Government policies and farm size: does the size concept matter?

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This paper employs a panel data set of 48 states from 1960 to 1996 to investigate the relationships of government policies (public agricultural research and development (R&D), extension, and government commodity program payments) to changes in farm size. Five different farm size measures are considered (acres operated per farm, real land and building value per farm, real cash receipts per farm, real cash receipts plus government payments per farm, and an imputed measure of the real capital service flow per farm) in order to make a more general statement about the impacts of government policies on farm size. It was found that the impacts of government policies on farm size are in general robust to the measure of farm size considered. More specifically, it was found that R&D, extension, and government payments all have positive effects on farm size.

I. Introduction

The consolidation of US agriculture is proceeding at a rapid rate. For example, between 1987 and 1997, the number of farms in the USA declined by 8%, and even more telling, the number of farms accounting for 50% of US production declined by 39% (USDC, 1989; USDA, 1999). The perception that ‘family farms’ are dwindling in number often results in expressions of social concern. At the same time, society benefits from having a highly productive farming system and low food prices that may come with increased consolidation. Because of the policy interest in the size distribution of farms, there is an interest in understanding the causes of changing farm sizes. The causes of changes in farm size are complex and interrelated and include government policies, technological change, and changes in farm and nonfarm markets.

A recent National Research Council (NRC) report (2001) Publicly Funded Agricultural Research and the Changing Structure of US Agriculture noted that (p. 29) ‘very little empirical evidence exists on the relationship between public sector agricultural research and structural change’. This is in sharp contrast to the huge empirical literature on the impacts of public agricultural research and development (R&D) and extension on productivity (e.g. Huffman and Evenson, 1993, and Yee et al., 2002).

The NRC report cited two empirical studies:

(i) Busch et al. (1984) employed state level data for 1915 to 1973. The study found evidence that publicly financed agricultural R&D is correlated with increases in farm size.

(ii) Huffman and Evenson (2001) employed state level data from 1950 to 1982. The farm structure variables they considered included crop and livestock specialization, farm size, and farmers’ off-farm work participation. They found that public R&D impacts farm structure. They also found that changes in farm commodity programmes had little relationship to farm structure.
Unlike for the case of productivity, there is no one single conceptual indicator of structure. Basic indicators of farm structure would certainly include farm size and participation in off-farm work. Farm size itself can be measured in several possible ways. Furthermore, the structural change process occurs rather slowly, over time, and hence empirical applications require extensive panel data.

Our paper adds to the small body of empirical evidence on the impacts of public policies on farm structure. More specifically, we will employ more recent data (1960 to 1996) at the state level to investigate the relationships of government policies (R&D, extension, and government payments) to changes in farm size. Huffman and Evenson (2001) used as their farm size variable a measure of the agricultural service flow from land and buildings. We will consider in this paper five different farm size measures in order to make a more general statement about the impacts of government policies on farm size.

There are a variety of ways to measure farm size. Size concepts are both output-based and input-based. Different size concepts can be constructed using different statistics. For a particular population of farms, say farms in one particular state, average farm sizes are most commonly reported. Other statistics provide information on the size distribution of farms for a particular population of farms, which may be especially important to consider because of the increasing proportion of farms at both tails of the size distribution.

The most useful farm size concept is one that yields a measure of the productive capacity of a farm firm. The most traditional way to measure farm size, for example, in US censuses of agriculture, is a spatial measure, in acres. Another common way to measure farm size is by the gross value of sales or product. While the number of acres in a farm, an input-based measure, is easy to quantify and usually does not change often, it has the disadvantage of not accounting for the productive capacity of land. For example, an acre of irrigated farmland has a much different productive capacity in a dry-land farming area, than would an acre that is not irrigated. Gross sales, an output-based measure, is an improvement over acres in that it provides some indication of the productive capacity of the land. Gross sales are relatively easy to measure, although they change for reasons unrelated to farm size over time, for example, from the impacts of weather on yields or annual fluctuations in commodity prices.

Land market data provide us with a preferred alternative for capturing a farm size concept based on the productive capacity of land. Land market data (land values and cash rent) capture information about the expectations for future agricultural returns of land and are not affected by short-term fluctuations in yields and prices. Unfortunately, land value data also capture the value of land for other than agricultural uses. In particular, market values for farmland near cities include the value associated with expected future development options. In contrast, agricultural rents do not generally capture this premium from expectations for future development. This is because the renter is only purchasing the temporary services of the land for agricultural purposes.

We examine five different size measures across time (1960–1996) and space (the 48 contiguous US states): acres operated per farm, real land and building value per farm, real cash receipts per farm, real cash receipts plus government payments per farm, and an imputed measure of the real capital service flow per farm. Imputed service flow per farm can be considered a measure of the agricultural service flow from the land and is calculated as the product of the rental rate per acre for rented farmland from the Census of Agriculture and the average acres per farm (both owned and rented) by state (assuming that the land and farm structures rented are representative of all land and structures in the state). We use the prices received (PR) index to deflate the two cash receipts-based measures and the imputed service flow measure. We use the GDP deflator to calculate real land and building value.

The common indicators of farm size all indicate that during the 1960–1996 period average farm size increased in the US, levelling off in the later part of the period. However the rate of growth for the different size measures differs for the full period, and for sub-periods. The most basic of measures, average acres per farm, has increased slowly and steadily over time. This is because, while the total land in farms has decreased slowly, the number of farms has decreased at a somewhat higher rate. Using the imputed service flow measure, the average US farm size increased at a faster rate than average acres in farms. The use of the prices received (PR) index to calculate real values for the cash receipts-based measures and the imputed service flow measure incorporates more annual variation in the farm size measures as a result of the usual fluctuation in annual

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1 Approximately 40% of US farms are located in areas designated as metropolitan and another 35% are in areas adjacent to metropolitan counties.
commodity price markets. The PR index and the GDP deflator increased at different annual rates. In particular, the PR index rose at a much slower rate in the latter part of the period than did the GDP price deflator.2

We will compare the results of empirically estimated models of the determinants of farm size, varying the farm size measure in an econometric model. We define farm size as described above and other variables are described in Appendix A. The data set is a panel data set of 48 states from 1960 to 1996. We highlight the econometric results for the government policy variables and the results for one particular measure of farm size, imputed service flow.

II. Empirical Model and Results

In spite of the lengthy history and volume of the literature on farm structural change, there is little agreement on a conceptual model for the structural change process in agriculture. Several useful review articles address the diversity and conflict among competing conceptual models (Harrington and Reinsel, 1995). Cochrane’s technology treadmill is perhaps the most widely recognized hypothesis on structural change forces (Cochrane, 1958). Cochrane’s hypothesis focuses on the impact of technological innovation reducing real per unit cost of output at the farm level and with competition encouraging farmers to adopt new technologies. As adoption becomes widespread, prices of farm commodities fall differentially across the country and possibly by size of farm, triggering structural adjustments. Technology adoption certainly plays a prominent role in the structural change process, but many mechanisms are believed to play important roles in this process. Instead of relying on the existence of scale economies to explain farm structural change, Kislev and Peterson (1982) showed that most of the changes in US farm size (between 1930 and 1970) could be explained by changes in relative factor prices. Other schools of thought, including asset fixity and political economy, also make contributions to understanding the structural change process in US agriculture. In this study of the determinants of farm size, we draw on many of these ideas in our specification and explanation of relationships.

We have specified a three equation simultaneous model. Besides the farm size equation, we include equations for productivity and the odds that an operator works off-farm at least 200 days per year. The basic conceptual model is similar to that found in Yee et al. (2004), except that we employ a 2SLS-estimation procedure. 3SLS can potentially yield estimators with greater asymptotic efficiency than 2SLS. However, if the equations of the 3SLS model are not correctly specified, the estimates of all of the structural parameters are affected. Since our main interest in this paper is farm size, we prefer to use 2SLS since 2SLS has been shown to be robust to possible specification errors in the other equations in the model (Kennedy, 1998).

For the variables of the size equation using the five different measures of farm size, Table 1 provides information on the regression results. Five of the 10 exogenous variables were significant with consistent signs for all five measures of size. Another two of the exogenous variables had consistent signs, when they were significant, but the exogenous variables were not significant in all of the size models. For the remaining three exogenous variables and the two endogenous variables (productivity and off-farm work of the operator), the results varied across the five models with differing size specifications. The size measures employed when the results were less common and/or counter-intuitive were those where farm size was measured as the average acres per farm and the average real land and building value per farm.

To highlight the sensitivity of the model to the size concept employed, we focus on the government policy variables (R&D, extension, and government payments). A state’s own research has a positive and significant effect on farm size for all five measures of farm size. Similarly, extension has a positive and significant effect on farm size for all five measures of farm size. Research performed in other states in the same region (spill-in) has a positive and significant effect on farm size for all but the two output-based measures of farm size. It is generally considered desirable that public investments in research and extension should be size neutral. However, our results indicate that both R&D investments and extension have

2 Varying the size concept will result in different conclusions about the size distribution of farms across countries, as well as was shown for a US and EU-15 comparison (Ahearn et al., 2004). In particular, when a spatial measure of farm size was used (hectares) the US farm structure was significantly larger than the EU-15. When an economic measure of farm size (the European Size Unit) was used, the US farm structure was still larger than the EU-15, but the differences were much less. This difference by size measure reflects the greater intensity of agriculture in general in the EU, compared to the US where large expanses of land in the West are relatively unproductive.
a positive influence on farm size over the time period studied. Given the fixed costs of the adoption decision, larger farms may experience economies of scale in using them. Our results are consistent with the Busch et al. (1984) and Huffman and Evenson (2001) studies.

Government commodity program payments has a positive and significant effect on farm size for all five measures of farm size. Farmers may use part of the commodity payments to expand their farm size. This finding is consistent with Cochrane’s ‘cannibalism’ model of payment recipients to outbid farmers not receiving payments for farm land (Cochrane, 1958). When size was measured as average acres per farm, payments had the largest coefficient. Of the two output-based measures, government payments was most significant when the output measure included consideration of payments. This is not surprising, given that payments added as much as 11% additional value to cash receipts at the US level, depending on the year.

Other variables may also affect farm size. We will discuss the results for what we believe is the superior measure of farm size, namely, the imputed service flow (last column of Table 1). Since farm size may vary by region, we include regional dummy variables in the regression. Given the log–log specification of the farm size equation, the coefficients can be interpreted as elasticities.

We turn first to the relationships among our three endogenous variables. We found that an increase in agricultural productivity increases farm size. Perhaps higher productivity translates into higher profitability. Increased off-farm work is associated with

Table 1. Two-stage least squares estimates of farm size equation: state aggregate data, 1960–1996 (n = 1776)

<table>
<thead>
<tr>
<th>Variables</th>
<th>Acres</th>
<th>Land &amp; bldg value</th>
<th>Cash receipts</th>
<th>Receipts &amp; govt. payment</th>
<th>Imputed service flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Productivity</td>
<td>−1.036</td>
<td>0.465</td>
<td>1.178</td>
<td>1.032</td>
<td>1.220</td>
</tr>
<tr>
<td>Off-farm work</td>
<td>−0.605</td>
<td>(2.561)</td>
<td>(10.142)</td>
<td>(8.890)</td>
<td>(6.091)</td>
</tr>
<tr>
<td>Own state</td>
<td>−0.791</td>
<td>(3.536)</td>
<td>−0.312</td>
<td>−0.344</td>
<td>−0.466</td>
</tr>
<tr>
<td>Own state research stock</td>
<td>0.166</td>
<td>0.066</td>
<td>0.175</td>
<td>0.197</td>
<td>0.072</td>
</tr>
<tr>
<td>Spill-in research stock</td>
<td>(5.144)</td>
<td>(2.080)</td>
<td>(8.645)</td>
<td>(9.754)</td>
<td>(2.066)</td>
</tr>
<tr>
<td>Extension research stock</td>
<td>0.200</td>
<td>0.174</td>
<td>0.018</td>
<td>0.008</td>
<td>0.319</td>
</tr>
<tr>
<td>Extension stock</td>
<td>(6.598)</td>
<td>(5.829)</td>
<td>(0.923)</td>
<td>(0.416)</td>
<td>(9.694)</td>
</tr>
<tr>
<td>Machinery price to labour wage ratio</td>
<td>−0.159</td>
<td>(−9.404)</td>
<td>(−3.499)</td>
<td>(−3.053)</td>
<td>(−3.593)</td>
</tr>
<tr>
<td>Specialization (Herfindahl)</td>
<td>1.031</td>
<td>−0.186</td>
<td>0.217</td>
<td>0.367</td>
<td>0.143</td>
</tr>
<tr>
<td>Commodity payments</td>
<td>0.047</td>
<td>0.029</td>
<td>0.026</td>
<td>0.042</td>
<td>0.039</td>
</tr>
<tr>
<td>Share with college</td>
<td>(5.355)</td>
<td>(−0.978)</td>
<td>(1.789)</td>
<td>(3.023)</td>
<td>(0.682)</td>
</tr>
<tr>
<td>Share with college aged</td>
<td>0.352</td>
<td>0.346</td>
<td>0.266</td>
<td>0.280</td>
<td>0.457</td>
</tr>
<tr>
<td>Share with college aged</td>
<td>(11.464)</td>
<td>(7.313)</td>
<td>(8.790)</td>
<td>(9.242)</td>
<td>(8.751)</td>
</tr>
<tr>
<td>Share with contracts</td>
<td>0.370</td>
<td>(−1.112)</td>
<td>0.199</td>
<td>0.243</td>
<td>0.096</td>
</tr>
<tr>
<td>Share with contracts aged</td>
<td>(3.570)</td>
<td>(−12.969)</td>
<td>(3.635)</td>
<td>(4.433)</td>
<td>(1.012)</td>
</tr>
<tr>
<td>Share of non-metro area</td>
<td>0.007</td>
<td>−0.074</td>
<td>0.048</td>
<td>0.055</td>
<td>0.004</td>
</tr>
<tr>
<td>Share of non-metro area</td>
<td>(0.562)</td>
<td>(−6.223)</td>
<td>(6.333)</td>
<td>(7.254)</td>
<td>(−0.334)</td>
</tr>
<tr>
<td>Time</td>
<td>0.151</td>
<td>−0.054</td>
<td>−0.007</td>
<td>−0.007</td>
<td>0.110</td>
</tr>
<tr>
<td>Time</td>
<td>(12.835)</td>
<td>(−4.654)</td>
<td>(−0.880)</td>
<td>(−0.879)</td>
<td>(8.569)</td>
</tr>
<tr>
<td>Time</td>
<td>(−0.020)</td>
<td>−0.007</td>
<td>−0.019</td>
<td>−0.018</td>
<td>−0.024</td>
</tr>
<tr>
<td>Time</td>
<td>(−6.063)</td>
<td>(−1.993)</td>
<td>(−9.094)</td>
<td>(−8.600)</td>
<td>(−6.584)</td>
</tr>
<tr>
<td>R²</td>
<td>0.863</td>
<td>0.754</td>
<td>0.860</td>
<td>0.860</td>
<td>0.724</td>
</tr>
</tbody>
</table>

Notes: A log–log specification was utilized. t-ratios in parentheses.
Regional dummy variables are included in each equation. The regions considered in this paper are:
1. Northeast (NE): CT, DE, ME, MD, MA, NH, NJ, NY, PA, RI, VT
3. Central (CENT): IN, IL, IA, MI, MO, MN, OH, WI
4. Northern Plains (NP): KS, NE, ND, SD
5. Southern Plains (SP): AR, LA, MS, OK, TX
6. Mountain (MOUNT): AZ, CO, ID, MT, NV, NM, UT, WY
7. Pacific (PAC): CA, OR, WA

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a smaller farm size, as more time spent working off-farm means less time available for working on the farm.

Turning to government policy effects, we found that R&D (both own and spill-in) and extension increase farm size. We found that government commodity payments were positively related to farm size. (As noted above, these results are robust to the farm size measure employed.)

Other factors also influence farm size. A decrease in the farm machinery price-hired farm labor wage ratio leads to an increase in farm size. A decrease in this ratio makes farm machinery cheaper relative to farm labor. Purchase of farm machinery generally entails a high fixed cost, which the farmer wants to spread over a higher level of output. An increase in the share of a state’s land in non-metropolitan areas increases farm size. This indicates that, with less competition for land for urban uses, farm sizes are larger. This finding is also consistent with the hypothesis that a major motivation for farm households to expand their farm size is to increase household income, for example, when off-farm work opportunities are not available. Specialization (computed as a Herfindahl index, based on 10 commodity categories) and the proportion of farms with production contracts were not significant in explaining farm size. The proportion of farm operators with a 4-year college education or more had a positive effect on farm size. However the proportion of farm operators 65 years old and over was not significant.

III. Concluding Remarks

Structural change in agriculture is of continual interest to policy makers, producers, and society in general. The motivation for this enduring interest includes issues associated with social sentiments regarding family farms and, more recently, recognition of the amenities of farm landscapes usually associated with family farms (OECD, 1998). In spite of this policy interest in understanding how public policies affect farm structure, there is a dearth of definitive empirical results. Our results have brought some empirical evidence to bear on the ongoing discussion regarding the impacts of government agricultural policies on farm size.

We considered in this paper five different farm size measures in order to make a more general statement about the impacts of government policies on farm size. For our study period, 1960–1996, we found that the impacts of government policies on farm size are in general robust to the measure of farm size considered. We found that both R&D and extension have positive effects on farm size. This is consistent with the Busch et al. (1984) and Huffman and Evenson (2001) studies. We also found that government payments have a positive effect on farm size. This result is consistent with Cochrane’s (1958) ‘cannibalism’ hypothesis, but inconsistent with Robinson’s (1975) hypothesis that government payments help to keep small farms in business. Our results reinforce the notion that government policies designed to impact a single target, such as productivity, will likely have structural implications. Besides government policies, we found that other key determinants of farm size are technological factors, farm organizational characteristics, operator demographic characteristics (including engagement in off-farm work), and urban influence.

It would be interesting to extend our analysis to later years, since Fig. 1 indicates farm size levelling off in the later part of the period. In addition, the post-1995 period has seen a major change in public

Fig. 1. Trends in US farm size using common size measures, 1960–1996
policies for transferring income to the farm sector, e.g. the introduction of decoupled payments. Other recent changes that are likely to have impacts on farm size measures include the adoption of new technologies, such as genetically modified seeds, and organizational changes in the supply chain for some commodities, such as the increase in contracting for hogs and tobacco. Each of these have differing implications for our measures of farm size.

Acknowledgements
The views expressed are of the authors and do not necessarily represent the policies or views of USDA.

References

Appendix A: Data and Variables

Total factor productivity. Total factor productivity (TFP) is the ratio of total outputs to total inputs. Data on TFP by state are available from the ERS homepage at: http://usda.mannlib.cornell.edu/datasets/inputs/98003. The TFP numbers for each state are spatially adjusted so that they are comparable across states.

Farm output consists of all crop and livestock products. Farm inputs include capital (durable equipment and real estate), labour, and intermediate inputs. Intermediate inputs consist of fertilizer, pesticides, energy, feed, seed, and intermediate livestock inputs.

Off-farm work. Off-farm work is measured as the odds of the farm operator working off the farm for 200 or more days per year.

Farm size. See text for description.

R&D stock (own and spill-in). Data on public agricultural research expenditures to enhance and maintain agricultural productivity up to 1995 were compiled by Huffman et al. (forthcoming). The annual nominal agricultural research expenditures by state are converted to real (1984 = 1.00) expenditures using Huffman and Evenson’s agricultural research price index (Huffman and Evenson, 1993).
Government policies and farm size

Research expenditures in a given year are expected to have an impact on productivity for many years. However, including a large number of lagged research expenditures in the productivity equation uses up a large number of degrees of freedom. Also, the lagged values of the research expenditures tend to be highly correlated. Consequently, we constructed a research stock variable as a weighted sum of current and past research expenditures.

Most studies of the impact of research, especially private research in manufacturing, construct the stock of research capital from research expenditures using the perpetual inventory method and assuming geometric decay. While geometric decay may be a reasonable assumption for physical capital, it is not plausible for research capital. We follow suggestions by Griliches (1979, 1998) to impose considerable structure on our timing weights. We constructed a research stock variable as a weighted sum of current and past research expenditures using the Huffman and Evenson (1993) trapezoidal-timing-weights over 33 years. The plot of the cumulative summation of these weights over time gives a sigmoid S-shaped pattern.

Two public research stock variables are used in this paper, an own-state and a spillover/spillover. For example, some of the public agricultural research discoveries in Iowa may spillover to one or more of the surrounding states or Iowa may benefit from public agricultural research conducted in surrounding states. We impose the simplifying assumption that benefits are regionally confined. For a given state in a region, the spillover (or spillover) stock is defined as the total public agricultural research stock of all states in the region less the state’s own public agricultural research stock. The states are grouped together into regions using regional boundaries defined by McCunn and Huffman (2000).

Extension stock. Data on professional extension full-time equivalents (FTE’s) by state and major program areas were compiled by Ahearn et al. (2003). Over most of the period, extension was organized into four program areas: agriculture and natural resources (ANR), community resource development (CRD), 4-H youth (4-H), and home economics (HE). This paper only considers the ANR programme area, which includes crop production and management, livestock production and management, farm business management, agricultural marketing and supply, and natural resources. An extension capital stock for each state is obtained as a weighted sum of current and past FTE’s with declining weights and dividing by the number of farms.

Specialization. Specialization is computed as a Herfindahl index based on cash receipts of 10 commodity categories. Cash receipts are the value of agricultural production sold in a particular calendar year. As such, it would include the value of product produced in previous years, stored and sold in the current year. It would exclude the value of product produced in the current year and stored for later sale. It would also exclude the value of product from current year, which is used on the farm from which it was produced, usually as livestock feed. Cash receipts are largely computed from annual USDA probability-based surveys of prices and quantities. In some cases, when a commodity is heavily concentrated in a few states or represents a small share of production, state-level agricultural statisticians provide the estimates of cash receipts of the commodity.

Commodity payments. Commodity payments are direct payments made to farm operators and others who own farmland and are eligible to receive subsidies under the continuing legislation of the so-called farm bill. The exact nature of the programmes and eligibility of the programmes has changed many times since the first Depression-era programme. The payments are made largely by the Federal government, although some state programme subsidies are included. The data are annual administrative records information on payments made for the agricultural programmes that are associated with agricultural production.

Contracting. Production contracts are the number of farms in a state that had any production contracts to produce any agricultural commodity. Under a production contract, an operator-grower contracts with a processor-integrator to produce and make available for delivery a specified product, sometimes with specified quality attributes for a specified time. The contractor takes possession of the commodity and pays the grower a fee. Terms of contracts vary widely. The Census of Agriculture, taken of farms every 4 or 5 years, provided us with the actual number of production contracts for the census years. We interpolated for intercensal years using a straight-line approach.

Machinery price-to-labour wage ratio. Where published government statistics existed we utilized those. However, for some years, state-level data were not available and so we estimated state-level data from regional data and/or interpolated between known benchmark data. Farm wage rates came from NASS, USDA. Farm machinery price is a national price from the ERS homepage.
Educational attainment. Operator educational attainment as a categorical variable is collected occasionally on the Census of Agriculture, for example, 1964. For the most recent year of our data series, 1996, we used an average of three years (1995–1997) from USDA’s Agricultural Resource Management Survey. We interpolated in between benchmarks.

Age of operator. The share of operators that are 65 years or older. Operator age is available from the Census of Agriculture. We interpolated in between Census benchmarks.

Non-metro area. The share of land acres in a state that is classified as non-metro, as determined by the decennial census of population.