How Quickly Do Farmers Adopt Technology? A KFMA Analysis

Terry W. Griffin (twgriffin@ksu.edu) – K-State Department of Agricultural Economics
Elizabeth A. Yeager (eyeager@ksu.edu) – K-State Department of Agricultural Economics
May 2019

Abstract
Precision technologies have been available at the farm level for decades. However, the rate at which adoption occurs varies. Some technologies have been readily adopted while others lagged. Analysis of 608 Kansas farms provided insights regarding duration of adoption. The lag, in years, between technologies becoming commercially available and being adopted were evaluated using non-parametric duration analysis. Duration for embodied-knowledge technologies were statistically sooner than for information-intensive technologies, indicating farmers adopt automated guidance 'quicker' than yield monitors. Duration was indirectly (directly) proportional to commercialization date of embodied-knowledge (information-intensive) technology. Results are useful to farmers considering adoption, retailers targeting customers, and manufacturers managing supply chains.

Introduction

Farm-level adoption of agricultural technologies remain a persistent issue among researchers and practitioners in terms of understanding the rate at which technologies are adopted, order in which adoption occurs, and the benefits the technology provides. Many precision technologies have been available since the early 1990s, yet adoption has not plateaued even after nearly three decades. Adoption of technology has been associated with perceived profitability from farm-level utilization. The benefits of precision agriculture have been said to be 'site-specific'. Given that the economics of technology are a function of the specific grower's fields and their management ability, profitability assessments of specific technologies have been elusive.

Data and Methods

The Kansas Farm Management Association (KFMA) maintains archives of farm-level agronomic and financial data since 1973. In 2015, KFMA economists began collecting and annually updating technology records. By September 2018, 608 farms reported either 'used' or 'never used' at least one of six technologies. Of the 608 farms, 519 (85%) adopted one or more technologies including: global navigation satellite system (GNSS) enabled yield monitors (GNSSYM), variable rate fertilizer (VRF), precision soil sampling (PSS), lightbar (LB), automated guidance (AGS), and automated section control (ASC).

Duration is the length of time after being able to adopt that adoption occurs. Lags are measured in years between the farm adopting technology and when the farm could adopt the technology. Individual farms could adopt technology after the farm began operating and technology became available (Figure 1).

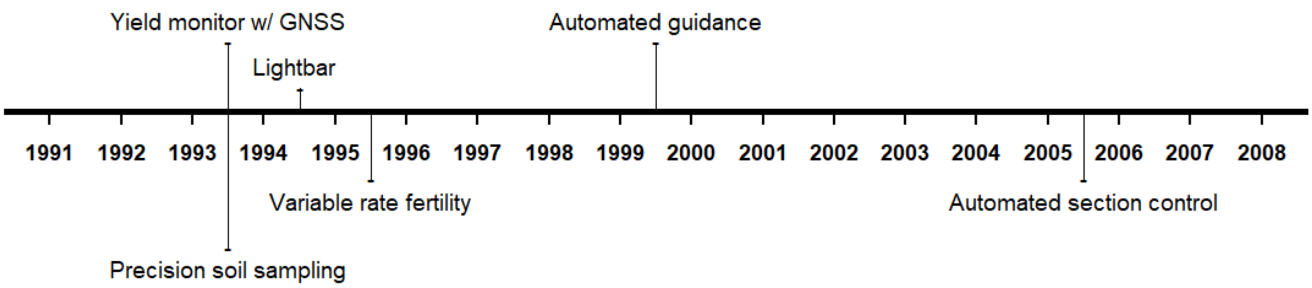

Figure 1. Date technology became commercially available

The year farm operations began was obtained from the KFMA Operator Database. In 2016, the KFMA Operator Database contained 1,776 unique farms replete with birthyear and year began farming. Joining the 1,776 observations on demographics and 608 farms reporting technology usage yielded 526 farms common to both datasets. Duration was measured for each technology, j, on 526 farms, k.

Duration was graphed as violin plots (Figure 2). Violin plots are a type of box plot that represent the relative size of the metric with areas scaled proportionally to number of observations. The x-axis scale is relative to when technologies were able to be adopted, with 0 as the base. The width of the violin plot represents proportion of farmers adopting specific technology during given duration. The purple dot represents median duration that KFMA farmers adopted the specific technology. The left side of the violin plot indicates when farmers reported first adopting the technology and the right side represents the most recent adoption observations.

Relatively newer technologies such as automated section control that have only been on the market for a few years, have shorter violins (as measured from left to right). Other technologies introduced to the marketplace earlier that remained on the farm longer have relatively longer violin shapes. Precision soil sampling and lightbar have longer violin shapes than other technologies.

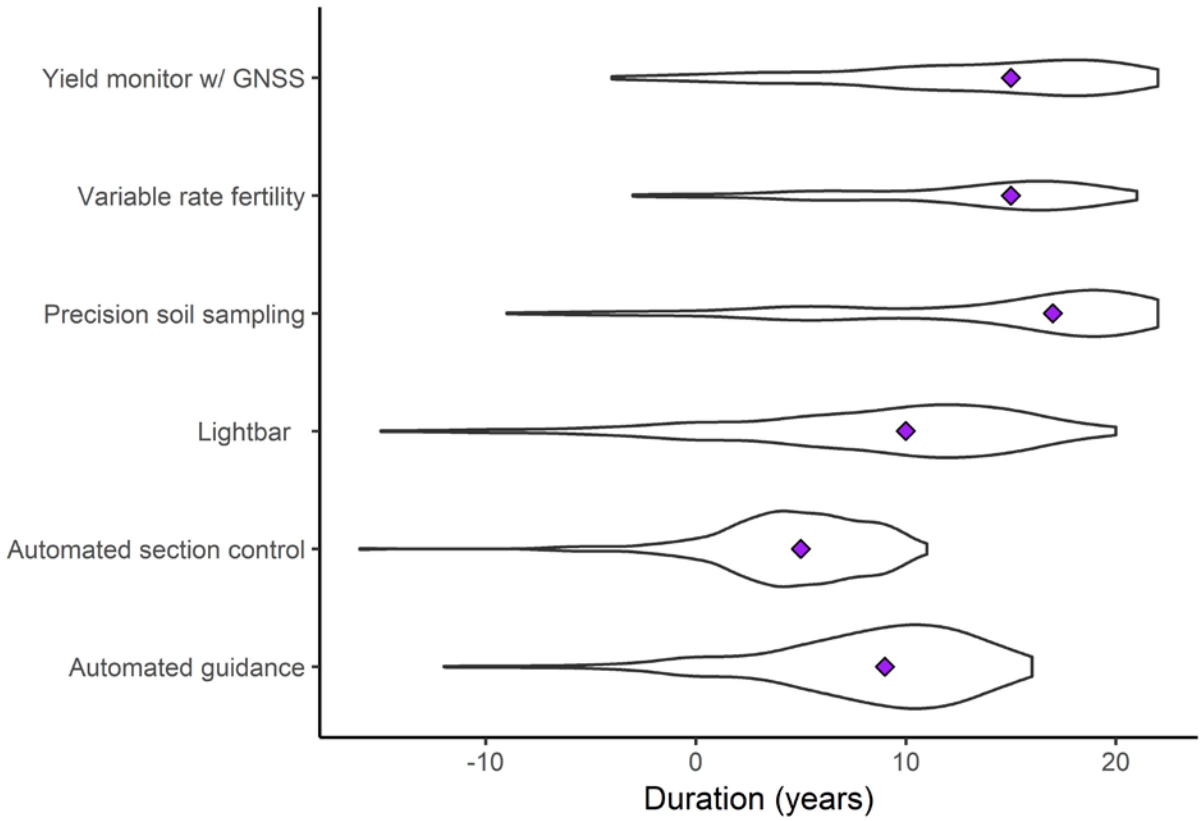

Figure 2. Violin plot of technology adoption. Plot width indicates number farms adopting.

Duration analysis is concerned with time-to-event data; in this study, when farms adopt technology. The specific question addressed by this study is "given that a farm has not adopted some technology by time *t*, what is the chance adoption occurs after time *t*?".

Results

Duration curves for two main categories of precision agriculture in addition to individual technologies were evaluated. When the duration curve was to the left of another curve, then adoption occurred sooner. Note that duration curves originate from survival probability equal to 1.0 on the y-axis. If the curves do not diverge, then adoption paths are generally not statistically different. Statistical significance was determined by chi-square statistic of log-rank tests using null hypothesis of no difference between curves.

All three embodied knowledge "automated" technologies (AGS, LB, ASC) were compared as a collective group (auto) to all three information-intensive technologies (GNSSYM, PSS, VRF) (data). Duration curves were statistically significantly different with embodied-knowledge technologies adopted sooner after commercialization than their information-intensive counterparts (Figure 3). Roughly one-third of

KFMA farms remain likely to adopt embodied-knowledge technology (per the end of the curve near plateau). Almost half of KFMA farm subjects remain as potentially adopting information intensive technology.

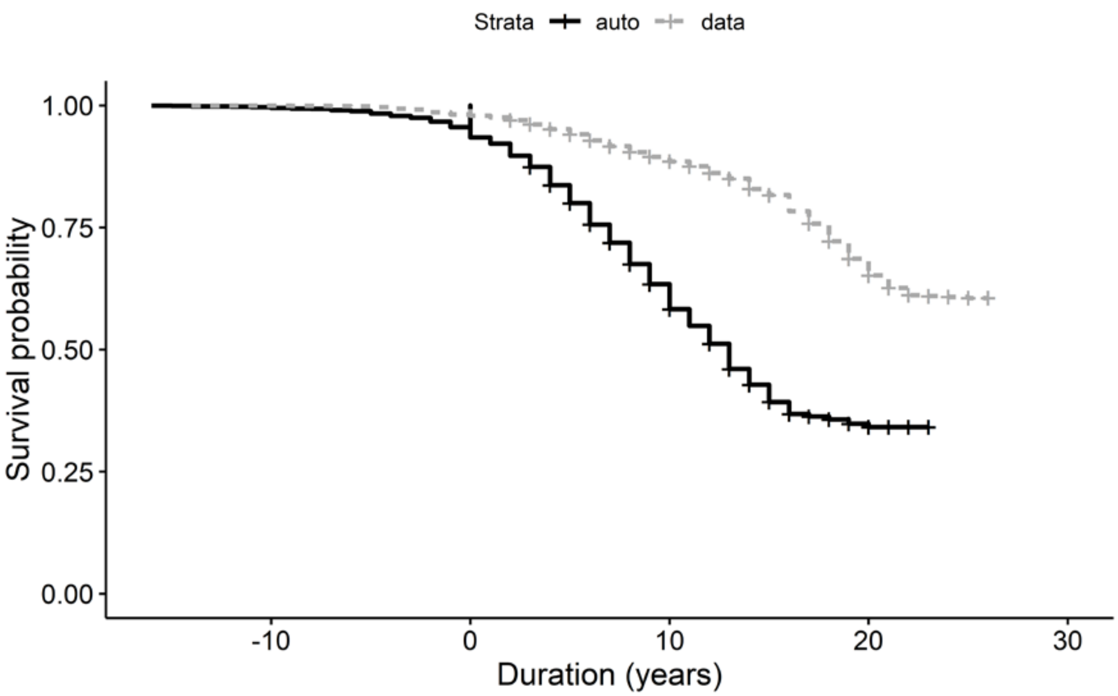

Figure 3. Duration of embodied-knowledge (auto) and information-intensive (data) technology adoption

In addition to comparing groups of technology, duration curves were estimated for individual technologies within each category. The duration curves for the three embodied-knowledge technologies were compared against each other. Results indicated that automated guidance and automated section control curves were not statistically different (p-value = 0.88) (Table 1) although automated section control (ASC) curve being to the left of automated guidance (AGS) and lightbar (LB) (Figure 4). Automated guidance was adopted in a relatively shorter amount of time than lightbar guidance. Automated section control is a relatively newer technology, i.e. with a more recent commercialization date; and has approximately half of farmers remaining as nonadopters. Lightbar has been commercially available longer than AGS or ASC; and has 40% of farms not adopting the technology. Automated guidance has the least number of subjects at risk for adoption at nearly one-third. Duration of adoption was indirectly proportional to the respective commercialization dates.

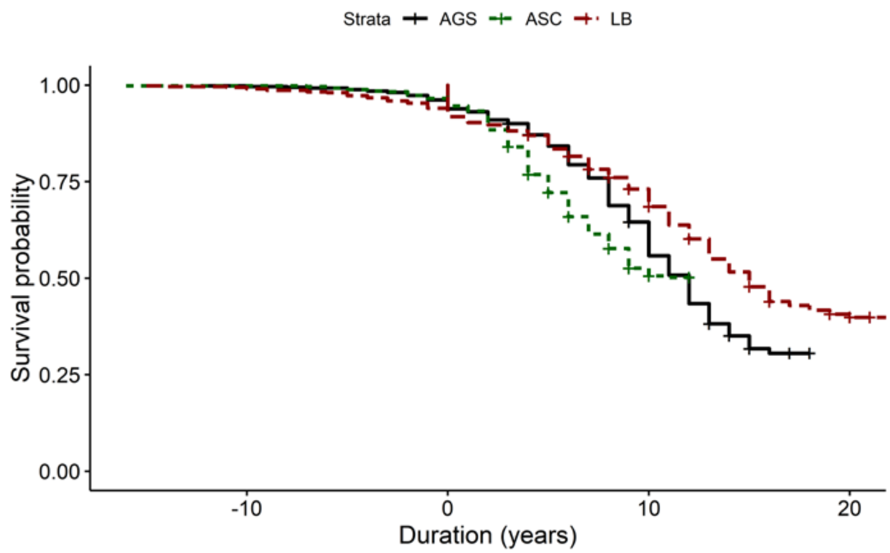

Figure 4. Duration of embodied-knowledge technologies including automated guidance (AGS), automated section control (ASC) and lightbar (LB)

The duration curves for three information-intensive technologies were compared against each other. Although GNSS-enabled yield monitor (GNSSYM) duration curves appears to the left of precision soil sampling (PSS), the null was not rejected at any conventional statistical level. Results indicated that variable rate fertility (VRF) duration curves were to the right of other information intensive technologies and statistically different (Figure 5). Unlike embodied-knowledge technologies, duration of information-intensive technology adoption was directly proportional to commercialization dates. More than half of farms are considered potential adopters of any information-intensive technologies.

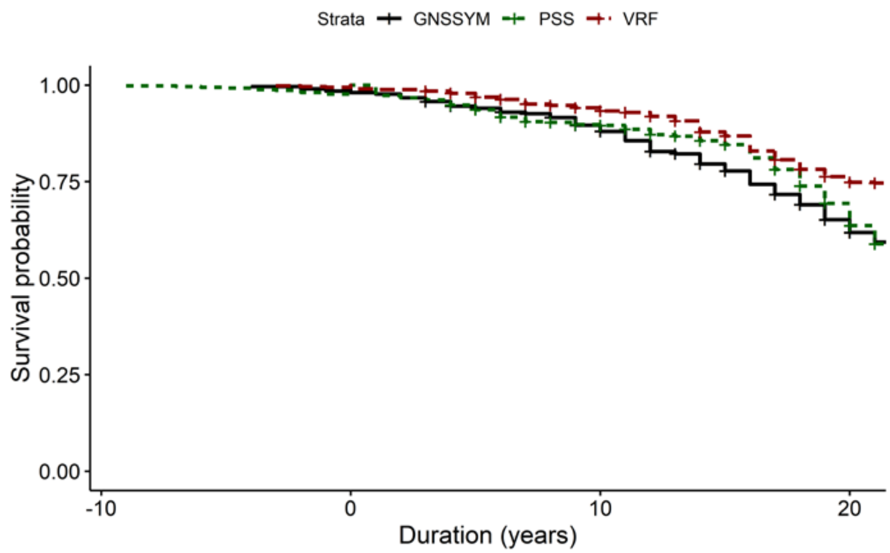

Figure 5. Duration of information-intensive technology including GNSS-enabled yield monitor (GNSSYM), precision soil sampling (PSS) and variable rate fertility (VRF)

Discussion

Duration curves of embodied-knowledge and information-intensive technologies were expected to substantially differ with the former being adopted sooner than the latter. Results confirmed duration statistically differed across these two broad categories. It was expected that automated guidance and section control were adopted at much higher rates than yield monitors due to differences in human capital costs necessary to use data. These were consistent with nearly all precision agriculture adoption studies.

Duration curves of similar technologies grouped within either embodied-knowledge or information intensive were not expected to substantially differ. However, some differences in duration curves were detected within groups. As expected, no differences between duration of the two automated technologies, automated guidance and automated section control, were detected (null failed to be rejected at p-value = 0.88) although section control duration curve visually appears to the left of guidance. Both automated technologies were significantly to the left of manual lightbar guidance (null rejected at p-value < 0.0001). Results may partially be explained by commodity prices and farm policies being favorable to expansion or shifts towards utilization of automated section control. Retailer marketing may also have played a role. Another testable hypothesis may be the duration of adopting the first technology may be longer than the duration between adopting the first and second technology, i.e. farmers who already had lightbar were already conditioned to accept technology and adopt automated guidance in less time.

Similar within-group results were found for information intensive technologies as embodied knowledge technologies. Although GNSS-enabled yield monitor duration curves visually appeared to the left of precision soil sampling, no statistical differences were detected (null failed to be rejected at p-value = 0.79). Both yield monitors and precision soil sampling were adopted sooner than variable rate fertility (null rejected at p-value < 0.0001). This may be due to ease of use or the perceived benefit GNSS-enabled yield monitors provide. Yield monitor adoption may also have been due to acquiring combine harvesters already equipped with the technology.

These results may be used to evaluate whether lightbar will continue to be considered an embodied-knowledge technology since the technology provides operators with visual aid to manually steer the equipment without automating the process. Arguments could be made that even though substantial technology was embodied into the lightbar, it was analogous to information-intensive given that the user must make use of the information albeit the action was reactive rather than proactive.

The left to right ordering of duration curves were indirectly proportional to commercialization dates of embodied-knowledge and directly proportional to dates of information-intensive technology. This was somewhat surprising and warrants further investigation. Future work also includes estimating semi-parametric models including explanatory variables. Model specification will include farm-specific financial performance and agronomic metrics plus exogenous variables such as commodity prices. These analyses should provide insights into farm characteristics useful in predicting when specific farms might adopt technology. Future duration analyses applied to these data include time from first to second technology adopted and the lag from adoption to dis-adoption. Uncertainty exists with respect to the exact dates that technologies became commercially available. Continued effort is being applied to finding historic documents that may push commercialization to earlier dates.

Conclusions

Automated technologies including guidance and section control were adopted sooner after becoming commercially available than more data intensive technologies such as yield monitors and precision soil sampling. It was somewhat unexpected that duration curves statistically differed among technologies within these two broad categories.

Results are useful for Extension personnel working directly with farmers. Uncertainty and misinformation exist regarding which geographical regions are ahead or behind the technology adoption curve. Even locally, many farmers believe that their cohort is more advanced with respect to technology utilization. These results are useful to share with farmers and their advisors regarding actual adoption trends especially the length of time before technologies are typically put into service.

As newer agricultural technologies are introduced, manufacturers are attempting to move toward automated or embodied-knowledge technologies than information intensive. This has been apparent with the traditional information intensive technologies such as yield data and especially analysis of that data to become more automated via streaming from equipment via telematics and automated processing via cloud computing. The next wave of digital technology is expected to have much shorter duration to adoption in part due to automation and in part due to farmers being acclimated to technology utilization.

Acknowledgements

The authors appreciate KFMA economists and member farms for supporting our research program; specifically, we thank Kevin Herbel for making this research possible and Koren Roland for data processing. We appreciate informal reviews from our graduate students including Luke Minnix, Emily Carls, Jared Cullop, and Madhav Regmi. We appreciate anonymous constructive criticism during the review process for the 2019 European Conference on Precision Agriculture. We appreciate informal comments during Department of Agricultural Economics seminar at Oklahoma State University 19 April 2019. We appreciate informal discussions with Robert Dinterman and Ani Katchova, Ohio State University, regarding methodology; plus Ani's Econometrics Academy website was useful to us: https://sites.google.com/site/econometricsacademy/.