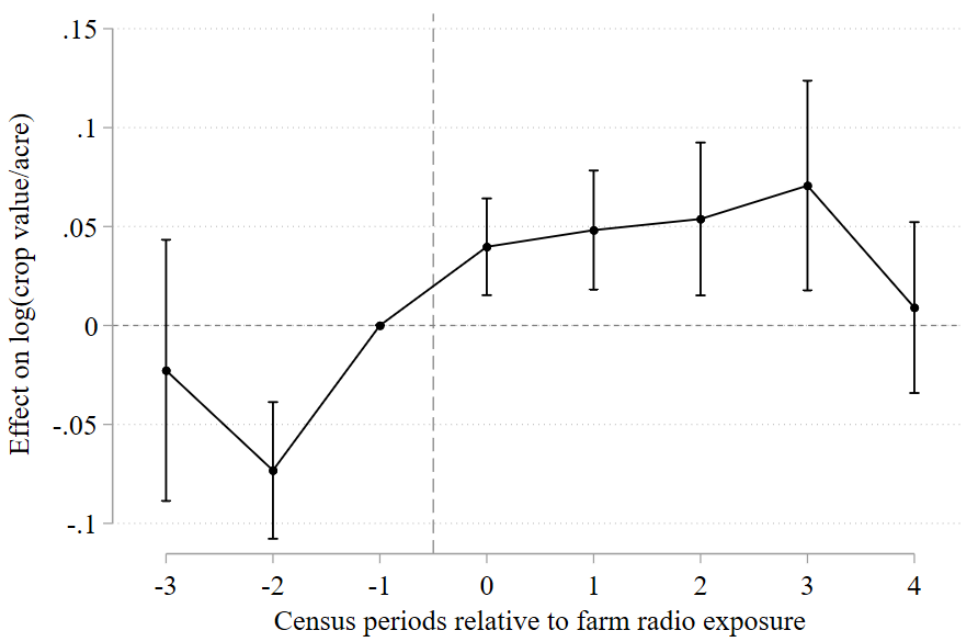
During the sample period, the quality of radio receivers available in households changed dramatically due to new technologies and to changes in the demand for portable radio sets as rural electrification programs brought electric power to farm families. These changes over time could have an unpredictable effect on the dichotomous treatment assignment based on a threshold of signal strength. Because of this limitation, together with the pre-trends of panel (b) in Figure 4, I interpret with caution these results as suggestive evidence that farm radio programming had lasting effects on agricultural productivity.

Figure 4: Cumulative effect of farm radio exposure

(a) Farm value per acre



(b) Crop value per acre



Notes: The figures show point estimates and 95% confidence intervals of the β_ℓ parameters from Equation 2, representing the dynamic cumulative effect of $FarmSignal$ on the outcomes of log of farm value per acre and log of crop value per acre on panels (a) and (b) respectively. The period prior to farm radio exposure is normalized to zero. Standard errors are corrected for clustering at the county level.

5 Channels

I now explore possible channels that might explain the short-run effects of farm radio documented on the previous section.

Other Radio Stations. A possible explanation for the main result presented on farm value is that the agricultural land prices reflect more than just productive value. A potential concern is that the main results could reflect exposure to radio programs in general. Radio offers consumers an amenity through general programming unrelated to information provision to farmers, and such benefits may be reflected on land prices. I explore this channel utilizing data on "other" radio stations that place less emphasis on locally targeted farm content, i.e., stations not included in the curated list from the State Agricultural Radio Programs in Brunner (1936).

Table 4 reports the results from estimating a statistical "horse race" version of equation 1 after adding to the richest specification the other radio stations' ITM-predicted and free space-predicted signal strengths, represented by the $OtherSignal$ and $OtherSignalFree$ variables in the table. While the results on farm radio remain unchanged, I find precisely estimated null effects on overall agricultural productivity, measured both by farm and crop value per acre. These results strengthen the interpretation of the previous subsection that targeted farm radio programming specifically drove productivity growth in the agricultural sector.

Next, I explore possible differential effects of farm radio due to county characteristics that may influence agricultural productivity. To do so, I add to equation 1 an interaction of the ITM-predicted signal strength of farm radio with a variable of interest. For ease of interpretation, these added variables discussed below are also standardized such that they have a mean of zero and standard deviation of one.

Information barriers. Farm radio may have larger benefits for farmers facing higher costs for information acquisition. I test this hypothesis by examining the interaction between farm radio signal and the signal of other radio stations, here acting as a proxy for media saturation. Columns (1) and (5) of Table 5 show that this interactive effect is negative, though only statistically significant for the farm value per acre measure, suggesting that farm radio was particularly helpful for farmers with less access to alternative sources of information. Farmers may also benefit more on areas with less knowledge flows. I utilize data on railroad networks in 1911 from Atack et al. (2010) to compute the distance from county centroids to the nearest segment of railroad, which I then interact with farm radio signal. Columns (2) and (6) show a strong and positive interaction effect, suggesting that more isolated areas with less transportation infrastructure received larger gains from farm radio.

Human capital and economic status. I now explore differential effects derived from demographic characteristics in 1930. Literature dating back to Nelson and Phelps (1966) posit that education can remove barriers to knowledge diffusion.[11] I examine the interaction between farm radio and illiteracy rates in 1930 and find on columns (3) and (8) of Table 5 that the effects of farm radio were larger among the less educated, although the effect is small and insignificant for farm value per acre. I similarly examine farm radio's interaction with economic status, proxied by occupational income score.[12] On one hand, farmers of lower economic status may have higher marginal returns for technology adoption. On the other hand, farmers with higher economic status face lower liquidity constraints and are able to make productivity-enhancing capital investments. Columns (4) and (9) show inconclusive results where the per acre effect of farm radio on farm value is significantly larger in areas with a lower occupational income score, but insignificant and of opposite sign for crop value.

[11] More recent work by Squicciarini and Voigtländer (2015) explore this idea on the context of upper-tail education.

[12] Direct measures on educational attainment and income are not available until the 1940 census. I use the share of illiterate among the population aged ten and above as a proxy for education level. I use county averages of the 1930 occupational income scores (sourced from the 1930 census microdata available at IPUMS), which is commonly used in studies of labor market outcomes from this era (Saavedra and Twinam, 2020).

Table 4: Robustness Check – Exposure to Other Radio Stations

	(1) Log(farm value/acre)	(2) Log(crop value/acre)
$FarmSignal$	0.022***	0.044***
	(0.005)	(0.009)
$OtherSignal$	0.001	-0.008
	(0.005)	(0.010)
County fixed effects	✓	✓
Year fixed effects	✓	✓
$FarmSignalFree$	✓	✓
$OtherSignalFree$	✓	✓
Baseline controls	✓	✓
Soil characteristics × year controls	✓	✓
Observations	13,380	13,380
Number of Clusters	2,230	2,230
Adjusted R-Squared	0.958	0.829

Standard errors in parentheses

Notes: $FarmSignal$ is a standardized measure (mean zero and variance one) of the predicted signal strength of farm radio resulting from the Irregular Terrain Model. $FarmSignalFree$ in contrast is the predicted signal strength assuming a smooth and featureless earth. $OtherSignal$ and $OtherSignalFree$ are similarly defined signal strengths for other (non-farm targeting) radio stations. Baseline controls include log of total population and farm population, percentage of farms with tenancy regime, and percentage of males, Black individuals, and manufacturing workers. Soil characteristics are time-invariant, and include soil water capacity, % of soil consisting of clay, soil erodibility (K) factor, soil drainage quality, liquid limit of the soil layer, and soil annual flood frequency. Farm value per acre is the ratio of the combined value of all farms and buildings over the acres of farm land and crop value per acre is the ratio of the aggregate value of all crops over the acres of harvested cropland. Standard errors are corrected for clustering at the county level.

Table 5: Potential Channels

	Log(farm value/acre)				Log(crop value/acre)			
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
FarmSignal	0.018***	0.021***	0.020***	0.019***	0.042***	0.044***	0.037***	0.044***
	(0.005)	(0.005)	(0.005)	(0.005)	(0.009)	(0.009)	(0.009)	(0.009)
$FarmSignal \times OtherSignal$	-0.006***				-0.004			
	(0.002)				(0.003)			
$FarmSignal \times RailroadDist$		0.016***				0.014***		
		(0.003)				(0.004)		
$FarmSignal \times \%Illiterate$			0.004				0.026***	
			(0.003)				(0.005)	
$FarmSignal \times OccScore$				-0.011***				0.003
				(0.002)				(0.004)
Year fixed effects	✓	✓	✓	✓	✓	✓	✓	✓
County fixed effects	✓	✓	✓	✓	✓	✓	✓	✓
FarmSignalFree	✓	✓	✓	✓	✓	✓	✓	✓
Baseline controls	✓	✓	✓	✓	✓	✓	✓	✓
Soil characteristics × year controls	✓	✓	✓	✓	✓	✓	✓	✓
Observations	13,380	13,380	13,380	13,368	13,380	13,380	13,380	13,368
Number of Clusters	2,230	2,230	2,230	2,228	2,230	2,230	2,230	2,228
Adjusted R-Squared	0.958	0.958	0.958	0.958	0.829	0.829	0.829	0.829

Standard errors clustered at the county level in parentheses

Notes: All baseline variables defined as previously in Tables 2 to 4. *RailroadDist* measures the distance from county centroids to the nearest segment of the railroad network in 1911. *%Illirate* is the percentage of illiterate population aged ten and above in 1930. *OccScore* is the occupational income score in 1930 from individual census microdata in IPUMS, averaged at the county level. These three interacted variables are standardized with a mean zero and variance one. Standard errors are corrected for clustering at the county level.

6 Additional Results

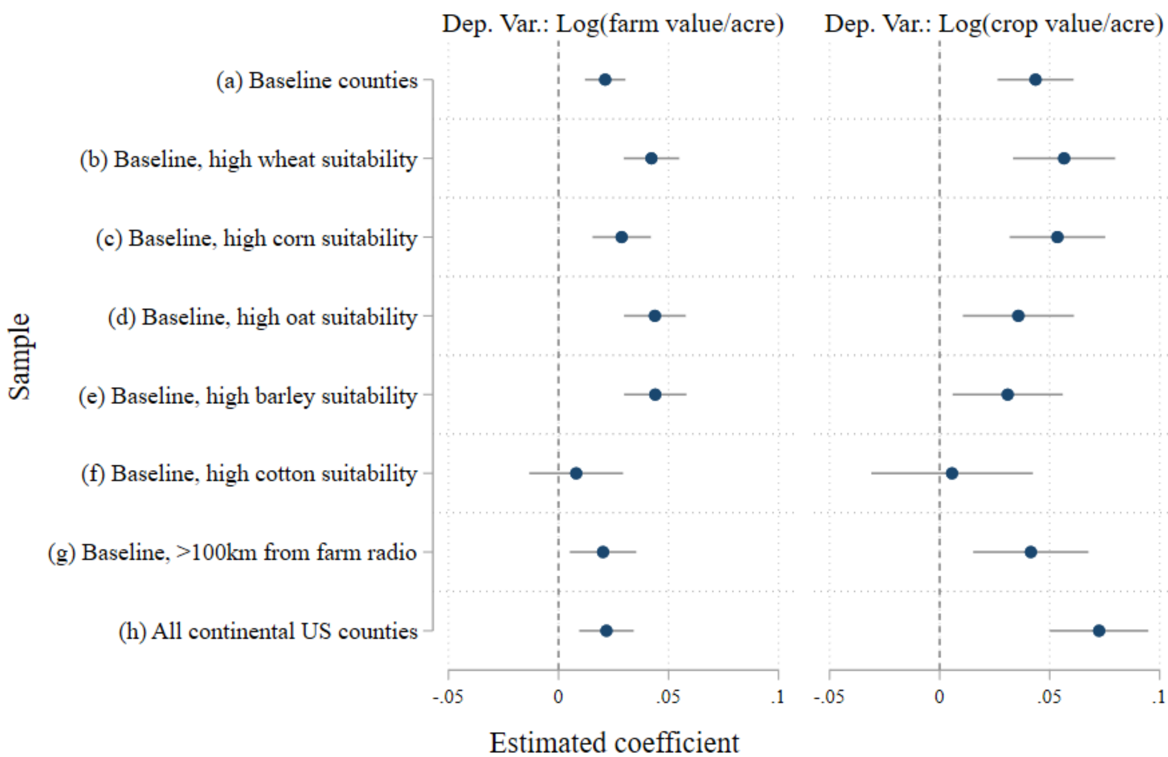
Alternative samples. The residual variation in signal strength from the ITM versus free space model can become larger as the distance increases between radio stations and county centroids. As such, this residual variation is minimized when the station is located inside the county, in which case controlling for free space signal may not fully address the concern of endogenous station location. Geography also matters for the suitability of different crops and the characteristics of farms. To examine the importance of these threats to identification, I re-estimate the impact of farm radio on agricultural productivity across different samples.

Figure 5 reproduces the estimates for farm value per acre on panel (a) and crop value per acre on panel (b) on various samples of counties. The baseline estimates on the top of each panel replicate column (4) of Table 2 and column (1) of Table 3 respectively. Moving downwards, I show the estimated coefficient of $FarmSignal$ from equation 1 on samples comprising counties with a high suitability for growing a specified crop, where a county-level crop suitability index is constructed from the FAO gridded data. Counties are considered highly suitable if the index is above 50%, a threshold which McGowan and Vasilakis (2019) find correlates positively – in the context of corn – with the probability that the crop is grown in the county. In my estimates, we see coefficients that are somewhat stable and comparable in magnitude with the full baseline sample, with the exception of cotton where the coefficients are in addition estimated with less precision due to the smaller sample size as this crop is predominantly grown on the American South. While the results are generally consistent with the baseline, it is worth noting that they are highest in magnitude on counties suitable for growing wheat. This could be partly due to the salience of wheat on farm radio programming, which is illustrated by a word cloud in Appendix Figure B4 of scientific terms constructed from transcripts of The National Farm and Home Hour.[13] Moving further down, we see that estimates are almost identical to the baseline for the sample of counties more than 100km away from farm radio stations in any period of the data, where farm radio exposure is even more likely to be exogenous. At the bottom of the figure we see that the

[13] As it refers to a nationwide program, the content of The National Farm and Home Hour may not accurately reflect farm programming at a local level.

main results are also robust to including all counties in the continental US, ignoring the issues of outliers introduced by measurement error and highly urbanized counties. The different samples shown in this figure can be visualized in maps shown in Appendix Figure B1.

Figure 5: Alternative Samples



Notes: Plotted estimated coefficients are for $FarmSignal_{ct}$ in the full model outlined by equation 1. The grey lines represent 95% confidence intervals. See Section 3.1 for sample selection leading to the baseline counties in estimate (a). High crop suitability in estimates (b) to (f) is assigned to counties with a crop suitability index above 50% using county averaged data from the FAO gridded suitability index. Estimate (g) drops counties within 100km of any farm radio station in any sample year. Estimate (h) includes all counties in the continental US.

Sensitivity to antenna height missing values. The identification comes from variation in signal strength due to topography which is measured by the irregular terrain model. Since antenna height – a key parameter on the signal strength prediction – is only available in one year of data, I here assess the sensitivity of the results to alternative approaches to handling missing antenna height values in the data. To do so, I recalculate the strongest farm radio signal strength[14] of each county in two alternative ways: (1) replacing the missing

[14]Only the signal strength calculated with the irregular terrain model is affected to changes in this param-

antenna height values with the median antenna height of 250ft from the available data in the 1940 issue of the *Broadcasting Yearbook*, and (2) replacing all antenna height values in all years with this same value of 250ft. In the data, the correlation between the baseline signal strength and the recalculated signal strength under different antenna height assumptions is over 0.99. Unsurprisingly, Appendix Figure B3 shows that the main results are virtually unchanged to different strategies to address the problem of missing antenna height values.

Binary signal strength. In alignment with the event study evidence presented in section 4, I perform an additional robustness check in Table 6 where the continuous measure of signal strength $FarmSignal$ gets replaced by an indicator equaling one if the ITM-predicted farm radio signal is at or above the 1925 median and zero otherwise. While the estimates remain qualitatively similar, the larger estimated coefficients obtained with the binary measure suggest the effect of signal strength is unlikely to be linear. Without information on the technical characteristics of farmers' radio receivers, it is difficult to pin down precisely the threshold of usable signal strength and improve upon $FarmRadio$ as a proxy for farm radio exposure. This limitation also highlights the fact that the residual variation in signal strength in my model is being used to identify the intent-to-treat effect of mass media (Crabtree and Kern, 2018).[15]

Alternative specifications. Lastly, I perform additional sensitivity checks in Appendix Table A2 showing in columns (2) and (5) that the main results are robust to flexibly controlling for free space signal propagation with a cubic polynomial that allows for a non-linear effect of proximity to radio station. Columns(3) and (6) show the results are also quantitatively similar after weighting the regression with the county's farm population.

eter. The antenna height input has no effect on the free space signal propagation since this model assumes there are no topographical features in the line of sight between the transmitter and receiver.

[15]Importantly, this proxy remains policy relevant as the availability of radio stations can be manipulated through investments in broadcasting infrastructure.

Table 6: Robustness check: Binary Signal Strength

	Log(farm value/acre)	Log(crop value/acre)	Log(wheat yield)	Log(corn yield)	Log(barley yield)	Log(oat yield)	Log(cotton yield)
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
$\mathbb{1}[FarmSignal > \mu_{1/2}^{1925}]$	0.024***	0.057***	0.100***	0.012	0.113***	0.088***	0.161***
	(0.008)	(0.014)	(0.015)	(0.012)	(0.020)	(0.013)	(0.019)
County fixed effects	✓	✓	✓	✓	✓	✓	✓
Year fixed effects	✓	✓	✓	✓	✓	✓	✓
$FarmSignalFree$	✓	✓	✓	✓	✓	✓	✓
Baseline controls	✓	✓	✓	✓	✓	✓	✓
Soil characteristics × year controls	✓	✓	✓	✓	✓	✓	✓
Observations	13,380	13,380	11,859	13,257	9,872	12,907	5,109
Number of Clusters	2,230	2,230	2,091	2,226	1,894	2,218	878
Adjusted R-Squared	0.958	0.829	0.616	0.792	0.486	0.598	0.685

Standard errors clustered at the county level in parentheses

Notes: $\mathbb{1}[FarmSignal > \mu_{1/2}^{1925}]$ is an indicator equaling one if the predicted farm radio signal strength meets or exceeds $\mu_{1/2}^{1925}$, the 1925 median. All other variables defined as previously in Tables 2 to 4. Standard errors are corrected for clustering at the county level.

7 Conclusion

I provide evidence that early radio stations that worked in collaboration with universities and agricultural experiment stations to broadcast farm programming had a measurable and persistent impact on agricultural outcomes. These impacts were more pronounced among disadvantaged farmers residing in counties with lower literacy and economic status and lower access to markets. The effects were felt across many of the most prominent crops grown in the country, and also captured by overall productivity measures related to land prices and total crop revenues. Still, a limitation of this study is the lack of key variable inputs, such as seed varieties, which would allow us to explore the importance of farm radio on the adoption of productivity-enhancing technologies.

The findings in this paper are relevant to the policymakers of today, who are searching for cost-effective alternatives to remove information barriers to farmers in developing countries. Despite being a century old technology, radio remains an affordable, long-reaching, easy-to-use, and relevant source of information (over 55% of sub-Saharan African households still tune in weekly, according to Aker (2011)). Previous findings of limited effectiveness of information offered by radio could be attributed to the lack of commercial incentives to provide locally targeted content to farmers. This issue can be overcome with government-sponsored programming, where radio broadcasters partner with extension services and research institutions to deliver locally relevant information in regions lagging in agricultural productivity.

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8 Appendix A – Additional Tables

Table A1: Baseline Specification Allowing for Spatial Correlation in Error Term

Distance cutoff:	25km	50km	100km	200km
	(1)	(2)	(3)	(4)
Panel A: Dependent Variable – Log(farm value/acre)				
FarmSignal	0.021***	0.021***	0.021**	0.021
	(0.000)	(0.001)	(0.030)	(0.109)
Panel B: Dependent Variable – Log(crop value/acre)				
FarmSignal	0.044***	0.044***	0.044**	0.044*
	(0.000)	(0.001)	(0.018)	(0.090)
Observations (Either Panel)	13,380	13,380	13,380	13,380

Standard errors clustered at the county level in parentheses

Notes: Table shows full baseline specification of equation 1 with error terms adjusted to allow for spatial correlation following Conley (1999)'s approach with various distance cutoffs.

Table A2: Robustness to Alternative Specifications

Dependent variable:	Log(farm value/acre)			Log(crop value/acre)		
Model:	Baseline	Flexibly control $FarmSignalFree$	Farm population weighted regression	Baseline	Flexibly control $FarmSignalFree$	Farm population weighted regression
	(1)	(2)	(3)	(4)	(5)	(6)
$FarmSignal$	0.021***	0.027***	0.026***	0.044***	0.053***	0.042***
	(0.005)	(0.005)	(0.009)	(0.009)	(0.009)	(0.015)
Full baseline controls and FEs	✓	✓	✓	✓	✓	✓
Observations	13,380	13,380	13,380	13,380	13,380	13,380
Number of Clusters	2,230	2,230	2,230	2,230	2,230	2,230
Adjusted R-Squared	0.958	0.958	0.963	0.829	0.829	0.835

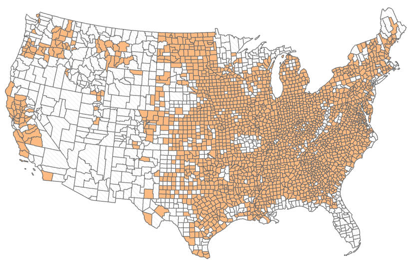
Standard errors clustered at the county level in parentheses

Notes: Table shows robustness checks on the baseline main results. Columns (1) and (4) reproduce main results previously shown in Table 2 and 3. Columns (2) and (5) control flexibly for farm signal in free space with a third order polynomial. Columns (3) and (6) weigh the baseline regression with the county's farm population. All regressions include the full set of controls and fixed effects used in the preferred specification.

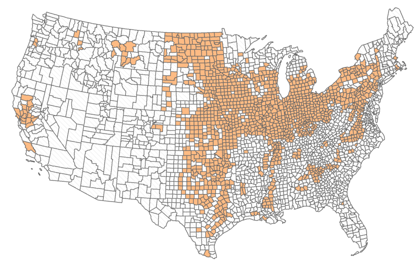
9 Appendix B – Additional Figures

Figure B1: Sample of counties in baseline and robustness checks

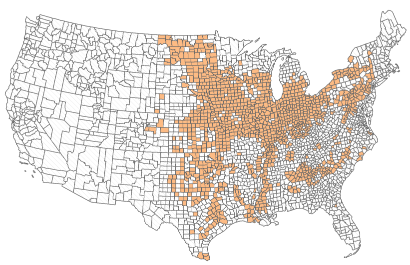
(a) Baseline counties



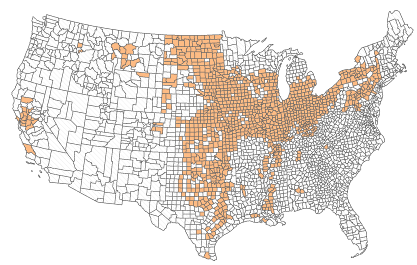
(b) Baseline , high wheat suitability



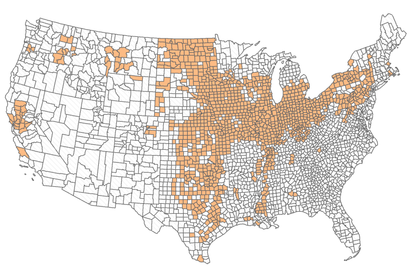
(c) Baseline , high corn suitability



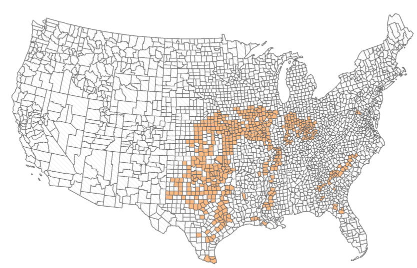
(d) Baseline , high barley suitability



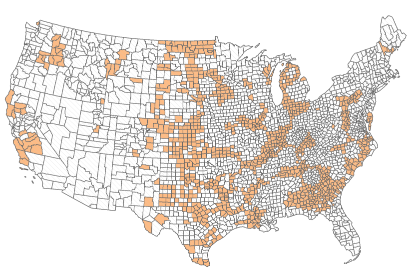
(e) high oat suitability



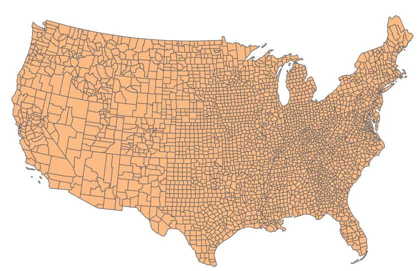
(f) Baseline , high cotton suitability



(g) Baseline, >100km from farm station

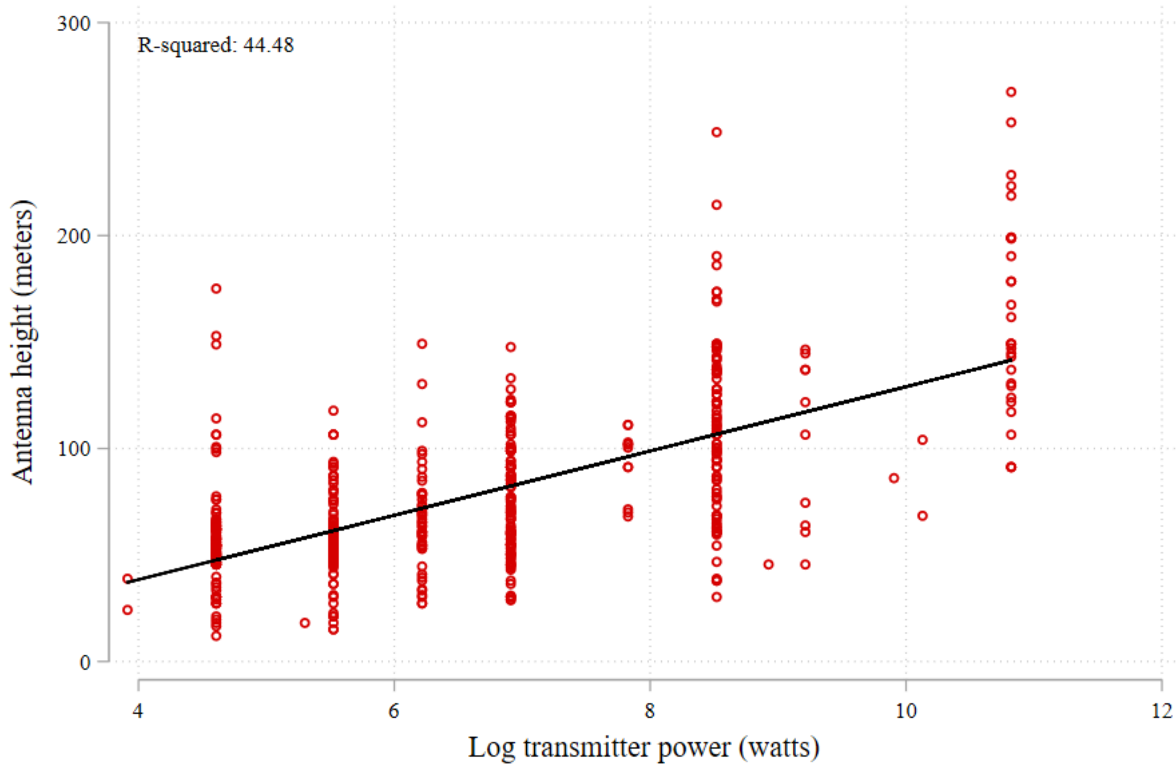


(h) All continental US counties



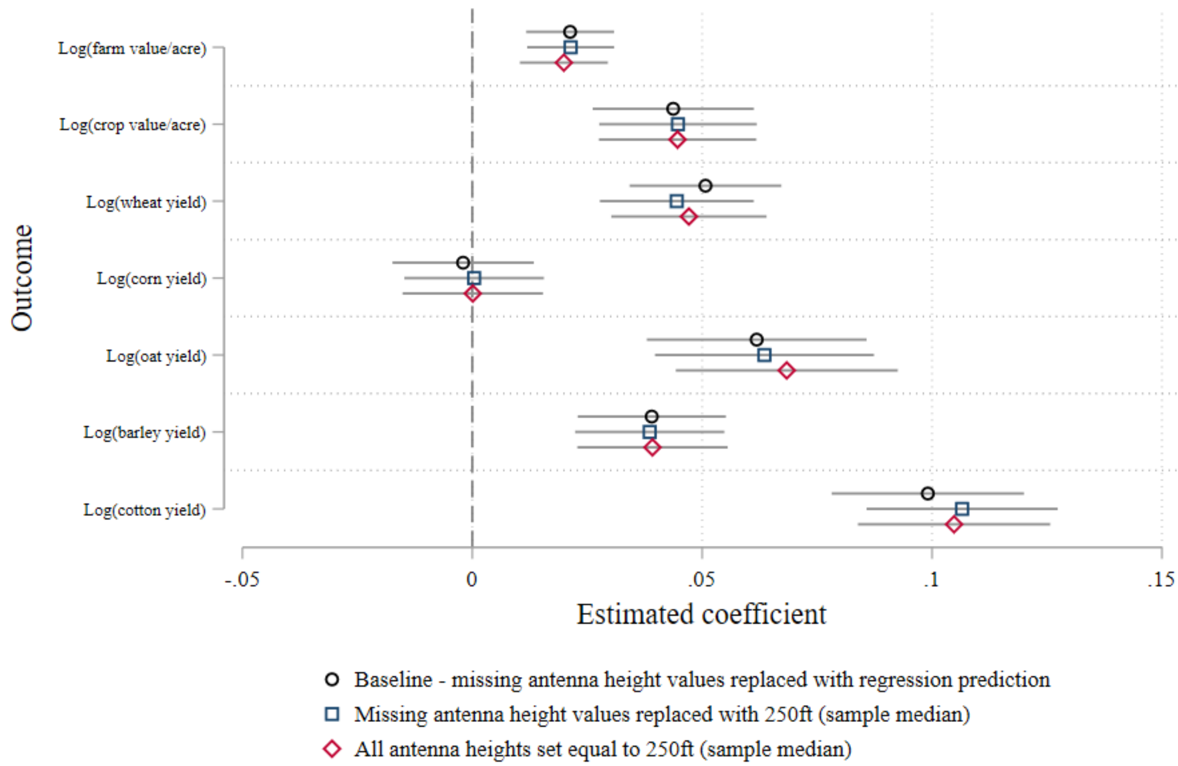
Notes: Panel (a) baseline corresponds to the main sample described in the Data subsection 3.1. Panels (b) to (f) comprises counties within the baseline with a county averaged suitability index above 50% for the specified crop. Panel (g) comprises counties within the baseline that are further than 100km from the nearest farm radio station in all periods between 1925-1950.

Figure B2: Predicting Missing Antenna Height Values



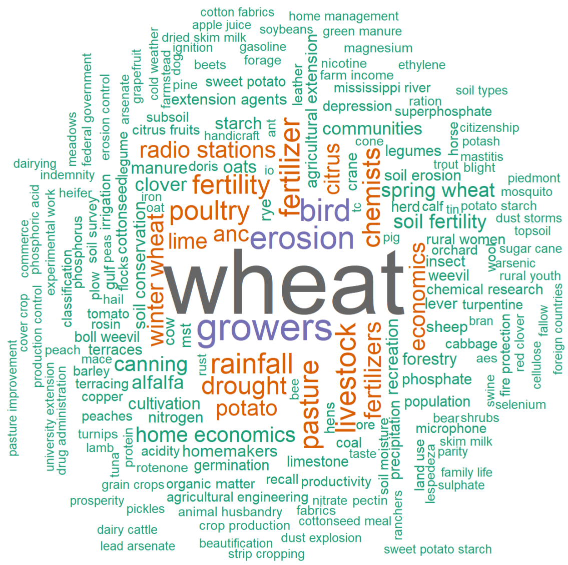
Notes: Antenna height data drawn from the 1940 issue of the *Broadcasting Yearbook* (Broadcasting Publications, Inc., 1959).

Figure B3: Alternative Treatment of Missing Antenna Height Values



Notes: This figure shows the sensitivity of the estimated effect of farm radio to different ways to fill missing values of antenna height. Antenna height data is only available for 1940 and on the baseline signal strength calculations using the ITM and free space propagation models the missing values are replaced with predictions from a simple linear regression of antenna height on log transmitter power ($R^2 = .44$). The figure additionally shows the estimated coefficients when the signal strength are calculated replacing missing antenna height values with the 1940 median height or when all antenna height values in the sample are replaced with the 1940 median height.

Figure B4: Wordcloud of relevant science terms on transcripts of The National Farm and Home Hour



Notes: These transcripts are an extensive (but not comprehensive) database of digitized scripts of the USDA's The National Farm and Home Hour, spanning the years 1929-1942, and available through the USDA's National Agricultural Library. The transcripts are hosted in an Internet Archive collection (url: `https://archive.org/details/usda-nationalfarmhomehour`), and was accessed in September 18 2021. The word cloud depicts the most commonly found terms – based on the ScienceDirect dictionary of scientific topics – on the set of digitally available scripts.

10 Appendix C – Select Radio Programming Excerpts

On soil erosion:

- "In the black land of Texas, some of the greatest cotton lands of the world, we have an erosion experimental farm near the town of Temple. The chief development there last year and the year before was along the line of strips cropping as already mentioned in connection with the Guthrie, Oklahoma, Station work. Under this method which Bennett has explained to you before, farmers plant strips of thick-growing, soil-saving crops, such as oats, sorghum, and sweet clover, along the contours of the field slopes.

These are comparatively narrow strips. Then they plant broader strips of the clean-tilled crops, such as cotton and corn, between the strips of soil-saving crops. Practically no erosion or run-off came from the strip-cropped fields at the Temple station."
– Dr. Henry G. Knight, Chief, Bureau of Chemistry and Soils, for The National Farm and Home Hour, Jan. 11, 1933.

On weather and crop outlook:

- "June weather, especially during the latter part of the month, was very trying to man, beast, and many crops over large sections of the country, especially in the States comprising the central valleys and the Northwest. However, a hot, dry spell could hardly have come at a better time, to cause the least amount of damage to staple crops. Winter wheat was largely too far advanced to be seriously harmed, and corn in the principal producing sections had not reached its critical stage of growth. Late spring wheat, oats, other small grains, potatoes, truck, and pastures were less fortunate, especially in the North-Central States, and these suffered considerable damage. Corn was not permanently injured in the main producing sections. In fact, it made exceptional and phenomenal growth, wherever there was sufficient soil moisture and, in general, the crop is in excellent shape at the present time and much ahead of an average season, except in some dry southern sections. In Oklahoma, corn is in a critical stage of growth, and needs moisture badly, while in many other southern localities, especially in the Southeast, the crop has been damaged by drought. Cotton, while late, continued to make mostly satisfactory growth, but moisture is needed in the northwestern Belt, especially in Oklahoma, and in the Southeast, notably in Georgia and some adjoining sections."
  – J.B. Kincer, Meteorologist, Weather Bureau, for The National Farm and Home Hour, July 8, 1931.

- "Taking the country as a whole, the weather was better in August than in July. The result – a 5 percent increase in the crop yield prospects. Although several crops are late and in danger from early frosts or wet weather, an abundant harvest now seems almost assured. The picture isn't equally bright in all sections of the country. Storms along the Louisiana and Carolina coasts caused losses of rice, tobacco, peanuts, and peaches. Dry weather continued through August in an area extending from east central Nebraska to central Colorado, and into late August in central Illinois, Kentucky, and New England, while in the northern and central portions of the Corn Belt and in the Southwest good weather brought marked improvement in the prospects for corn, sorghums, small grains, and other crops. [...] The estimate for September 1 is slightly over 2 and a quarter billion bushels, that's an increase of about 49 million bushels over a month ago [about corn]. The estimate is for nearly 785 million bushels, up more than 20 million bushels in the past month [about wheat]. About 52 million bushels, nearly 3 million less than expected a month ago [about rice]. "

– E. J. "Mike" Rowell, Agricultural Marketing Service, for The National Farm and Home Hour, Sep. 11, 1940.