Planting date and climate change in cereal production in Norway

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ABSTRACT

Timeliness in planting is critical in cereal production. Current decisions about when to plant are made based on a number of factors, including available soil moisture content and temperature. If climate change results in large shifts in the factors that determine optimal time, then farmers could potentially gain by changing the timing of their crop production. Shifting current planting dates is one strategy that farmers can use to maintain or increase crop yields in the face of a changing climate. Using a stochastic production function the objective of this study is to estimate the effect of planting dates on growth and yield in cereal production in Norway. Results suggest that there is a strong positive relationship between planting date and temperature, indicating evidence that planting dates shifted in response to changes in temperature. While there is no substantial yield premium for early planting, there is notable yield penalty for late planting. We conclude that planting date decisions are strongly influence by weather and climatic factors.

Keywords: Planting date, cereals production, climate change, timeliness

Introduction

Timeliness in planting is critical in cereal production. Planting too early when the soil is cool and wet can result in increased disease in seedlings and susceptibility to insect pests. Planting too late can result to early flowering, reduced moisture availability, and reduced yield because of the shorter growing season. Hence, if planting or farm operation is performed earlier or later, the value of crop may decrease due to changes in quantity and/or quality.

The issue of planting date is also of paramount importance under climate change. Current decisions about when to plant are made based on a number of factors, including available soil moisture, the expected timing of temperature extremes, and the demands of multi-cropped systems. Shifting current planting dates is one strategy that farmers can use to maintain or increase crop yields in the face of a changing climate (Lauer et. al, 1999). If climate change results in large shifts in the factors that determine optimal planting time, farmers could potentially gain by further changing the timing of their crop production (Burke and Lobell, 2010). For example, adjustment of planting dates to minimize the effect of temperature-induced spikelet sterility can be used to reduce yield instability, by avoiding the coincidence of the flowering period with the hottest period (Mahdi et al, 2015). In Norway current growing season length is limited by colder temperature. A warmer climate would allow earlier planting and less stress during sensitive growth stages of crop.

Adaptation strategies are expected to be helpful in dealing with climate change but there remains considerable uncertainty about their impacts and effectiveness (Challinor et al, 2014). While there are statistical models that have been developed by analyzing historical relationships between climate and crop yield (Lobell and Asner, 2003; Lobell and Field, 2007; Lobell et al., 2008; Schlenker and Roberts, 2009; Burke and Emerick, 2016), uncertainties remain large due to inherent errors from the input data sets used (Deryng et al 2011). Most of the studies only used aggregate national data or experimental data, which do not necessarily replicate real agricultural settings, rather than actual data from farmers. Weather data such as temperature and precipitation are widely acknowledged to have measurement errors (Lobell 2013).

The climate adaption potential of some technologies such as shifting planting date has been tested using crop models. However, there exists little empirical evidence of the effectiveness and impacts of shifting planting date due to lack of suitable data sets. In addition, existing crop models do not explicitly account for agricultural management practices such as planting dates and fertilizer use. Very few reports are available to explain the effect of planting date and nitrogen application on crop growth, grain yield and yield components (Chisanga et al., 2009).

The objective of this paper is to estimate the effect of planting dates on mean yield in selected cereal production in Norway. Particularly, we want to test if there is a substantial premium in early planting and/or notable yield penalty in delayed planting. The analysis relies on the use of actual farmer-managed fields/plots' data from 1993-2013. This data set will allow one to study how weather affects yield in a setting in which farmers based their decisions on observed weather. The measurement error is likely small as well using data with weather collected on site (Lobell 2013). Results indicate that there is a strong positive relationship between planting date and temperature, indicating evidence that planting dates shifted in response to changes in temperature. There is no substantial yield premium for early planting but a notable yield penalty for late planting. We conclude that planting date decisions are strongly influence by weather and climatic factors.

Data and Estimation

The data used in this study come from three sources: (1) the Norwegian Agricultural and Environmental Monitoring Program (JOVA in its Norwegian acronym)[2] annual farmer surveys of cereal production and input use in Skuterud, Ås (figure 1) from 1993-2013; (2) the Agrometeorology Norway (www.lmt.nibio.no) climate data that consist of actual daily precipitation and mean temperature taken in Skuterud, Ås from 1993-2013; and (3) Riley (2016) calculated values for soil moisture content in Ås. The JOVA farmer surveys focus on the production of three cereal crops namely: barley, oats, and spring wheat. The data include grain yield, input use, and actual farming practices of farmers such as planting date. Input and output data are available at the plot-year level. The unit of observation is thus plot. Socio-demographic data are not collected in the JOVA surveys. The precipitation data are aggregated by taking the total of daily values over the growing season.

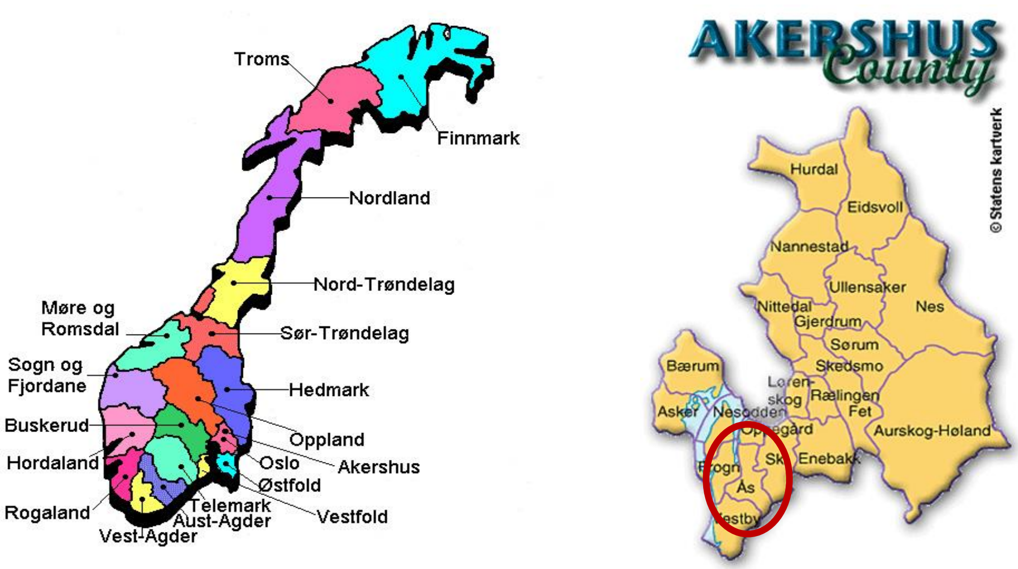

Figure 1. Area of study

[2] The aim of JOVA is to document the environmental consequences of the current and continuing changes in agricultural practices.

Methodology

Without loss of generality, the stochastic production function can be written as:

(1) $$\boldsymbol{y} = g(\boldsymbol{x}, \boldsymbol{v})$$

where $\boldsymbol{y}$ is a vector of logarithm of yield in kilogram per decare (kg/da), $\boldsymbol{x}$ is a vector of inputs and $\boldsymbol{v}$ is a vector of unobserved factors not under the control of the farmer (i.e. unobserved weather variables, production or pest conditions). The input variables are planting date (April 20 is set as "ideal planting date" set as 0, which is equal to 110 Julian days), applied Nitrogen fertilizer (kg/decare), soil moisture content at the topsoil (mm), farm/plot area (decare), and weather variables such as temperature at planting (degree C) and seasonal precipitation/rainfall (mm). Although planting decisions may also be influenced by other factors of production such as labor and tractor availability, we assume that temperature and soil moisture content at the top soil are generally strong determinants of planting dates. For instance, in temperate countries such as Norway, planting occurs when temperature is at least sufficiently warm to protect crops from frost. Similarly, in tropical countries with distinct wet and dry periods, planting usually occurs at the start of the rainy season (Sacks et al., 2010). A detailed description of the all the variables used in the analysis is shown in table 1.

Table 1. Variable definitions

Variable name	Definition
Dependent	
Yield	Log of yield of barley, oats, and spring wheat (kg/da)
Independent	
Planting date	Number of days before or after April 20 (110 Julian days)
Nitrogen	Nitrogen fertilizer use (kg/da)
Temperature	Mean temperature (°C) at planting date
Precipitation	Total precipitation (mm) in growing spring season
Plot size	Area of the plot (da)
Soil moisture	Soil moisture content at topsoil (mm)

Results and Discussion

Table 2 shows the summary statistics for the regression variables. The average planting times for barley, oats, and spring wheat are all considered late as compared to April 20. For all crops, farmers perform planting crops one to four weeks after April 20 (figure 2), and the average temperature at planting is between 5 to 12 degrees C (figure 3). From 1993 to 2013, the mean temperature (figure 4) and mean precipitation (figure 5) in Skuterud fell in some years while rising in others.

Table 2. Summary statistics, cereal production, Skuterud, Ås, 1993-2013.

Variable	Mean	s.d.	Min	Max
Barley (n=154)				
Yield (kg/da)	524.69	93.49	312.00	750.00
Planting Date	April 28	12.77	April 5	June 3
Temperature (°C)	9.25	5.03	0.10	19.60
Precipitation (mm)	328.09	96.32	87.20	578.60
Soil moisture (mm)	72.12	7.84	43.22	88.08
Nitrogen (kg/daa)	12.19	2.51	0.00	15.66
Farm size (daa)	58.46	29.19	3.00	141.00
Oats (n=320)				
Yield (kg/daa)	472.97	116.54	150.00	730.00
Planting Date	May 2	11.88	April 4	June 5
Temperature (°C)	9.40	4.18	-0.10	19.30
Precipitation (mm)	322.77	114.43	72.40	679.60
Soil moisture (mm)	71.85	9.21	46.03	90.00
Nitrogen (kg/da)	11.87	2.67	0.00	34.90
Farm size (da)	42.44	30.07	3.00	149.00
Spring wheat (n=133)				
Yield (kg/daa)	492.49	104.22	200.00	750.00
Planting Date	April 29	11.24	April 3	May 23
Temperature (°C)	9.03	4.48	0.10	19.30
Precipitation (mm)	377.50	86.39	155.60	635.00
Soil moisture (mm)	71.73	8.36	47.44	90.00
Nitrogen (kg/da)	15.24	2.68	0.00	20.10
Farm size (da)	50.12	33.39	3.00	141.00

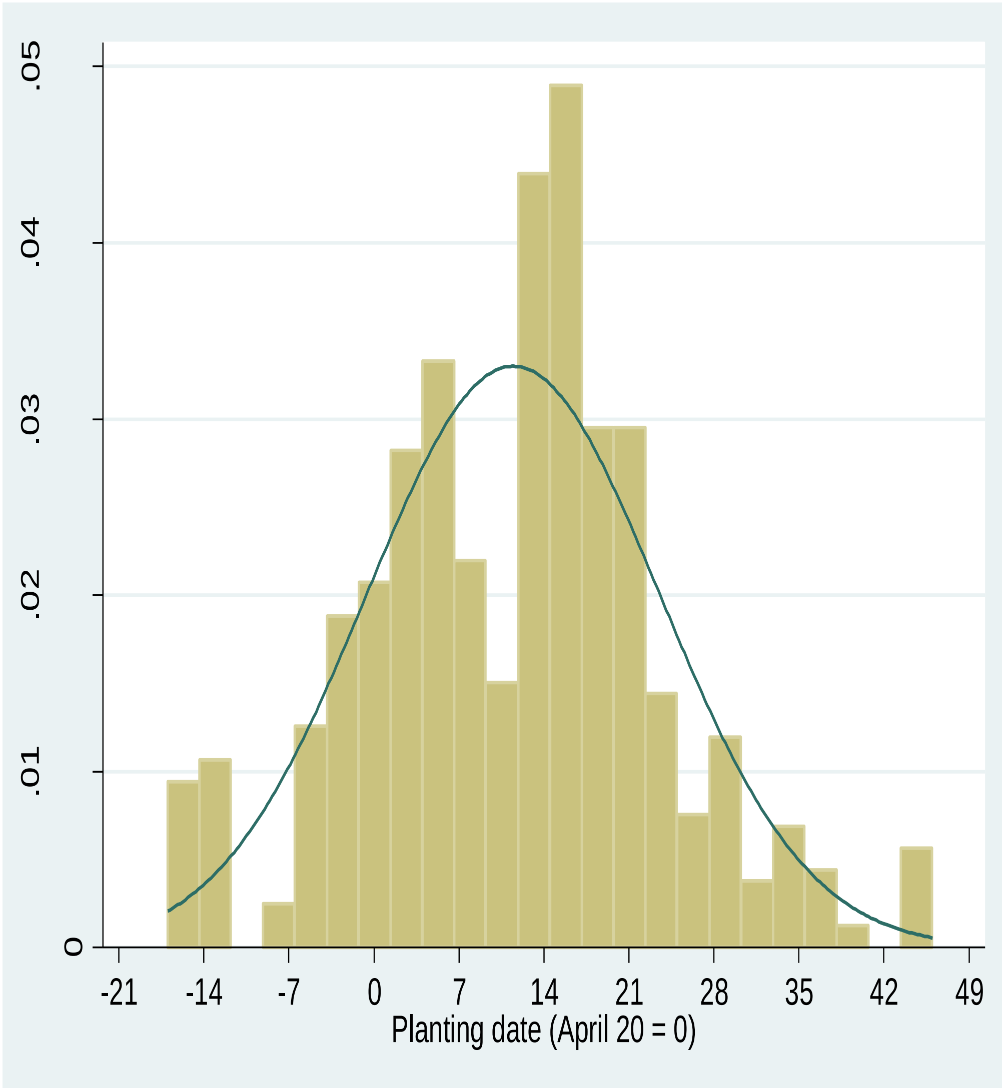

Figure 2. Planting dates for all crops, Skuterud, Ås

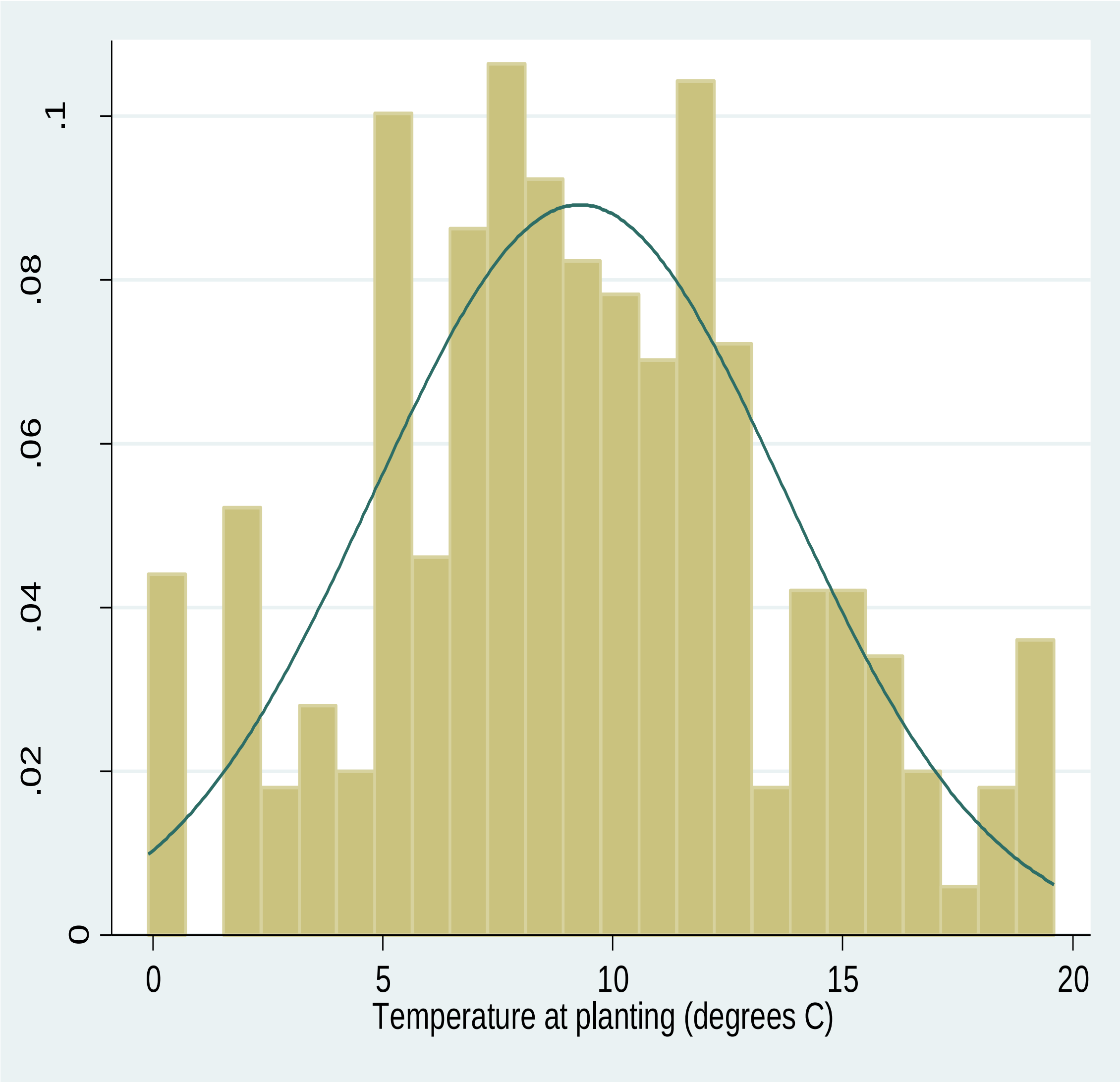

Figure 3. Average temperature at planting for all crops, Skuterud, Ås

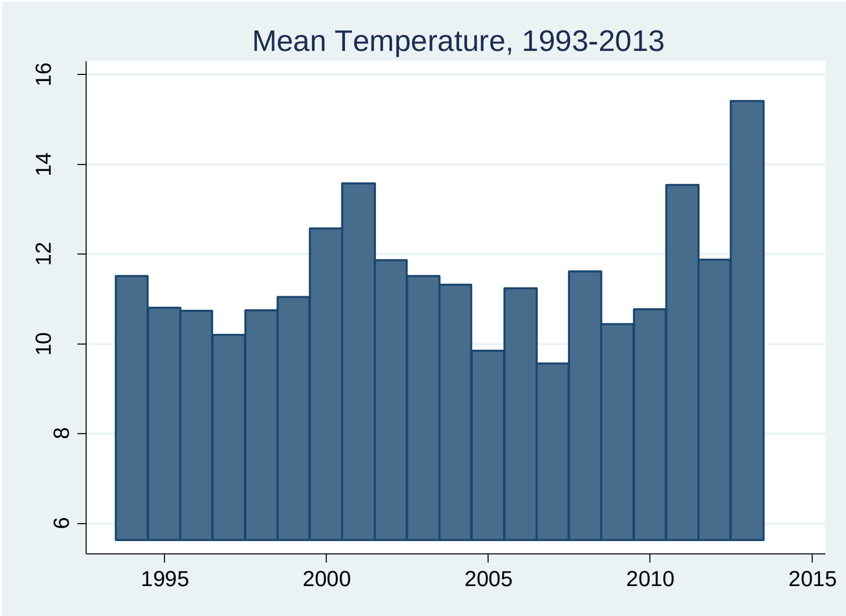

Figure 4. Average mean temperature, Skuterud, Ås, 1993-2013

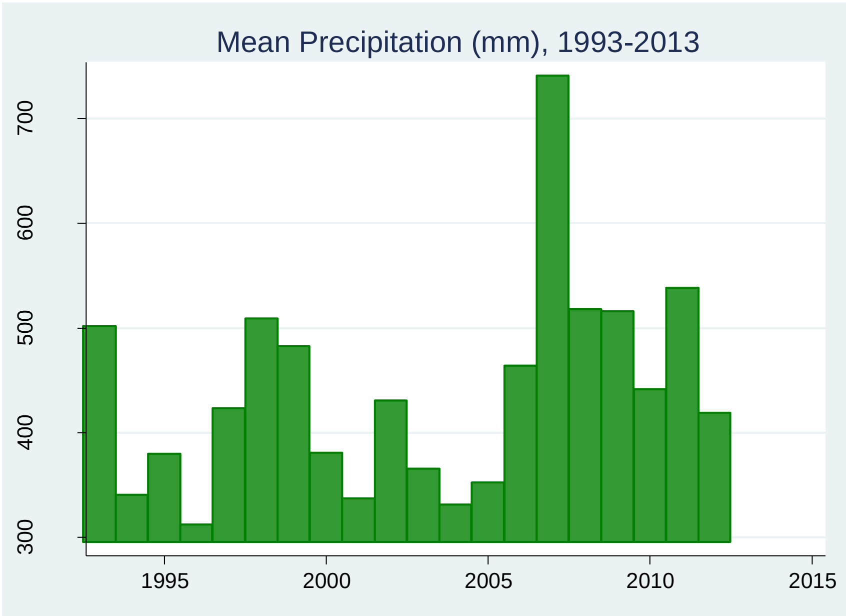

Figure 5. Total precipitation, Skuterud, Ås, 1993-2013

Table 3 reports the OLS regression results for equation (1). All the coefficients have the expected sign. There is a strong positive relationship between planting date and temperature, indicating evidence that planting dates shifted in response to changes in temperature (significant at 1% level). We find no evidence that farmers' planting date decisions are based on the soil moisture content at the topsoil.

Table 3. Regression results

	CROPS (Log yield)			
	ALL CROPS (1)	OATS (2)	BARLEY (3)	WHEAT (4)
April 20	-0.00368**	-0.00559*	-0.00187	-0.0034
April 20 squared	-0.000252***	-0.000342***	0.0000357	0.000205
April 20 x temperature	0.000942***	0.00156***	-0.0000127	0.000183
Temperature (°C)	-0.0109***	-0.0217***	-0.0037	0.00286
Precipitation (mm)	0.0428***	0.0758***	0.0508**	-0.0317
Nitrogen (kg/da)	0.0357***	0.0590***	0.0588**	-0.0625***
Nitrogen squared	-0.000634**	-0.00109***	-0.00257**	0.00271***
Plot size (da)	0.00220***	0.00171***	0.00129**	0.00315***
Soil moisture (mm)		-0.001	-0.002	-0.002
April 20 x soil moisture		0.000	0.000	0.000
Oats	0.0437*			
Barley	0.104***			
Constant	5.636***	5.468***	5.764***	6.346***
No. of observations	607	320	154	133
Adjusted R squared	0.227	0.267	0.1	0.4
Akaikr Information Criteria	-96.74	1.133	-82.74	-81.51
Bayesian Information Criteria	-48.25	35.05	-55.41	-55.5

*p<0.10,**p<0.05,***p<0.01

In addition, if a farmer delays his/her planting routine by one day, a yield reduction by 0.3% maybe observed (statistically significant at 10% level). Using the mean estimates, we plot the effect of planting dates on yield (figure 6). Results suggest that there is no substantial yield premium for early planting and that there is notable yield penalty for late planting. The delay in farm operations such as planting could lead to crop failure and decreased number of harvests (Sawano et al., 2008).

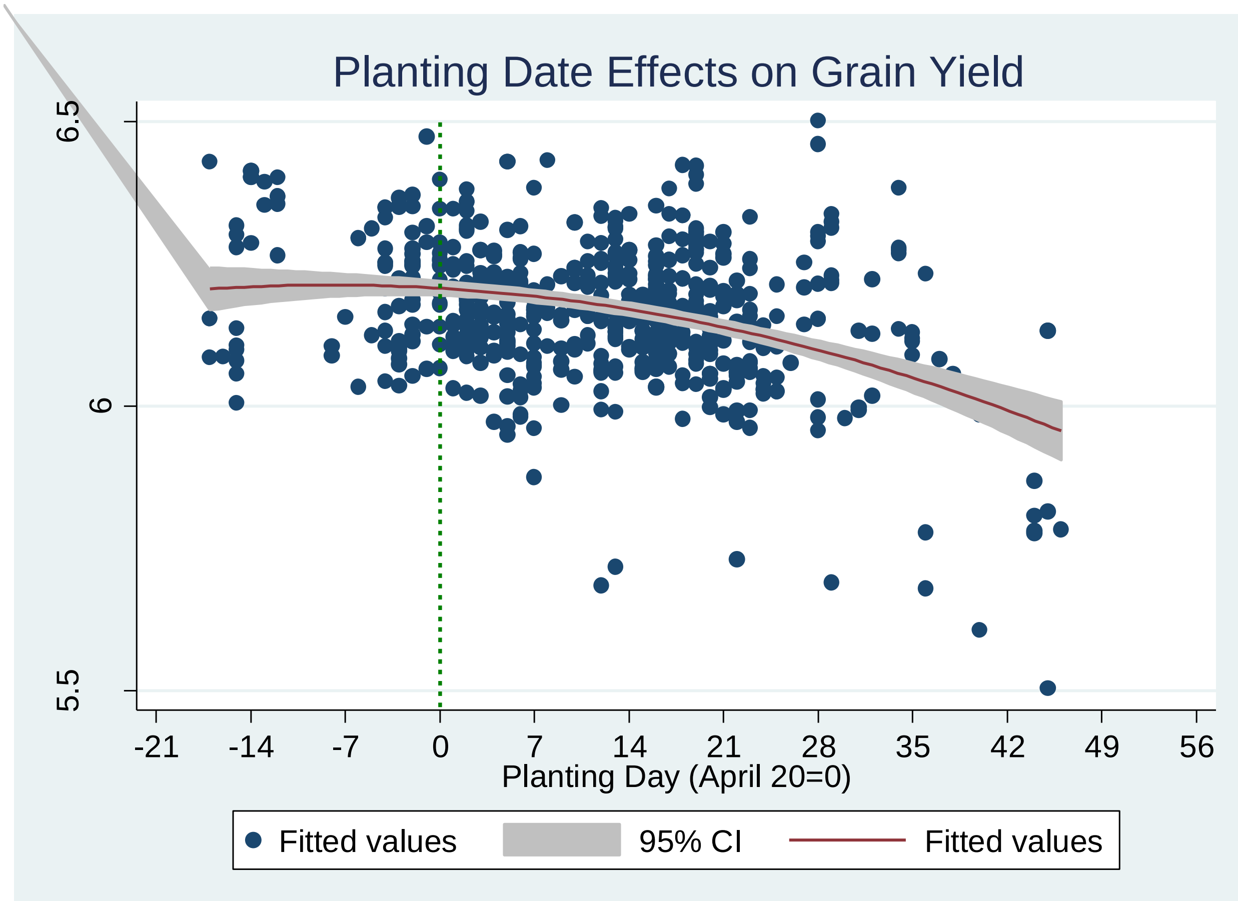

Figure 6. Relationship of planting date and yield, Skuterud, Ås, 1993-2013

Meanwhile, increased temperature and precipitation have contrasting effects on crop yield. For every one degree C increase in temperature, the yield may decline by 1% (significant at 5% level). Increased temperature can potentially affect insect survival, development, geographic range, and population size (Lal 2005). On the other hand, an increase in precipitation (in mm) will increase yield by 0.03% (statistically significant at 1% level). If water availability is reduced in the future, soil with high water holding capacity will be better to reduce the frequency of drought due to climate change and improve the crop yield (Popova and Kercheva, 2005).

Furthermore, other factors of production such as Nitrogen fertilizer use and plot size have positive significant effects on crop yield. A one kilogram increase in the N fertilizer applied and a one decare increase in the plot size managed increase yield by 3.53% (statistically significant at 1% level) and 0.22% (statistically significant at 1% level), respectively.

Conclusion

We conclude that planting date decisions are strongly influence by weather and climatic factors. Evidence suggests that planting dates shifted in response to changes in temperature and not on changes in soil moisture content. While there is no substantial yield premium for early planting, there is notable yield penalty for late planting. Moreover, crop yield is more sensitive to changes in temperature than changes in precipitation.

Shifting of planting date has a potential to mitigate the negative impact of climate change. While shifting planting date is a no-cost decision to farmer, it can interfere with the agro-technological management of farmers. Hence, in the future we plan to look at the timeliness costs or the economic consequences of performing a field operation at non-optimal time. Machinery capacity decisions are influenced by the fundamental relationships between planting date and yield. Economic trade-offs exist since the increase planting capacity necessary to improve timeliness implies increased machinery and labor costs.

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