Estimating the impacts of changes in weather circadian rhythms on French agricultural production

Simone Pieralli, Ph.D.

Marie Skłodowska-Curie Fellow, UMR Économie Publique, INRA/AgroParisTech, Paris/Grignon, France

Abstract

This study analyzes the impact of changes in stochastic (soil and climatic) and non stochastic (farm managed) inputs on the production of a representative sample of 2076 French field crop agricultural farms **between 1990 and 2015**. The study quantifies the production impact by decomposing output changes over time via **Luenberger** indicators, through econometric estimation of a **second-order flexible parametric technology**. This decomposition method provides an empirical parametric measure of the impact of soil and climate, of non stochastic inputs, of technological change, and of heterogeneity, on changes of farm output.

Introduction

Agricultural production relies on soil, climate, agricultural inputs, and farmers. The importance of climate and soil inputs has been recently reconsidered in agricultural production. If it is true that climate is changing, an estimation of climate change impacts on agriculture free of undesired assumptions is the key to understanding a strategy towards a sustainable future. A sector of human activity which has close relationship with climate is agriculture. A changed climate, in turn, could either be detrimental or beneficial to agricultural outcomes.

The impacts of precipitation, temperature and its timing on French field crop output remain imperfectly understood despite a growing interest on the impact of weather on European Union (EU) agriculture. Recent empirical estimates (e.g. Moore and Lobell, 2014) are based on the effects of aggregated outputs and inputs, including temperature and precipitation. These studies show that increased temperature over the growing season decreases barley and wheat yields but does not significantly decrease economic profits across countries in the EU. Most recent studies, usually, do not consider farm management in the estimates of the impact of climate on French wheat and barley production.

The quantification of the impact of climate change on agricultural production has been conducted mainly with regression methods that impose undesired assumptions on the obtained results. The functional forms used in analyzing the response of crops to climatic and weather variables have been very often quite restrictive, not considering interactions between inputs. In this study the technology is represented by a **second-order flexible functional form that includes interaction between inputs**.

Because night temperatures have increased more than daily temperatures, the timing of thermal exposure is subdivided into heat during the day and during the night.

Methods

The present contribution extends to a directional distance function (Chambers, Chung, Färe, 1996) context the methods developed by Färe, Grosskopf, Norris, Zhang (1994) and Kumar and Russell (2002) and is based on the intuition by Guarda, Rouabah, Vardanyan (2013).

The usual agricultural technology is augmented to include soil characteristics (soil carbon and pH) and weather stochastic inputs (rainfall and thermal exposure), in addition to non stochastic farm managed inputs and technological change.

$$T = \{(\boldsymbol{x}, \boldsymbol{c}, t, y) \in \mathbb{R}_{+}^{U+W+2} : (\boldsymbol{x}, \boldsymbol{c}, t)\ can\ produce\ y\}$$

$$\vec{D}_O(\boldsymbol{x}, \boldsymbol{c}, t, y; 0^{U+W+1}, g_y) = \sup\{\phi : (\boldsymbol{x}, \boldsymbol{c}, t, y + \phi g_y) \in T\}$$

$$\vec{D}_O(\boldsymbol{x}, \boldsymbol{c}, t, y + \lambda g_y; 0^{U+W+1}, g_y) = \vec{D}_O(\boldsymbol{x}, \boldsymbol{c}, t, y; 0^{U+W+1}, g_y) - \lambda,\ \lambda \in \mathbb{R}$$

$$y = \vec{D}_O(\boldsymbol{x}, \boldsymbol{c}, t, 0) - v + \mathcal{E}$$

$$y_1 - y_0 = f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_1) - f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_0) - v_1 + v_0 + \mathcal{E}_1 - \mathcal{E}_0$$

$$y_1 - y_0 = X(\boldsymbol{x}_1, \boldsymbol{x}_0; t, \boldsymbol{c}) + C(\boldsymbol{c}_1, \boldsymbol{c}_0; t, \boldsymbol{x}) + T(t_1, t_0; \boldsymbol{x}, \boldsymbol{c}) - v_1 + v_0 + \mathcal{E}_1 - \mathcal{E}_0$$

$$C(\boldsymbol{c}_1, \boldsymbol{c}_0; t, \boldsymbol{x}) = \frac{\mathbf{1}}{\mathbf{6}} * \begin{pmatrix} f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_0) - f(\boldsymbol{x}_1, \boldsymbol{c}_0, t_0) + f(\boldsymbol{x}_0, \boldsymbol{c}_1, t_1) \\ -f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_1) + f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_1) - f(\boldsymbol{x}_1, \boldsymbol{c}_0, t_1) \\ +f(\boldsymbol{x}_0, \boldsymbol{c}_1, t_0) - f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_0) + f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_1) \\ -f(\boldsymbol{x}_1, \boldsymbol{c}_0, t_1) + f(\boldsymbol{x}_0, \boldsymbol{c}_1, t_0) - f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_0) \end{pmatrix}$$

$$X(\boldsymbol{x}_1, \boldsymbol{x}_0; t, \boldsymbol{c}) = \frac{\mathbf{1}}{\mathbf{6}} * \begin{pmatrix} f(\boldsymbol{x}_1, \boldsymbol{c}_0, t_0) - f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_0) + f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_1) \\ -f(\boldsymbol{x}_0, \boldsymbol{c}_1, t_1) + f(\boldsymbol{x}_1, \boldsymbol{c}_0, t_0) - f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_0) \\ +f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_1) - f(\boldsymbol{x}_0, \boldsymbol{c}_1, t_1) + f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_0) \\ -f(\boldsymbol{x}_0, \boldsymbol{c}_1, t_0) + f(\boldsymbol{x}_1, \boldsymbol{c}_0, t_1) - f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_1) \end{pmatrix}$$

$$T(t_1, t_0; \boldsymbol{x}, \boldsymbol{c}) = \frac{\mathbf{1}}{\mathbf{6}} * \begin{pmatrix} f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_1) - f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_0) + f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_1) \\ -f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_0) + f(\boldsymbol{x}_1, \boldsymbol{c}_0, t_1) - f(\boldsymbol{x}_1, \boldsymbol{c}_0, t_0) \\ +f(\boldsymbol{x}_0, \boldsymbol{c}_1, t_1) - f(\boldsymbol{x}_0, \boldsymbol{c}_1, t_0) + f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_1) \\ -f(\boldsymbol{x}_1, \boldsymbol{c}_1, t_0) + f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_1) - f(\boldsymbol{x}_0, \boldsymbol{c}_0, t_0) \end{pmatrix}$$

Contact

Simone Pieralli, Ph.D.

UMR Économie Publique, INRA/AgroParisTech, Paris/Grignon, France

Email: simone.pieralli@inra.fr

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Data

Weather data come from the **daily European Commission JRC Agri4Cast** data set. The grid data are at a resolution of **25x25Km** all over Europe. The precipitation is accumulated daily rainfall in each grid location. The temperature data is thermal power (in Growing Degree Days, GDD) accumulated over different months along the growing season, during the day and the night for different temperature ranges. Soil data are yearly interpolated **soil carbon** and **soil pH** from BDAT GISSOL database. The data on single farms are from the **European Commission Farm Accountancy Data Network** database from 1990 to 2015. They include economic accounts and management data.

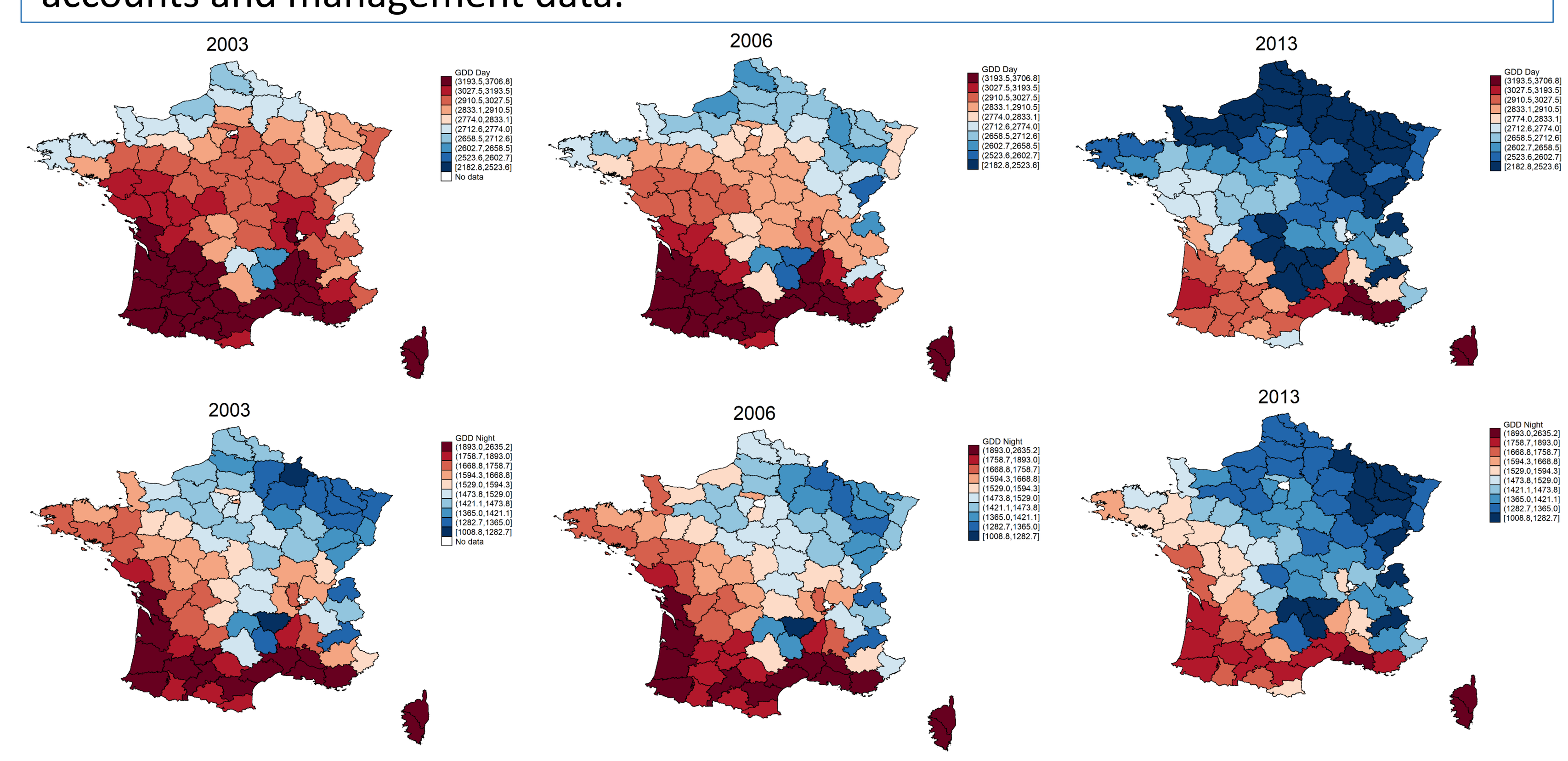

Figure 1. GDD accumulated during the day and night in different years.

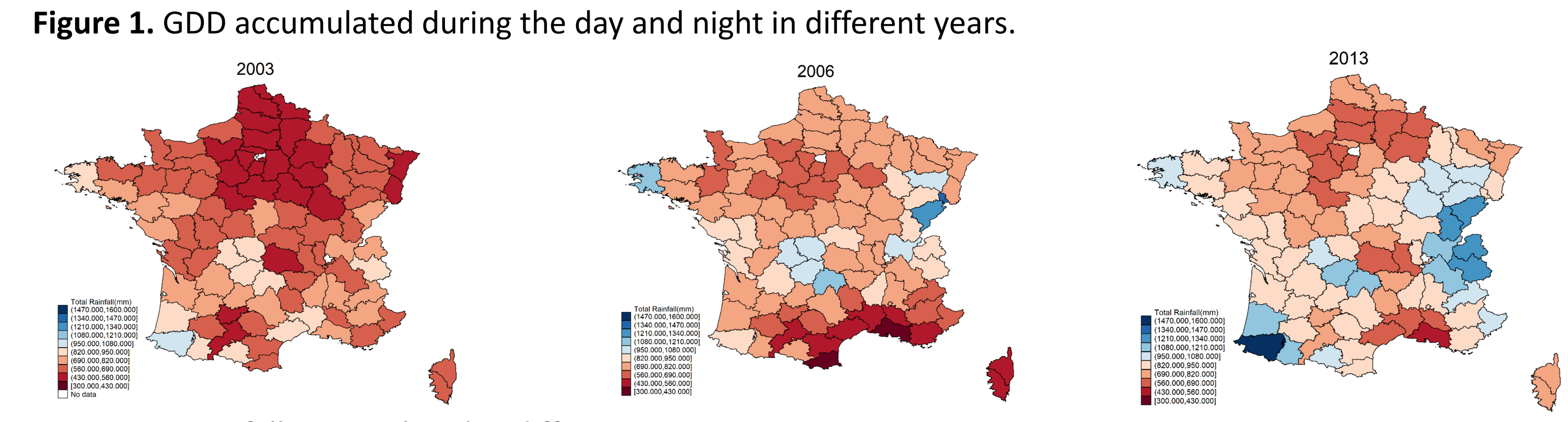

Figure 2. Rainfall accumulated in different years.

Results

The model decomposes farm implicit quantity output changes along 26 years of farm data, from 1990 until 2015.

Results vary widely regionally among different departments. The effects vary depending on the timing of the heat and of rainfall extremes.

Some of the worst climatic events occurred in France are characterized regionally. For example, during the Summer 2003, most of the regions producing summer field crops (e.g. maize) in the South received very negative impacts from unusual heat during the months of June, July, and August. In 2006, winter crops were more negatively affected by the cold winter and wet spring (March until May) in the Center and East (exceptional rains in Clermont Ferrand, Strasbourg, Grenoble).

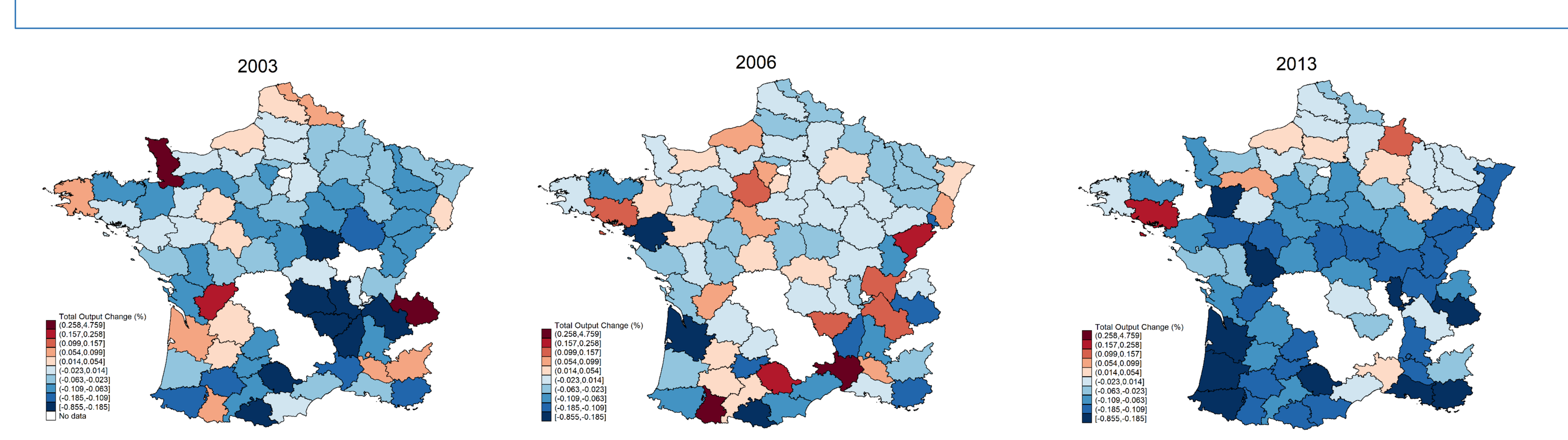

Figure 3. Output (implicit quantities) changes for different years

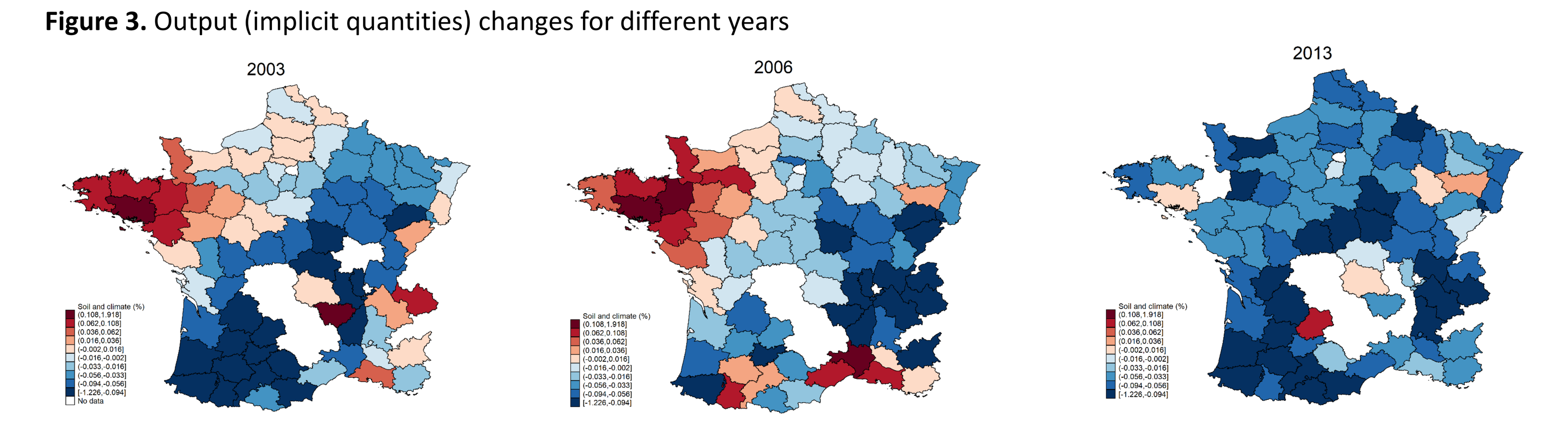

Figure 4. Yearly soil and climate impact changes for different years

Conclusions

The importance of this methodology is in quantifying how much of output change is due to soil and climate, to technological change, to farm-managed inputs, or to structural heterogeneity among farms.

Ultimately, this process of attribution of the changes in output from year to year is fundamental to make policy-relevant statements about the relative importance of different inputs to changes in output.

References

1. Chambers, R.G., Chung, Y., and R. Färe. 1996. Benefit and distance functions. Journal of economic theory, 70(2): 407-419.
2. Färe, R., Grosskopf, S., Norris, M. and Z. Zhang. 1994. Productivity growth, technical progress, and efficiency change in industrialized countries. The American Economic Review, 84(1): 66-83.
3. Guarda, P., Rouabah, A., and M. Vardanyan. 2013. Identifying bank outputs and inputs with a directional technology distance function. Journal of Productivity Analysis, 40(2): 185-195.
4. Kumar, S. and R.R. Russell. 2002. Technological change, technological catch-up, and capital deepening: Relative contributions to growth and convergence. American Economic Review, 92(3): 527-548.
5. Moore, F.C. and D.B. Lobell. 2014. Adaptation potential of European agriculture in response to climate change. Nature Climate Change, 4(7): 610-614.