How Economic Conditions Changed the Number of U.S. Farms, 1960-88: A Replication and Extension of Gale (1990) to Midsize Farms in the U.S. and Abroad

Ana Claudia Sant'Anna[1*] and Ani L. Katchova[2]

1 Division of Resource Economics and Management, West Virginia University, U.S.A,

2 Agricultural, Environmental, and Development Economics Department, The Ohio State University, U.S.A

Contributed Paper prepared for presentation at the 96th Annual Conference of the Agricultural Economics Society, K U Leuven, Belgium

4 – 6 April 2022

*4411 Ag Sciences Bldg, PO Box 6108, Morgantown, WV 26505-6108, anaclaudia.santanna@mail.wvu.edu.

Abstract

We replicate and extend the analysis of Gale (1990) to find that economic factors like population pressure, financial stress, and infrastructure play an important role in explaining the growth rate in the number of farms by farm size. We do not find support for the disappearing middle hypothesis, despite a declining trend in the number of midsize farms in the U.S. over time. Economic factors are also important to explain the increase in small and midsize farm numbers in Brazil, and the decreasing small farm numbers in the Eurozone, showing opposite trends in farm numbers globally.

Keywords farm numbers, midsize farms, farm exits

JEL code Q12, Q14

“What role is played by economic conditions in influencing changes in the number of farms?” (Gale 1990, p.22). This is a question answered in Gale (1990) for the period of 1960-88 for U.S. farms. Is the role of economic conditions on the changes in U.S. farm numbers still the same? Is this role the same for changes in the number of midsize farms in the U.S. and in other countries? To answer these questions, we replicate Gale (1990) time series regression, expand the model to include more variables and more years, and apply the model to farm numbers by farm size categories and for other countries and regions.

The topic of declining farm numbers remains current: “the number of U.S. farms continues to decline slowly” (Kassel 2020). In fact, the number of U.S. farms has been declining since the 1940s. A sharp drop in the number of U.S. farms occurred between 1935 and 1970s, from 6.8 million to under 2.9 million in 1970 (Figure 1). Since then, the number of farms has continued to decline, though at a slower pace. From 1970 to 2020, the number of U.S. farms declined from 2.8 million to 2.02 million (Figure 1). An analysis of how economic conditions can impact the annual change in farm numbers in the short term is necessary to guide farm policy discussions. These changes can happen very quickly, even within a year. For example, the number of licensed dairy farms dropped by 3,281 between 2018 and 2019 (USDA 2019). The decline in farm numbers, in turn, implies losses in employment, income generation, and the generation of agricultural products. Identifying the impact of economic conditions can help in the design of policies to slow down the number of farm exits.

Another important question is to understand how economic conditions affect changes in U.S. farm numbers by the size of farm operations. We define farm size in terms of acreage (small farms with less than 50 acres, midsize farms between 50 to 999 acres, and large farms over 1000 acres) following Ahearn et al. (2005). The decline in U.S. farm numbers is even more evident among midsize farms. From 1959 to 2017, the number of midsize farms declined by 1.5 million, small farms declined by 0.2 million, and large farms increased by 0.3 million

(Figure 2). The importance of midsize farms has also been discussed within a global context. Lowder, Skoet, and Raney (2016) find that globally, the average farm size has increased because of economic growth. However, while the number of small farms (less than 2 hectares) has increased in countries with significant agricultural areas (e.g., U.S. and Brazil) and the number of large farms has also increased, little has been studied about the trend in the number of midsize farms (Lowder, Skoet, and Bertini 2019). Patterns of increases in the number of large farms are also evident in Europe and in countries with large agricultural areas (Lowder, Sanchez, and Bertini 2019).

Previous literature has focused primarily on productivity of small farms versus large farms or on explaining the trends in the number of small and large farms. For instance, Lowder, Skoet, and Raney (2016), Lowder, Sanchez, and Bertini (2019), and van Vliet (2015) discuss trends in the number of small and family farms, while Deininger and Byerlee (2012) discuss the increase in the number of large farms. Rada and Fuglie (2019) argue that discussions on farm size and productivity have focused on the effects of land and labor on production for small and large farms. Using data from India, Foster and Rosenzweig (2021) study the relationship between farm size, scale, and productivity. We contribute to this body of literature by analyzing the relationships between economic conditions and the growth rates in the number of farms by farm size.

It is likely that policy may not be one-size-fits-all, and therefore may need to be designed based on farm size. Hence, it is important to understand the short-term impact of economic factors for each farm size category, yet research on U.S. and other countries' midsize farm numbers is limited. Kirschenmann et al. (2008) identify two farm structure paths: small farms that thrive in direct markets, and large, consolidated farms that have established supply chains and mass production. Thus, research related to U.S. midsize farms focusses on understanding the supply chains for midsize farms (Brekken et al. 2021). Globally, Lowder, Sanchez, and Bertini (2019) state that research has concentrated on small farms and that little is known about midsize farms. We use the model proposed by Gale (1990) to fill this gap in the literature. Our objectives are two-fold: 1) to understand the role of economic factors on the decline of farm numbers in the U.S., specifically in the case of midsize farms, and 2) to investigate whether these economic factors identified in 1) have the same effect in other countries. Results from the latter objective can justify the use of agricultural policies from one country in other countries. We provide insight into the role of economic conditions on farm distributions in the U.S. and abroad. In this study, we apply our analysis to farm numbers in Brazil and the Eurozone, as they are large economies representing different regions of the world. Our underlying hypothesis is that the effects of the economic factors on the change in farm numbers remain the same (in terms of direction) over the years and are independent of farm size category and country/region.

Farm numbers in the U.S. and globally: the case of midsize farms

Knowledge of farm numbers and farm structure is important when designing policies focused on agricultural development. For instance, the goal of the 2030 Agenda for Sustainable Development is to promote sustainable agriculture with increased productivity and income by 2030 (Erenstein, Chamberlin, and Sonder 2021, UN 2015). Yet, Erenstein, Chamberlin, and Sonder (2021) project a decline of 32 million farms globally by 2030.

A decline in farm numbers does not automatically translate to farm exits from agriculture. The decline in farm numbers may also come from farm consolidation. While U.S. farm numbers have decreased over time, land in farms has increased. In fact, the average size of a U.S. farm has increased from 589 acres in 1982 to 1,105 acres in 2007 (MacDonald, Korb, and Hoppe 2013, Key 2019). Increases in farm size can indicate higher incomes to farmers and increased use of hired and contracted labor (MacDonald 2021). Changes in farm structure in the U.S. and abroad have been attributed to factors such as technology (e.g., labor-saving technologies), infrastructure, property rights, economic conditions, market failure and policy, population density and growth, and off-farm income (MacDonald, Korb, and Hoppe 2013, Deininger and Byerlee 2012, Gale 1990, Lowder, Sanchez, and Bertini 2019). Many of these factors are explored in this study. We consider and control for several economic factors: infrastructure by accounting for the length of roads and highways, labor supply by accounting for unemployment rates, markets by controlling for interest rates, farm prices as well as off-farm income. Although we do not control for specific policy, we account for the economic conditions that are a result of macroeconomic policies (e.g., interest rates, housing permits, and other development pressures). Thus, understanding the trends in farm numbers while accounting for farm structure and size is pertinent.

As we examine farm numbers by farm size, one common measure of farm size that is used in the literature is farm size in acres or hectares. In the U.S., farm sales (used up to 2013) and gross cash farm income are also used because they measure economic activity (Hoppe and MacDonald 2013, Whitt, Todd, and Keller 2021). Nevertheless, determining farm size by farm sales or gross cash farm income has its limitations. To reflect changes in commodity prices and inflation, categories need to be updated frequently (Hoppe and MacDonald 2013). Therefore, using acreage to define farm size in the U.S. is also common (e.g., Key 2019, Ahearn et al. 2005). Ahearn et al. (2005) define small farm operations as those under 50 acres and large as those over 1,000 acres. Globally, Jayne et al. (2016) define small farms as those with less than 5 hectares and midsize farms as those between 5 and 100 hectares. Lowder, Sanchez, and Bertini (2019) define small farms as those under 2 hectares and large farms as those over 50 hectares. Because the aim of this study is to compare trends in farm size across countries and regions, we define farm categories by farm size measured in acreage (acres or hectares).

While there is evidence of U.S. farm consolidation, there is also evidence of increases in the number of small farms in the U.S. (Ahearn et al. 2005). The increase in the number of small farms has also coincided with a decreasing trend in the number of midsize farms. The decline of 5% in the number of U.S. midsize farms from 1992 to 2012 can be attributed to farm exits and transitions to larger farm size categories (Burns and Kuhns 2016). Kirschenmann et al. (2008) argue that the decrease in midsize farms is due to market structure: small farms using direct markets and large farms using established supply chains, leaving midsize farms without well-specified markets. The term “disappearing middle”, referring to the declining number of midsize farms in the U.S. agriculture, was first defined in 1980s (Stevenson et al. 2014). However, its relevance is controversial. There are arguments that midsize farms are a vital part of local and regional food systems (NC-1198 2021) and that they are largely represented by family farms (Kirschenmann et al. 2008). Family farms make up 90% of all farms in the world (Lowder, Skoet, and Raney 2016). Therefore, the disappearance of midsize farms can be a source of inequality and can affect rural development since large farms usually depend on economies of scale and technology which may imply less need for labor (Lowder, Sanchez, and Bertini 2019, Kirschenmann et al. 2008). In turn, there are arguments that if the objective is to increase production and food supply, large farms can produce enough food to fulfill food demand (Lowder, Sanchez, and Bertini 2019, Kirschenmann et al. 2008). Because of that, the declining number of all farms or more specifically the declining number of midsize farms may not be a critical issue.

Policy makers need to consider farm size and farmland distribution when designing public policy. Focusing only on the reduction of poverty through improvements in small farm productivity ignores other important issues which involve midsize and large farms, such as ensuring sustainable farming practices. Globally, the number of small farms surpasses that of midsize and large farms. Farmland distribution can have important implications for policy. An increase in the number of small or even large farms may not always be beneficial. Lowder, Sanchez, and Bertini (2019) argue that the increasing number of small farms in countries with extensive agricultural land can indicate prevalence of subsistence farming, while the increasing number of large farms in other countries may indicate an industrialization of the food system. Worldwide, farmland concentration is closely linked to economic growth: while average farm numbers in developed countries have increased, they have decreased in developing countries (Lowder, Sanchez, and Bertini 2019).

Farm structure is heterogeneous globally (Figure 3). Higher-income countries have a greater distribution of small, midsize, and large farms, while lower- and middle-income countries have a larger share of small farms and very few large farms. Lowder, Skoet, and Raney (2016) find evidence of increases in the number of small farms (less than 2 hectares) in countries with significant agricultural area and with a history of large farms (e.g., Brazil and U.S.). Lowder, Sanchez, and Bertini (2019) also identify a pattern of increases in farmland concentration in larger farms. Similarly, van Vliet et al. (2015) find a declining number of midsize farms not only in the U.S. but also in Brazil and the Netherlands, where there has been an increase in the number of small and large farms. Worldwide, the polarization of farmland distribution is also linked to food systems (Lowder, Sanchez, and Bertini 2019). Nevertheless, the disappearance of midsize farms may have consequences for equity and the food supply chain. In the next sections, we provide a replication of Gale (1990)'s study and then extend and apply his methodology to examine the role of economic conditions on the changes in farm numbers within the U.S. and abroad.

Replication of Gale (1990)

We begin our analysis by replicating the results from Gale (1990). We use the same regression models and time periods and attempt to match the data sources as close as possible.

Methodology used in Gale (1990)

Gale (1990) examines how economic factors contribute to the decline in U.S. farm numbers by estimating a first-order difference equation (1). Equation (1) shows how the change in farm numbers occurs at a declining rate based on the number of farms in the past year:

$$F_t - F_{t-1} = \alpha(F_{t-1} - F_n) + D_t \quad (1)$$

where F_t is the number of farms in the U.S. in year t, α and F_n are parameters following the restrictions: $-1<\alpha<0$, $F_n>0$, and D_t is a deviation. Here, $\boldsymbol{F}_n$ is a fixed constant representing the number of farms that the declining number of farms converges to from above. The deviation D_t is hypothesized to be influenced by economic conditions (X_{jt}) and can be expressed as:

$$D_t = b_0 + \Sigma_{j=1}^{k} b_j X_{jt} + e_t \quad (2)$$

where b_j are the parameters to be estimated and e_t is the error term. Substituting equation (2) into (1) we can see how the change in the number of farms is explained by the number of farms in the previous year and the economic factors X_{jt} (Gale 1990):

$$F_t - F_{t-1} = -\alpha F_n + \alpha F_{t-1} + \Sigma_{j=1}^{k} b_j X_{jt} + e_t \quad (3)$$

where X_{jt} is expressed in terms of mean deviations which makes the intercept b_0 equivalent to zero. This process was done in order to facilitate the derivation of F_n. Therefore, the change in farm numbers is a function of an intercept $-\alpha F_n$, the lagged number of farms, and economic factors, such as non-farm earnings, interest rates, prices, and land value. Because land value is considered endogenous and, possibly, correlated with interest rates, it is instrumented using exports of farm products, real interest rates, and actual inflation. Equation (3) is estimated using the Yule-Walker procedure for correcting for first order autocorrelation, also named Prais-Winston estimates (Daniela 2010). Prais-Winston is preferred over other procedures to correct for autocorrelation (e.g., Cochrane-Orcutt method) particularly for small samples because the first observation in the data is not lost (SAS Institute Inc. 1999).

Data used in replication of Gale (1990)

Data are collected from various sources to replicate the analysis in Gale (1990). The data sources are matched as closely as possible to those used in Gale (1990). Data on non-agricultural weekly earnings and exports come from the U.S. Statistical Abstracts available on the U.S. Census website. Data on recent years 2017 to 2020 were added from the U.S. Agricultural Trade Data Update using calendar year information. Missing years (1961 to 1964 and 1966) in non-agricultural weekly wages are approximated using the average of the ratio of weekly gross earnings for non-agricultural and manufacturing weekly wages from 1960 to 1972. Information on land values per acre and parity of prices paid and received by farmers comes from USDA-NASS Quickstats. Information on net farm income comes from the farm income and wealth statistics from USDA-ERS. Data on the GNP deflator and prime rate charged by banks (Dprime) comes from the Federal Reserve Bank of St. Louis.

We construct the needed variables following Gale (1990). Real interest rates are calculated by subtracting the prime rate from inflation (calculated using the GNP deflator). Exports are deflated using prices received by farmers (in 1977 dollars). Inflation is measured by the GNP deflator. The ratio of nonfarm wages to farm income is constructed by dividing annual non-agricultural earnings by the net farm income per farm. Annual non-agricultural earnings are calculated as the weekly non-agricultural earnings times 50. Net farm income per farm was obtained by dividing the total net farm income by the number of farms.

Table *1* compares the descriptive statistics of the data collected for our replication analysis with those provided in Gale (1990). Summary statistics on the ratio of non-farm earnings to real earnings were not available in Gale (1990). The means and coefficient of variation (CV) are close in values between the original study and our replication, but some small differences are present which may be due to updates to the dataset after his article was published. Gale (1990) notes that the changes in the number of farms, prices, land values, and interest rates have a higher coefficient of variation in the second sub-period (1975-88) compared to the first sub-period (1960-74), indicating greater volatility during the 1980s farm crisis.

We extend the replication model to include other factors which may influence farm numbers. These factors generally represent the strength of the general economy and farm sector and infrastructure. Specific variables used in our analysis include debt-to-asset ratios, population, length of highways in miles, unemployment rate, and housing permits. Debt-to-asset ratio data were collected from the farm income and wealth statistics available by the Economic and Research Service. Population in millions was from the World Bank dataset. Unemployment rates were collected from the Federal Reserve Bank of St. Louis. Highway mileage (the length of highways in miles) comes from the office of highway and policy information part of the U.S. Department of Transportation and Federal Highway Administration. Housing permits represent the number of new privately owned housing units authorized building permits available through the U.S. Census.

Table 2 provides an overview of the variables in Gale (1990) and those we use in the extended model, as well as the expected signs of the coefficients of these variables on the change in the number of farms, indicating farm entry or exit. The long-term trend representing the effects of the number of farms on the change in the number of farms is expected to be negative, representing a long-term decline in the number of farms. A high price ratio which is an index of the price received to price paid that is greater than 1 would mean that farmers are receiving more than what they pay to produce and is expected to motivate the entry of new farms. Land values are expected to have a positive relationship with the change in farm numbers because they reflect the future profitability of the land (Gale 1990). Land values can be interpreted as the discounted net present value of land payments such as cash rent. Interest rates reflect the price of credit and are expected to have a negative effect on the number of farms. A high ratio of non-farm wages to real farm income that is greater than 1 is expected to have a negative effect on the number of farms. In other words, an increase in compensation of the non-farm sectors as compared to the farm sector would lead to farm exits. An increase in off-farm income is also expected to have a negative effect on the number of farms (Gale 1990). Debt-to-asset ratios represent the financial stress farms face. High debt-to-asset ratios are expected to put pressure on farms to exit. The effects of population can be positive or negative. Increases in population and housing permits can place urbanization pressures and cause the exit of farms. In turn, increases in population can lead to higher demand for farm products leading to farm entry. Similarly, an increase in highway mileage can facilitate farm products reaching their markets but can also lead to increased urban development pressures. Hence, an increase in highway mileage can motivate either entry or exit of farms. Unemployment rates provide a proxy for worker supply, therefore, increases in unemployment rates can mean greater availability of workers for agriculture, and therefore entry into farming. Thus, we expect the unemployment rate to be positively related to the change in farm numbers.

Replication results for Gale (1990)

Gale (1990) conducted the analysis for the period from 1960-1988 and then for the two sub-periods of 1960-74 and 1975-88. The second sub-period roughly coincides with the 1980s farm crisis which was characterized by rising land values, excessive debt on real estate loans, and high interest rates which lead to increased farm bankruptcies and farm exits. Gale (1990) concludes that during the first sub-period the trend toward fewer farms appears to be dominating, while during the second period, the economic conditions had more significant effects on the number of farms.

The largest difference in the replication analysis is the coefficients of the ratio of nonfarm earnings to real farm income. This difference probably stems from the construction of the variable and the sources used. Unfortunately, summary statistics on this variable were not available to allow for a comparison. Other differences in magnitude are likely due to updates in the historical data by various agencies or the data source being different in the two studies. For example, NASS periodically revises numbers based on additional recent Census of Agriculture data.

Following Gale (1990), we first estimate an equation of land values being regressed on exports, real interest rate, and actual inflation (see Table 3). Coefficients from the replication have the same sign as those in Gale (1990). However, the coefficients on the interest rate and inflation are smaller in magnitude. Extending the period from 1960 to 2020 reveals that the signs of the coefficients remain unchanged, as well as their statistical significance.

We then use the fitted values from the land value regression in the regression for the change in farm numbers. Table 4 shows the results from estimating equation (3) with the fitted land values. Gale (1990) shows that α is 0.07, indicating a 7% annual decline in the number of farms toward a fixed value for the long-term number of farms. Our replication analysis shows this effect to be 8%. The effect of the ratio of prices received to prices paid by farmers has a statistically significant effect in Gale (1990) but not in our replication analysis for the same time period. This coefficient is statistically significant when the period of 1960-2020 is used. In fact, land values and real interest rates which are statistically significant in the replication model become insignificant when the period was extended. There is a shift in which economic factors explain the change in farm numbers. From the price of credit and the future earnings (represented by land values) for the early period of 1960-88 to the ratio of prices received to prices paid for the full period of 1960-2020. The lack of significant effects of land values and interest rates on the change in the number of farms over the extended period maybe due to these factors changing values through multiple economy expansion and contraction periods.

We also replicate Gale (1990)'s results for the two sub-periods from 1960-74 and 1975-88 (table A.1 in the Appendix). In the first sub-period of 1960-74, we find a stronger trend of a 9% decline in farm numbers as opposed to the 6.3% decline found in Gale (1990). These econometric results indicate that during the first sub-period of 1960-74, the downward long-term trend is the main explanatory factor for the decrease in the change in farm numbers. During the second 1975-88 sub-period, which coincided with the farm crisis and greater volatility in the agricultural sector, economic factors played a significant role in affecting the change in the number of farms. Looking back, the 1980s were characterized by increased farm exits which occurred particularly because of difficulties in servicing farm debt. Our replication results show that nonfarm earnings and the cost of credit are negatively related to the change in farm numbers. Our replication analysis confirms the original findings that the economic factors have more significant importance in the second subperiod, while in the first subperiod there is a strong downward trend in the number of farms with less influence from the economic factors.

Extensions of Gale (1990) for U.S. farms - full period and disappearing middle

We extend the analysis using the Gale (1990)'s model to include the full time period of 1960-2020 and more economic factors and show the results in column (1) in table 6. The inclusion of other economic factors shifted the factors that impact the annual change in farm numbers from the ratio of prices received to prices paid to measures of urbanization pressure represented by population and financial stress represented by the debt-to-asset ratio (table 4 column (5) versus table 5 first column). The long-term trend in the change in farm numbers changed from -11% to -15%. We ran checks for multicollinearity using the variance inflation factor (VIF) and a correlation matrix and did not identify VIF larger than 10 or correlations among variables that were larger than 0.9 for the variables in the regression.

We also extend the analysis to different farm sizes since the trend of decline in farm numbers may apply differently for small, midsize, and large farms. We also estimate how the impact of the factors on the change in farm numbers differs by farm size categories (small, midsize, large) and investigate whether the effects remain the same. We again measure the change in farm numbers as an annual growth rate in farm numbers for each category, assuming constant growth rate between Censuses. Summary statistics are provided in table 5. This allows us to investigate the effect of the short-term economic factors on the growth rate in the number of midsize farms. The changes in the number of small, midsize, and large farms are likely to be related to each other. Therefore, we expect the error terms of these regressions to be correlated and, as such, we use seemingly unrelated regression (SUR) for the empirical estimation. The Breusch-Pagan test statistics justify the use of SUR in our case.

The results for the estimation by farm size are shown in columns (2) to (7) of table 6. Using the original variables in Gale (1990), the long-term trend of decline in farm numbers toward a long-term value is 0.4% for small farms, and 0.1% for midsize farms. These effects are not significant when more economic factors are added. Therefore, the disappearing middle hypothesis does not seem to be supported by our results, but rather the impact of economic factors plays a more significant role in explaining the changes in farm numbers. The increase in nonfarm earnings to real farm income is associated with an increase in the number of small farms but a decrease in the number of large farms, implying that a strength in the nonfarm economy leads to small farm entry and large farm exits. This is in line with the findings in Brown and Weber (2013) who report farms that have little agricultural production have high off-farm income. When adding more variables, these effects are replaced by the effect of unemployment rate, which positively affects the number of small farms but negatively affects the number of large farms. An increase in unemployment could be such that the relative cost of capital is higher than the cost of labor, impacting large farms, which are less labor intensive, and favoring small farms. Small farms, especially those that are focused on vegetable and fruit production, are more labor intensive (Jayne et al. 2016). The magnitude of the effect of unemployment on the growth rate of large farms is small likely due to the lower participation in labor by large farms (MacDonald 2020). The ratio of prices received to prices paid continues to have a negative and significant effect on the number of small and midsize farms. The negative impact on midsize farms could imply a transition to larger farms. High financial stress expressed as high debt-to-asset ratio has a negative effect on the number of midsize farms, unsurprisingly leading to farm exits. Overall, we find results that are consistent with Gale (1990)'s conclusions that economic factors, rather than long-term trends, affect the number of farms. While these economic factors have different effects particularly for small versus large farms, we do not find strong evidence to support the disappearing middle hypothesis.

Extension of Gale (1990) for farms in Brazil

The United States and Brazil are among the top ten countries with the largest shares of the world's agricultural area (Featherstone 2017). Brazil's agricultural expansion has been characterized by large farms (Ferreira Filho and Freitas Vian 2016). Even with increases in the number of small farms over time, Hoffman and Ney (2010) were not able to identify reductions in inequality. More recently, Telles et al. (2021) identified an annual decline of 4.5% in the number of midsize farms (between 50 and 100 hectares) between 2004 and 2015. Therefore, understanding the role of economic conditions on the growth rates of farms by small, midsize, and large categories can provide guidance for policy design.

Information on farms by small, midsize, and large categories comes from the Brazilian Agricultural Census of 1950, 1960, 1970, 1975, 1985, 1995, 2006, and 2017. Growth rates are assumed to be constant between the Ag Census years when calculating annual growth rates. Small farms were defined as less than 10 hectares, midsize farms between 10 and 1,000 hectares, and large farms over 1,000 hectares. The choice on the farm size categories was set by matching the U.S. categories with those available from the Brazilian Ag Census information. Figure 4 shows the trends in farm numbers in Brazil by different farm size categories. The number of large farms remained stable over time while the number of small and midsize farms increased between 1940 and 1970, with the number of small farms surpassing that of midsize farms after the 1970s. We do not see a large drop in the number of midsize farms in Brazil in the last few decades as we do in the case of steadily declining number of U.S. midsize farms.

Data on population, inflation, interest rates, and prices received by farmers were collected from Ipeadata (IPEA 2021). Prices received by farmers were proxied by IPA (Broad Index of Prices to the Producer). IPA measures the variation in prices received by domestic producers in the sale of their products (IPEA 2021). Inflation was measured by the consumer price index and prices paid by farmers were proxied by the IGP-OG (General Price Index-Global Supply). The IGP-OG covers trends in prices of inputs as well as other production costs (IPEA 2021). The high averages of inflation and real interest rates were due to the periods of hyperinflation that Brazil experienced in the early 1990s. For example, in 1990, the inflation rate in Brazil was over 4000%. Information on population and non-farm wages comes from the World Bank while exports come from FAO. Non-farm wages are the total paid in non-farm wages during the year. Real farm income was proxied using the value of agricultural production. Land value data comes from the Brazilian Institute of Economics within the Getulio Vargas Foundation (IBRE-FGV). Information on total roads comes from the National

Agency of Ground Transportation's Statistics on Ground Transportation Yearbook. Summary statistics are provided in table 5.

The estimation results for the SUR model for Brazil are shown in table 7. The number of farms has a positive effect on the growth rate in the number of small and midsize farms in Brazil, but a negative effect on the growth rate for large farms in the extended model. These results are consistent with figure 4 and indicate that the numbers of small and midsize farms in Brazil are increasing toward a long-term value. The ratio of prices received to priced paid by small and midsize farms in Brazil has a negative effect on the growth rate for these farms, similar to the U.S. case. In addition, this trend is also present for Brazilian large farms. Interestingly, the unemployment rate has a positive effect on the growth rate in the number of large farms in Brazil, where the opposite effect was present for U.S. large farms. An increase in highway mileage has a positive effect on the growth rate of small and midsize farms. This finding is in line with the discussion by Rada (2013) on how increased logistic infrastructure provided more production opportunities to agriculture in the *Cerrado* region.

Extension of Gale (1990) for farms in the Eurozone

We apply the methodology in Gale (1990) to examine the role of economic conditions in the 19 European Union countries that are currently in the Eurozone (EU-19). According to the European Central Bank, EU-19 is composed of the following countries: Austria, Belgium, Cyprus, Finland, France, Germany, Grece, Ireland, Italy, Luxemburg, Malta, The Netherlands, Portugal, Slovenia and Spain. Lowder, Sanchez, and Bertini (2019) and Deininger and Byerlee (2012) identify increases in the number of large farms within larger European countries. On the other extreme, about 50% of the farms in the European Union have a size less than 2 hectares (Lowder, Skoet, and Raney 2016). These facts warrant an analysis of how economic conditions impact midsize farms in the EU-19.

Information on European farms by small, midsize, and large categories comes from Eurostat. Growth rates are assumed to be constant over the years. Lowder, Skoet, and Raney (2016) classify small farms as those below 2 hectares and large farms as those above 50 hectares. To make the analysis consistent across the different countries and regions for our study, we defined small farms as less than 5 hectares, midsize farms between 5 and 50 hectares, and large farms over 50 hectares. The choice on the farm size categories was set by taking into consideration the size of large farms in the Eurozone, U.S., and Brazil farm size categories, as well as categories for small and large farms used in the literature. Similar to the case of Brazil, there is a rise in the number of small and midsize farms in the Eurozone from 1999 to about 2005, followed by a decline in farm numbers since then (figure 5). The decline in farm numbers is greater for small farms than for midsize farms. The number of large farms in the Eurozone has remained relatively stable since 1999.

Data on unemployment, inflation, value added from agriculture, and wages (hourly compensation) were collected from the European Central Bank. Exports, population, agricultural land area, and producer price index came from FAOstat data. Land values were estimated by dividing value added agriculture by the agricultural land area. The nonfarm wages over real farm income variable is calculated by dividing the hourly compensation by value added from agriculture. Hourly wages are available as an index, therefore, value added from agriculture was also transformed to an index prior to the division. Summary statistics are provided in table 5.

The SUR models by farm size for EU-19 use as dependent variables the growth rates in the number of farms in each category of small, midsize, and large farms (table 8). The EU-19 data covers only the more recent period of 1999-2018. The results show no significant relationship between the number of farms in each category and the growth rates in farm numbers. These results are also consistent with Gale (1990) showing no convergence to long-term trend using more recent data. The ratio of nonfarm wages to the value-added from agriculture index has a negative effect on the growth rates in the number of farms for small and midsize farms. This effect is not significant when more variables are included in the model for small farms, but population has a negative effect on the growth rate in the number of small farms. These findings indicate that nonfarm opportunities and population pressure lead to lower growth rates of particularly small and midsize farms. Higher interest rates also hinder the growth rate in small and midsize farms, as higher credit costs make farm entry more difficult.

Research limitations and suggestions for future research

This study has some limitations. First, given the different sizes of the countries/regions considered in our study and the available data, there is no one-size-fits-all category to define small, midsize, and large farms. Thus, the farm size categories we used vary according to the data available, and the country or region we considered. Using other options to define farm size also has limitations. Using farm sales, for instance, does not account for the effect of inflation which could make small farms to be considered as midsize over time. Also, information on farm numbers by acres or hectares is more readily available for other countries/regions. We leave to future studies the design of an appropriate farm typology when looking at farms globally.

Our sample size is a further limitation. Access to data can be challenging as reported in Lowder, Sanchez, and Bertini (2019). In fact, studies looking at small and family farms or large farms generally present data for a limited number of years and not always for the same countries or regions (Hazell et al. 2010, van Vliet et al. 2015, Lowder, Skoet, and Raney 2016, Deininger and Byerlee 2012). Another limitation, as discussed in Lowder, Sanchez, and Bertini (2019) is the occurrence of agricultural census which may not be periodic, for instance Brazil’s last two censuses had a 10-year gap between them. Similarly, the definition of what constitutes a farm may change over time. For instance, there was a change in how farms were defined in the U.S. in 1974 (Gale 1990). A change was also made in the U.S. farm typology, which now considers gross cash farm income instead of farm sales (Hoppe and MacDonald 2013). Additionally, we look at countries and EU-19 at the aggregate level. While this complements and allows for comparison to past research on global trends in farm numbers, it does not account for regional differences, and it does not consider different types of agricultural production. Future studies would benefit from the use of farm-level datasets. Regardless of these limitations, we believe this study sheds light on critical issues which can help guide policy makers.

Conclusions and policy implications

Gale (1990) was one of the early studies that examined the economic factors affecting farm numbers in the U.S. and a convergence of farm numbers to a long-term trend. In this study, we replicate the analysis of Gale (1990) and extend it to include the more recent period as well as to study these effects by farm size. We also extend the analysis to other countries and regions, including Brazil and the Eurozone. After replicating Gale (1990)'s results, we show that over the period that includes more recent data, a convergence toward a long-term trend in farm numbers is of smaller magnitude and not significant. Economic factors like population pressure, financial stress, and infrastructure play an important role in explaining the growth rate in the number of farms by farm size. We also do not find strong evidence to support the disappearing middle hypothesis, even though graphically we see a declining trend in the number of midsize farms in the U.S. over time.

Expanding the analysis to examine the same trends in farm numbers to other countries and regions, we see different trends in terms of reduction in the number of small farms while only a slight decline in the number of midsize farms in the Eurozone but increases both the number of small and midsize farms in Brazil. While economic factors are important in explaining these growth rates in farm numbers, for Brazil, there is also a significant upward trend in the number of small and midsize farms and a downward trend in the number of large farms. The disappearing middle hypothesis is also not supported, especially for Brazil. These findings illustrate important differences across countries and regions in terms of trends in farm numbers by farm size, and the economic factors that affect them.

We reject our main hypothesis that economic conditions have the same effect (in terms of direction), independent of farm size category and country/region. In fact, our results indicate that policymakers should take into consideration the intrinsic characteristics of the country when designing policy. For instance, the way in which a country was colonized can help explain current farmland distribution (Eastwood, Lipton, and Newell 2010). As such, countries with similar agricultural production scale cannot adopt policies that work well in another country without making adaptations.

The 2030 Agenda for Sustainable Development aims at eradicating poverty by allocating resources toward the promotion of sustainable agriculture and rural development (UN 2015). To achieve this aim, farmland distribution must be considered when designing public policies. There are strong linkages between economic growth, farmland distribution, and farm size (Lowder, Sanchez, and Bertini 2019, Eastwood, Lipton, and Newell 2010). Understanding how economic conditions affect farm numbers according to their size categories provides insights to policy makers, as they design policies linked to the 2030 Agenda. Afterall, policies aimed at poverty eradication and sustainable farming practices cannot target simply one farm size group.

Farmland distribution can help explain inequalities in land distribution. Eastwood, Lipton, and Newell (2010) find high levels of farmland Gini in developing countries, while Chamberlin and Jayne (2020) find linkages between farm sizes and rural household incomes. Therefore, it is important to ensure consistent growth rates among all farm sizes. This means ensuring opportunities for farms of various sizes to sell their output. As our results imply, for the cases of Brazil and the U.S., increases in prices received may motivate farms to grow and change to higher farm size categories. Rural development and urbanization can impact farmland distribution. Small farms may thrive more in more populated regions, while small and midsize farms may increase their growth rate as their access to infrastructure increases.

Currently, policy makers have targeted their policies for small farms while diverting their focus away from midsize and large farms. Our results for the U.S., Brazil, and the Eurozone show that generally economic conditions impacted small and midsize farms similarly in terms of direction but with a different magnitude. This may explain the disappearing midsize farms in certain countries/regions. By focusing policies on small farms, these policies may only have indirect effects on midsize farms. By recognizing farmland distribution, policy makers can tackle their goals of reducing poverty by promoting sustainable agriculture with increased productivity and income. Ignoring trends in farm sizes and the role of economic conditions will not allow for an objective view of the state of equality within agricultural production. Policy makers in different countries and regions can learn from experience of the role of economic conditions on farm growth rates but should take into consideration characteristics that are intrinsic to their country. Future studies should attempt to identify what these intrinsic characteristics are, as well as the best practices in terms of policies that motivate an increase or sustainability in the number of farms, particularly for midsize farms.

References

Brekken, CA, C. Dickson, H.H. Peterson, M. Ostrom, G. Feestra, and K. Tanaka. (2021) "Economic Impact of Values-Based Supply Chain Participation on Small and Mid-sized Produce Farms". Journal Food Distribution Research. Forthcoming.

Brown, J. P., & Weber, J. (2013). *The off-farm occupations of US farm operators and their spouses.* USDA-ERS Economic Information Bulletin, (117).

Burns, C., & Kuhns, R. (2016). *The changing organization and well-being of midsize US farms, 1992-2014* (No. 1477-2017-3956).

Chamberlin, J., & Jayne, T. S. (2020). Does farm structure affect rural household incomes? Evidence from Tanzania. *Food Policy*, 90, 101805.

Daniela, D. (2010, June). Correcting the influence of autocorrelated errors in linear regression models. In *9th RoEduNet IEEE International Conference* (pp. 140-144). IEEE.

Deininger, K., & Byerlee, D. (2012). The rise of large farms in land abundant countries: do they have a future? *World development*, *40*(4), 701-714.

Eastwood, R., Lipton, M., & Newell, A. (2010). Farm size. *Handbook of agricultural economics*, *4*, 3323-3397.

Erenstein, O., Chamberlin, J., & Sonder, K. (2021). Farms worldwide: 2020 and 2030 outlook. *Outlook on Agriculture*, 00307270211025539.

Featherstone, A. M. (2018). The Farm Economy: Future Research and Education Priorities. *Applied Economic Perspectives and Policy*, *40*(1), 136-154.

Ferreira Filho, J. B., & Freitas Vian, C. (2016). The evolving role of large and middle size farms in Brazilian agriculture. *Agricultural Economics*, 47(S1), 215-225

Hazell, P., Poulton, C., Wiggins, S., & Dorward, A. (2010). The future of small farms: trajectories and policy priorities. *World Development*, *38*(10), 1349-1361.

Hoppe, R. A., & MacDonald, J. M. (2013). Updating the ERS farm typology. *USDA-ERS Economic Information Bulletin*, (110).

IPEA – Instituto de Pesquisa Economica Aplicada 2021. *Ipeadata*. Macroeconomic and regional data. Available at: www.ipeadata.gov.br. [Accessed on: Jan 2021]

Jayne, T.S., Chamberlin, J., Traub, L., Sitko, N., Muyanga, M., Yeboah, F.K., Anseeuw, W., Chapoto, A., Wineman, A., Nkonde, C. and Kachule, R., (2016). Africa's changing farm size distribution patterns: the rise of medium-scale farms. *Agricultural Economics*, *47*(S1), 197-214.

Key, N. (2019). Farm size and productivity growth in the United States Corn Belt. *Food Policy*, *84*, 186-195.

Kirschenmann, F.; Stevenson, G. W.; Buttel, F.; Lyson, T.A.; Duffy, M. (2008). Food and the Mid-Level Farm: Renewing an Agriculture of the Middle, pp. 3-22, Food, Health, and the Environment series. Cambridge and London: MIT Press.

Lowder, S. K., Sánchez, M. V., & Bertini, R. (2019). *Farms, family farms, farmland distribution and farm labour: What do we know today?* FAO (No. 854-2020-093).

Lowder, S. K., Skoet, J., & Raney, T. (2016). The number, size, and distribution of farms, smallholder farms, and family farms worldwide. *World Development*, 87, 16-29.

MacDonald, J. M. (2021). How farm consolidation affects farmers and farmworkers. In *Handbook on the Human Impact of Agriculture*. Edward Elgar Publishing.

MacDonald, J. M. (2020). Tracking the consolidation of US agriculture. *Applied Economic Perspectives and Policy*, *42*(3), 361-379.

MacDonald, J. M., Korb, P., & Hoppe, R. A. (2013). *Farm size and the organization of US crop farming* (No. 1477-2017-3987).

Rada, N. (2013). *Assessing Brazil's Cerrado agricultural miracle*. Food Policy, 38, 146-155.

SAS Institute Inc. (1999). SAS OnlineDoc®, Version 8, Cary, NC: SAS Institute Inc., 1999.

Telles, T.S., Castro, G.H.L.D., Furlaneto, T.L.R. and Costa, G.V.D., 2021. A decline in number of farms in Brazil. Revista de Economia e Sociologia Rural, 60.

USDA-ERS. *U.S. Agricultural Trade Data Update*. Available at: <https://www.ers.usda.gov/data-products/foreign-agricultural-trade-of-the-united-states-fatus/u-s-agricultural-trade-data-update/>. [Accessed on: Jan 2021].

UN (2015). Transforming Our World: The 2030 Agenda for Sustainable Development. New York, NY: UN.

van Vliet, J. A., Schut, A. G., Reidsma, P., Descheemaeker, K., Slingerland, M., van de Ven, G. W., & Giller, K. E. (2015). *De-mystifying family farming: Features, diversity and trends across the globe*. Global food security, 5, 11-18.

Whitt, C., J. Todd, and A. Keller. (2021). "America's Diverse Family Farms: 2021 Edition." Economic Information Bulletin Number 231, Economic Research Service, US Department of Agriculture, December 2021.

Tables and Figures

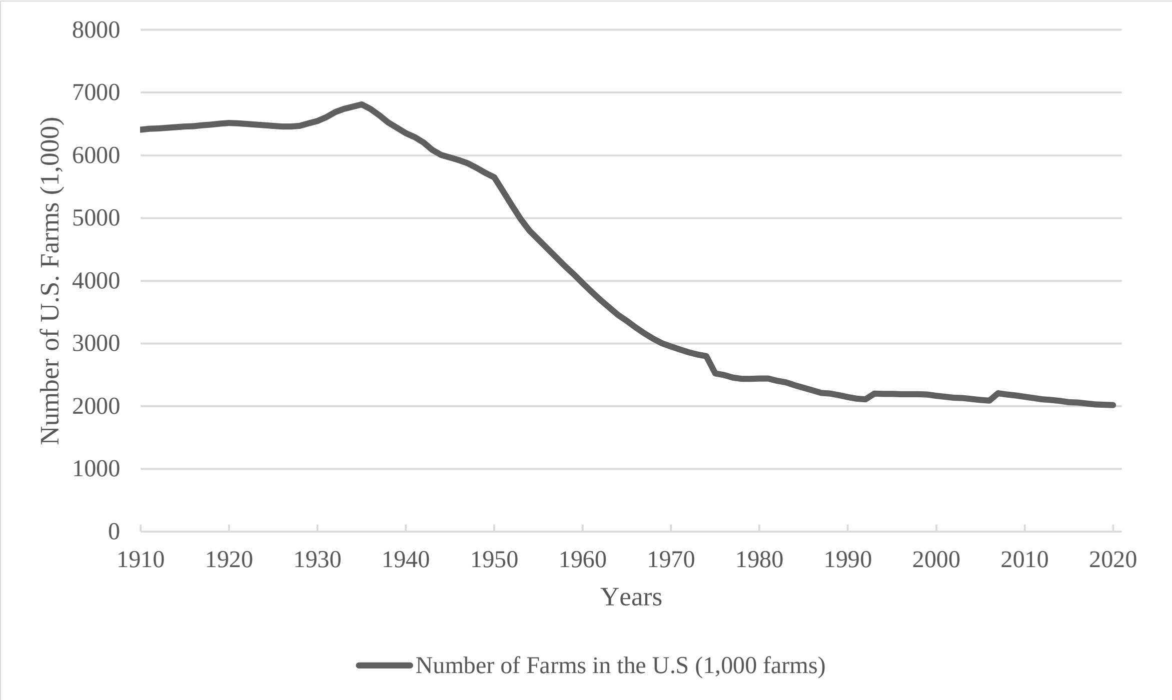

Figure 1: Number of farms and rate of change in farm numbers 1910 to 2020. Replication of figures 1 and 2 in Gale (1990).

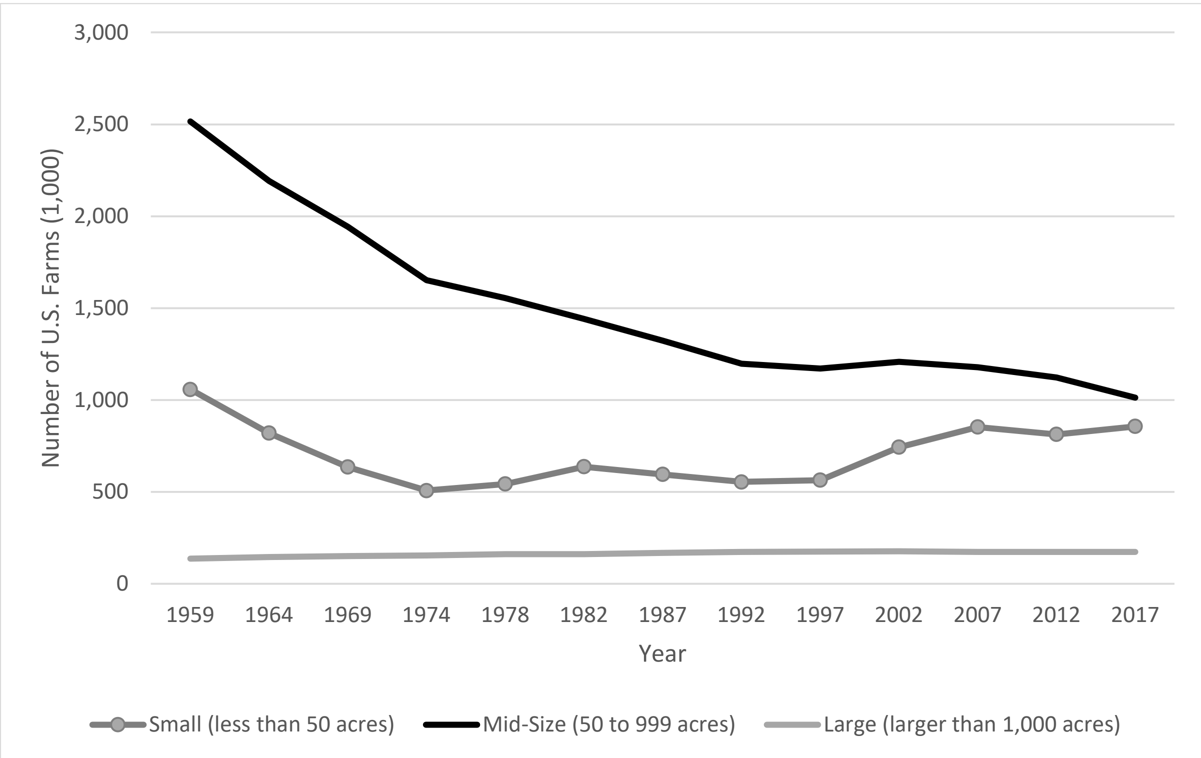

Figure 2: Change in number of U.S. farms by farm size categories in the indicated periods. Source: Agricultural Census from 1959 to 2017

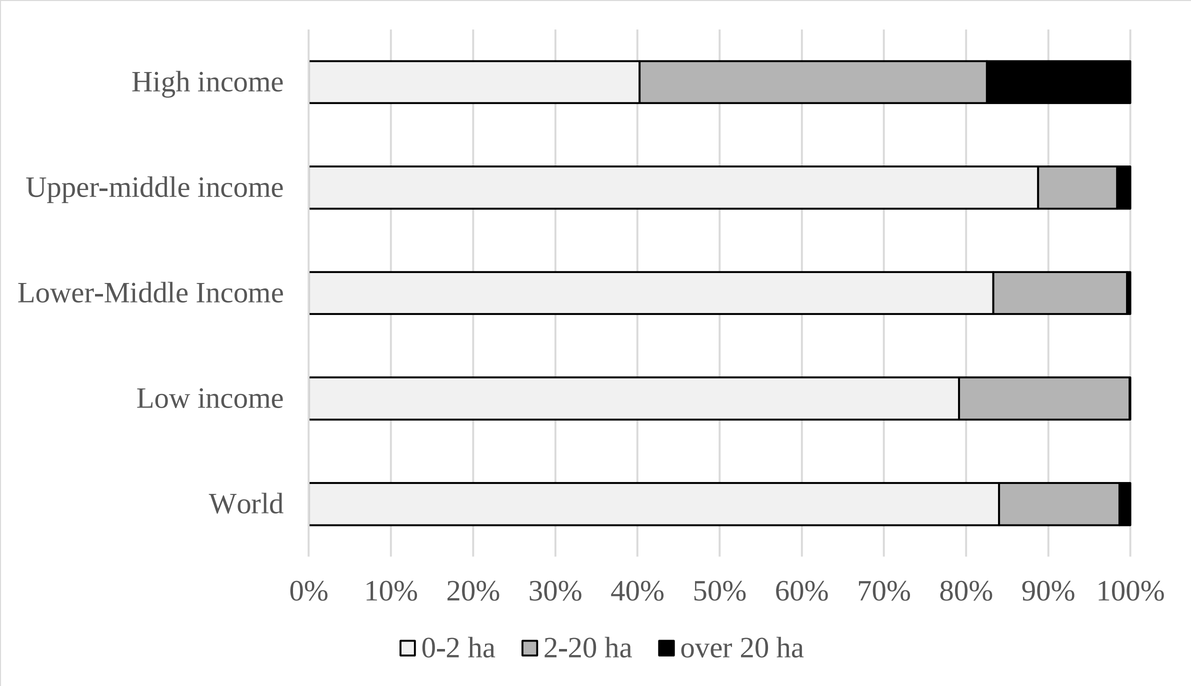

Figure 3: Distribution of farm numbers by farm size and country income level. Graph elaborated by authors based on data from Lowder, Sanchez and Bertini (2019)

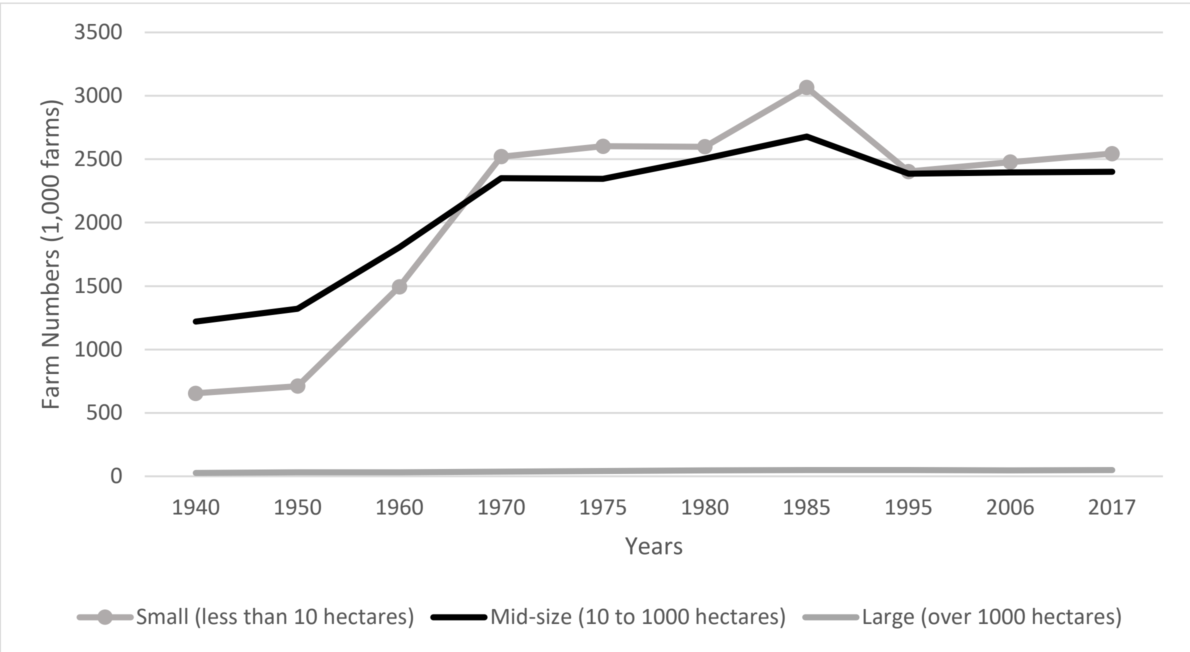

Figure 4: Change in number of farms by farm size categories in Brazil in the indicated periods. Source: Brazilian Agricultural Census from 1940 to 2017

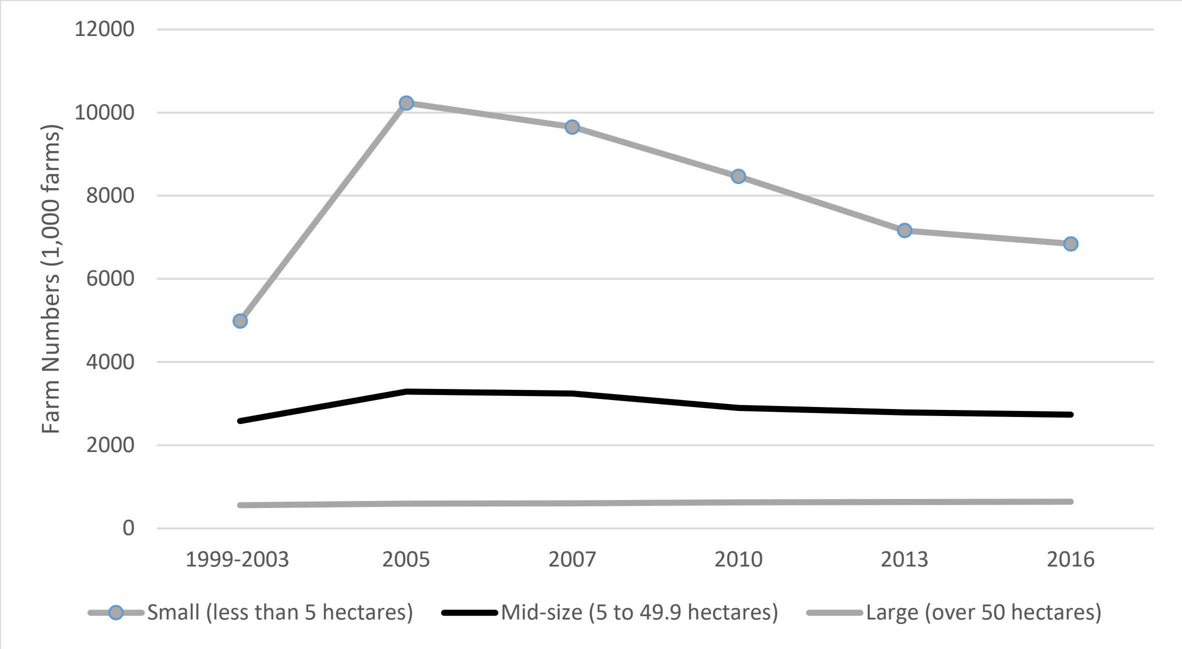

Figure 5: Change in number of farms by farm size categories in the Eurozone (EU – 19) in the indicated periods. Source: Eurostat for 2005 onwards and Lowder, Skoet, and Bertini (2019) for 1999-2003. EU – 19 countries are Austria, Belgium, Cyprus, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Portugal, Slovakia, Slovenia, and Spain.

Table 1: Descriptive statistics for U.S. farms by sub-period

	Replication 1960-74		Gale 1960-74		Replication 1975-88		Gale 1975-88	
Variable	Mean	CV	Mean	CV	Mean	CV	Mean	CV
Number US farms	3000684	12.74	3054361	13.99	2353988	4.61	2366450	4.99
Annual change in number of US farms	-87271	-44.57	-87271	-44.57	-24779	-68.32	-27961	-68.62
Percentage Change in number US farms	-2.52	-35.05	-2.76	-34.68	-1.05	-68.37	-1.19	-70.45
Ratio Prices received to prices paid by farmers	1.17	7.03	1.17	6.85	0.93	13.64	0.93	13.57
Average Value/acre of farm real estate (1977 dollars)	291	11.74	439	14.97	474	17.21	740	22.18
Real Interest Rates (%) (1977)	2.73	29.49	2.11	45.15	5.20	63.33	4.67	76.46
Ratio of Non-farm earnings to real farm income	1.42	13.42	NA	NA	3.43	42.05	NA	NA

CV is the coefficient of variation. Prices were deflated using the GNP deflator. NA: Not applicable. Gale (1990) does not present descriptive statistics for the ratio of non-farm earnings to real farm income.

Table 2: Explanatory variables in Gale (1990), extended model and their expected effects

Variables	Explanation/Representation	Expected sign
Number of farms	Long-term trend	Negative/Exit
Ratio prices	Index price received to price paid	Positive/Entry
Land value	Reflects future profitability	Positive/Entry
Real Interest rate	Price of credit	Negative/Exit
Ratio non-farm wages to real farm income	Attractiveness of nonfarm employment	Negative/Exit
	Extended model	
Debt-to-Asset	Financial stress	Negative/Exit
Population	Development pressure/ demand for foods	Undefined
Highway Mileage	Logistics / Development Pressure	Undefined
House Permits	Development pressure	Negative/Exit
Unemployment Rate	Worker supply	Positive/Entry

Table 3: Results from the regression creating a proxy for land values

	Replication (1960-1988)		Gale		Extended (1960-2020)	
	Land Value		Land Value		Land Value	
	(1)		(2)		(3)	
Exports	0.01	**	0.014	***	0.004	***
	(0.003)		(0.003)		(0.0014)	
Real interest rate	6.54	**	13.38	**	6.89	***
	(3.062)		(5.86)		(2.555)	
Actual inflation	2.28		23.99	***	2.75	
	(4.012)		(6.67)		(3.086)	
Constant	177.56	***	172.1	***	391.57	*
	(47.859)		(28.83)		(205.092)	
Observations	29		29		61	
R^2	0.49		0.9		0.14	
F Statistic	10.00*** (df = 3; 25)				7.44*** (df = 3; 57)	

Note: *p<0.1; **p<0.05; ***p<0.01. Gale (1990) does not inform the statistical significance of the coefficients (column 2). Asterisks in Gale (1990) were added based on the standard deviation. Model (1) uses Cochran Orcutt. Model (3) extends the dataset until 2020.

Table 4: Regression results for the annual change in the number of U.S. farms, 1960-88

	Replication (1960-88)		Gale		Replication (1960-2020)	
	Δ Farm Numbers (1)	Δ Farm Numbers (2)	Δ Farm Numbers (3)	Δ Farm Numbers (4)	Δ Farm Numbers (5)	Δ Farm Numbers (6)
Number of farms {t-1}	-0.08 ***	-0.09 ***	-0.07 ***	-0.08 *	-0.11 ***	-0.09 ***
	(0.0121)	(0.0095)	(0.01)	(0.01)	(0.013)	(0.0066)
	0.01312429					
Ratio of prices received to prices paid by farmers {t}	33,953.47		53,683 **		52,633.39 **	
	(25,381.54)		(27,282)		(24,973.01)	
	[0.63]		[0.93]			
Average value/acre of farm real estate (1977 dollars) {t-1}	347.92 **		112.81 *		40.51	
	(135.781)		(28.95)		(82.200)	
	[2.37]		[1.07]			
Real Interest rate {t-1}	-4,756.86 *		-3,432 **		261.50	
	(2344.478)		(1,395)		(917.569)	
	[0.14]		[0.18]			
Ratio of nonfarm earnings to real farm income {t-1}	-2,680.18		2,525		-125.22	
	(2,491.717)		(5,282)		(3,845.225)	
Intercept	29,730.84	185,813.90 ***	133,486 ***	162,128 ***	167,283.70 ***	182,323.90 ***
	(67,479.32)	(31,354.63)	(28,760)	(38,882)	(83,639.59)	(19,060.58)
Observations	28	28	28	28	60	60
Durbin-Watson statistic	1.70	1.69	1.05	0.47	2.00	2.01
Adjusted R-squared	0.85	0.72	0.9	0.57	0.65	0.61

Results obtained using a procedure to correct for autocorrelation of the error terms. ( ) = Standard errors. [ ] = Elasticity computed at the means. Asterisks in Gale (1990) columns were calculated based on standard deviation provided. Statistical significance levels $^{*}p<0.1$; $^{**}p<0.05$; $^{***}p<0.01$.

Table 5: Summary statistics for variables in the regressions

Variables	U.S.A		Brazil		Eurozone (EU-19)	
	Mean	Standard Deviation	Mean	Standard Deviation	Mean	Standard Deviation
Change in Farm Numbers	-30,172.46	45,040.68				
Exports[A] (Millions)	33,440.17	18,179.04	51,200.00	46,600.00	15,200.00	4,694.50
Inflation	3.11	2.09	181.36	636.48	1.76	1.00
Growth Small Farms (%)	-0.56	3.69	-1.37	3.51	1.84	9.44
Growth Midsize Farms (%)	-1.33	1.00	-0.70	1.50	-0.005	2.93
Growth Large Farms (%)	0.32	0.41	-0.23	0.72	0.79	0.47
Number of farms lagged	2,407.31	409.64	5,092.68	123.83	11,803.95	1,437.92
Ratio prices (Indexes)	0.82	0.26	1.00	0.44	85.02	10.82
Land value lagged ($)	508.90	209.04	1,432.51	465.97	1,234.21	106.65
Real Interest rate lagged (%)	4.02	2.43	90.55	832.13	2.99	0.98
Ratio non-farm wages to real farm income lagged	3.59	1.77	3.04	1.19	0.96	0.08
Debt-to-Asset lagged (%)	15.27	2.43				
Population lagged (Million)	255.03	44.94	173.26	18.51	0.33	0.01
Unemployment Rate lagged (%)	5.97	1.59	8.48	1.85	9.70	1.36
Highway Mileage lagged (km)	3,155.27	228.47	1,667.97	65.93		
Number Ag worker lagged	1,078.31	346.71				
House Permits lagged	1,356.07	369.81				

[A] US$ Millions for US, RS$ Millions for Brazil and EUR$ Millions for EU. Note that mean and standard deviations for inflation and interest rates in Brazil are high due to hyperinflation experienced in early 1990s. Values in 1977 dollars for USA, following Gale (1990), and 2015 for Brazil and EU-19.

Table 6: Results SUR Model – U.S., 1960-2020

	Extended Model	Variables in Gale			Extended Model		
	Change in Farm Numbers	Growth rate (%)					
		Small	Midsize	Large	Small	Midsize	Large
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Number of farms (per 1,000) {t-1}	-0.15 ***	-0.004 ***	-0.001 ***	0.000	-0.001	-0.0001	-0.0003
	(0.0239)	(0.0010)	(0.0003)	(0.00015)	(0.0016)	(0.00059)	(0.0002)
Ratio of prices received to prices paid by farmers {t}	7133.07	-2.79	-3.85 ***	0.075	-17.21 ***	-4.87 **	-0.53
	(52,188.57)	(4.3607)	(1.2391)	(0.3874)	(5.8699)	(2.0105)	(0.8253)
Average value/acre of farm real estate (1977 dollars) {t-1}	144.21	-0.013	-0.007 *	-0.003 ***	0.013 **	0.000	-0.001
	(167.614)	(0.0146)	(0.00406)	(0.0012)	(0.0050)	(0.00186)	(0.0007)
Real Interest rate {t-1}	13.34	0.19	0.013	0.018	0.022	0.005	-0.03
	(2,681.028)	(0.1676)	(0.03900)	(0.0165)	(0.2137)	(0.0630)	(0.0236)
Ratio of nonfarm earnings to real farm income {t-1}	4,065.78	0.82 **	0.016	-0.070 *	0.24	-0.105	-0.019
	(3,936.427)	(0.3728)	(0.1307)	(0.0384)	(0.3721)	(0.1339)	(0.0401)
Population (Million) {t-1}	-1.20 ***				-0.0001 **	0.000	0.000
	(0.3583)				(0.00005)	(0.00002)	(0.00001)
Debt-to-Asset {t-1}	-10,376.76 ***				-0.090	-0.13 *	-0.0061
	(3,596.657)				(0.2350)	(0.0710)	(0.0367)
Unemployment Rate {t-1}	1,061.61				0.60 ***	0.16 **	-0.07 ***
	(1,379.865)				(0.2024)	(0.0678)	(0.0227)
Highway Mileage {t-1}	1.90				0.003	0.001	-0.0004
	(7.1703)				(0.0032)	(0.0016)	(0.0007)
House Permits {t-1}	13.41				0.006 ***	0.002 ***	-0.0002 **
	(11.8271)				(0.0011)	(0.0003)	(0.0001)
Intercept	672,596.30 ***	14.70	7.18 **	2.32 **	16.41	2.74	7.03 **
	(209,721.7)	(5.185)	(3.2974)	(0.9691)	(24.2698)	(10.4228)	(4.1510)
Observations	60	60	60	60	60		
R-squared	0.81	0.61	0.57	0.72	0.79	0.74	0.82
System F-Statistic		17.00 ***	11.64 ***	27.74 ***	18.06***	14.16***	22.91***
Breusch-Pagan (χ2)			49.214 ***			35.90 ***	

Prais-Winston used for results in column (1). SUR results, columns (2) to (7) have bootstrapped standard errors 5000 iterations. Statistical significance levels: *p<0.1; **p<0.05; ***p<0.01

Table 7: Results for the SUR Model – Brazil, 1990-2017

	Variables in Gale			Extended Model		
	Growth rate (%)					
	Small (1)	Midsize (2)	Large (3)	Small (4)	Midsize (5)	Large (6)
Number of farms (per 1,000) {t-1}	0.017 ***	0.007 ***	-0.001	0.014 **	0.006 **	-0.0031 **
	(0.0044)	(0.0018)	(0.0019)	(0.0063)	(0.0026)	(0.0015)
Ratio of prices received to prices paid by farmers {t}	-5.03 **	-2.17 **	-1.32	-8.45 **	-3.59 **	-1.92 **
	(2.761)	(1.1523)	(1.3215)	(3.5810)	(1.4785)	(0.7933)
Average value/acre of farm real estate {t-1}	0.005 ***	0.002 ***	0.001	0.001	0.001	0.000
	(0.0009)	(0.00037)	(0.00044)	(0.0023)	(0.00094)	(0.0005)
Real Interest rate {t-1}	0.001	0.000	0.000	0.001	0.004	0.000
	(0.00277)	(0.00117)	(0.0022)	(0.00217)	(0.00090)	(0.0005)
Ratio of nonfarm earnings to real farm income {t-1}	0.635	0.249	0.142	-0.131	-0.071	-0.34 ***
	(0.5586)	(0.2318)	(0.2766)	(0.7527)	(0.3114)	(0.1292)
Population (Million) {t-1}				0.149	0.062	0.034
				(0.1087)	(0.04509)	(0.0248)
Unemployment Rate {t-1}				-0.272	-0.11	0.30 ***
				(0.3390)	(0.1405)	(0.0748)
Highway Mileage {t-1}				0.012 *	0.005 *	0.000
				(0.0070)	(0.0029)	(0.0022)
Intercept	-93.27 ***	-39.13 ***	6.21	-110.75 ***	-46.17 ***	9.39
	(21.028)	(8.6384)	(8.6170)	(28.291)	(101.6963)	(8.131)
Observations	27	27	27	26	26	26
R-squared	0.88	0.88	0.27	0.91	0.91	0.88
System F-Statistic	29.49 ***	30.34 ***	1.55	20.72***	21.38***	16.15***
Breusch-Pagan (χ2)		28.676***			26.821***	

Note: Bootstrapped standard errors in parenthesis, 5000 iterations. *p<0.1; **p<0.05; ***p<0.01

Table 8: Results for the SUR Model – EU-19, 1999-2018

	Variables in Gale			Extended Model		
	Growth rate (%)					
	Small	Midsize	Large	Small	Midsize	Large
	(1)	(2)	(3)	(4)	(5)	(6)
Number of farms (per 1,000) {t-1}	-0.0001	0.001	0.000	0.000	0.001	-0.0002
	(0.0044)	(0.00124)	(0.0002)	(0.0034)	(0.0011)	(0.000176)
Ratio of prices received to prices paid by farmers {t}	0.08	0.14	-0.03	0.26	0.19 *	-0.03
	(0.6430)	(1.1595)	(0.321)	(0.3662)	(0.1139)	(0.02318)
Average value/acre of farm real estate {t-1}	-0.057	-0.008	-0.004	-0.005	0.005	-0.002
	(0.0570)	(0.0152)	(0.0029)	(0.0505)	(0.0173)	(0.003625)
Real Interest rate {t-1}	-3.869	-1.051	0.015	-6.476 *	-1.723 *	-0.059
	(4.1607)	(1.1016)	(0.1488)	(3.6043)	(1.0650)	(0.1824)
Ratio of nonfarm earnings to real farm income {t-1}	-76.247 *	-33.369 ***	1.401	-40.164	-24.454 **	2.61
	(40.1965)	(11.0482)	(2.3390)	(43.1485)	(11.7887)	(2.5442)
Population (Million) {t-1}				-2,082.385 *	-510.235	-71.586
				(1,144.38)	(358.4582)	(72.0060)
Unemployment Rate {t-1}				-0.699	-0.26	0.02
				(2.1352)	(0.6983)	(0.1322)
Intercept	151.02 *	21.56	8.92	740.81 **	166.38	29.05
	(81.1310)	(23.7312)	(3.8800)	(352.739)	(108.5846)	(20.6039)
Observations	18	18	18	18	18	18
R-squared	0.75	0.80	0.77	0.90	0.89	0.86
System F-Statistic	6.06 ***	8.24 ***	6.56***	10.75***	9.64***	6.97***
Breusch-Pagan (χ2)		19.166***			13.984***	

Note: Bootstrapped standard errors in parenthesis, 5000 iterations. *p<0.1; **p<0.05; ***p<0.01

Appendix

Table A.1 – Regression by sub-period annual change in number of U.S. farms

	1960-1974				1975-1988			
	Replication		Gale		Replication		Gale	
	Δ Farm Numbers	Δ Farm Numbers	Δ Farm Numbers	Δ Farm Numbers	Δ Farm Numbers	Δ Farm Numbers	Δ Farm Numbers	Δ Farm Numbers
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Number of farms {t-1}	-0.09 ***	-0.09 ***	-0.063 ***	-0.087 ***	-0.25 ***	-0.04	-0.305 ***	0.04
	(0.0223)	(0.0101)	(0.012)	(0.009)	(0.0416)	(0.0517)	(0.041)	(0.065)
Ratio of prices received to prices paid by farmers {t}	24,371.80		46,077		151,658 **		189,063 ***	
	(17,302.99)		(34,469)		(64,784.23)		(56,060)	
					[5.64]		[6.29]	
Average value/acre of farm real estate (1977 dollars) {t-1}	215.95		234.03 **		857.19 **		267.04 ***	
	(269.961)		(99.36)		(188.354)		(38.17)	
	[0.82]		[1.14]		[15.5]		[7.06]	
Real Interest rate {t-1}	1,578.09		-2,258		-7,422 *		-5,725 **	
	(5,566.077)		(2,438)		(3,374.66)		(2,141)	
	[0.05]		[0.14]		[1.67]		[0.91]	
Ratio of nonfarm earnings to real farm income {t-1}	6,936		28,500.00		-4,494 **		7,815	
	(12,150.62)		(23,894)		(1,691.57)		(5,303)	
Intercept	435,611 *	197,173 *	106,897 **	182,746 ***	156,143 **	59,953	702,403 ***	-37,631
	(182,955)	(35,328.55)	(37,778)	(29,805)	(55,497.74)	(126,688.90)	(97,807)	(154,981)
Observations	14	14	14	14	14	14	14	14
Durbin-Watson statistic	1.88	1.50	1.23	0.46	2.31	1.68	2.93	0.9
Adjusted R-squared	0.90	0.90	0.98	0.87	0.65	0.00	0.95	0

Results obtained using a procedure to correct for autocorrelation of the error terms. ( ) = Standard errors. [ ] = Elasticity computed at the means. Stars in Gale (1990) columns were calculated based on standard deviation provided. Statistical significance levels *p<0.1; **p<0.05; ***p<0.01.