POLITECNICO MILANO 1863

Nonparametric Analysis of

Agricultural Productivity In U.S.

Sofia Moroni

Nonparametric Statistics (5 CFU)
MSc. Mathematical Engineering

RESEARCH QUESTIONS

The project addresses **Policymakers** of US and their **Economic Advisers**

01 How Agricultural Growth has changed from the past

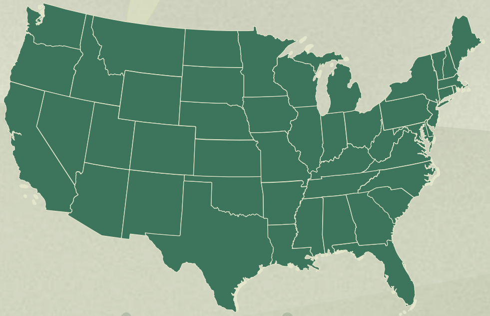
02 Which are the Primary Drivers of the agricultural sector’s growth

03 Which States are leading in Agricultural Production and why

DATASET PRESENTATION

For each U.S. State

YEAR from 1960 to 2004



National Level Observations

YEAR from 1948 to 2019

- **Total Agricultural Output**
- **Intermediate Input**
- **Labor Input**
- **Capital Input**

DATASET PRESENTATION

The variables are indexes of growth with respect to year 2015

Total Agricultural Output
Gross production leaving the farm

Capital Input
Wide range of physical assets used in agricultural activities

- Durable Equipment
- Service Buildings
- Inventories
- Land

Labor Input
Total human effort in agricultural production

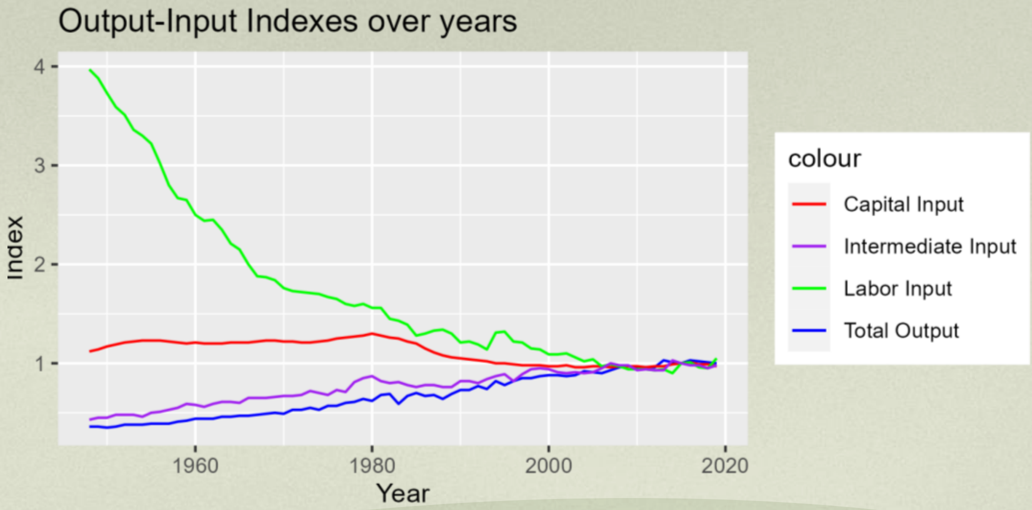
- Hired Labor
- Self Employed & Unpaid Family

Intermediate Input
Resources used within the production process but not directly transformed into the final output

- Feed and Seed
- Fertilizer
- Energy
- Pesticides
- Purchased Services

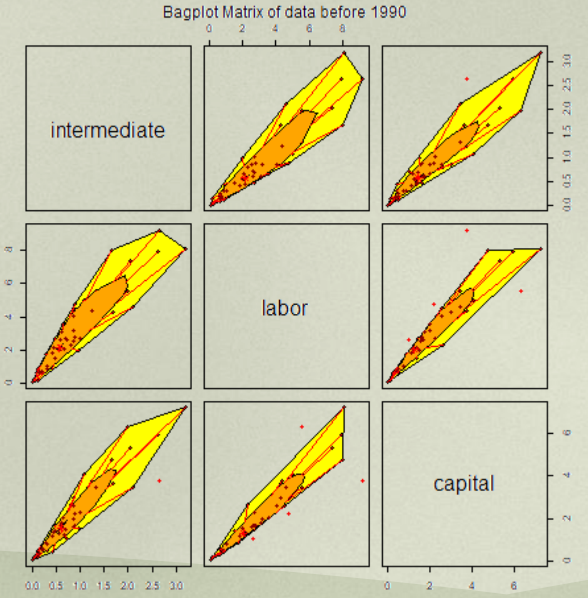
GENERAL TRENDS IN DATA

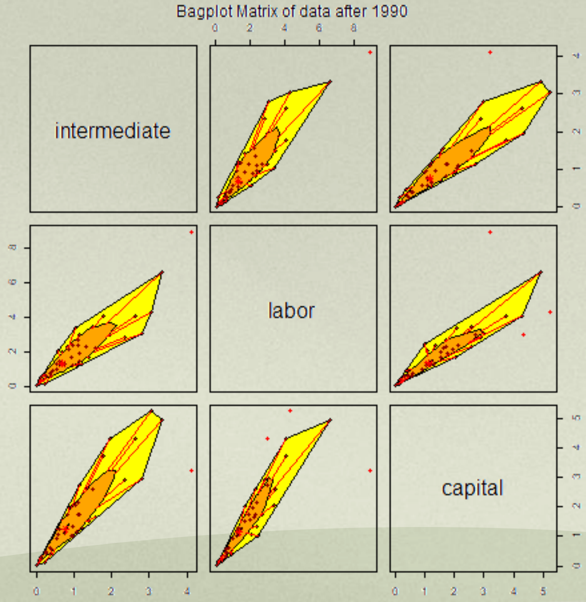
Different composition of *Inputs* along Years



From → Human Labor & Land (Capital Input) → Towards → Farm Machinery (Capital Input) & Intermediate Resources

GENERAL TRENDS IN DATA





Two Paired Samples Multivariate Permutational test

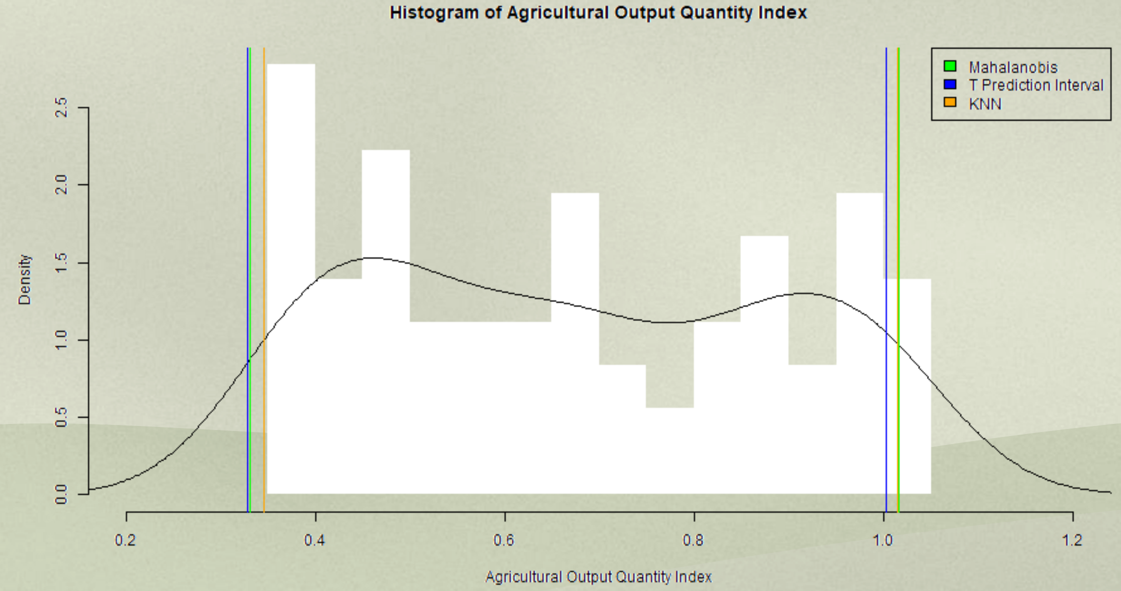
There is statistical evidence of difference between the means of first period and second period

SPEARMAN CORRELATION

	Total Output 48-90	Total Output 90-2015
Capital Input	0.1656040	- 0.3183969
Labor Input	- 0.9876408	- 0.8513482
Intermediate Input	0.9568786	0.7858585

- **Intermediate Input:** strongly positive correlation
- **Labor Input**: excessive or inefficient allocation of labor → reduction in productive efficiency
- **Capital Input** : shift from weakly positive to negative → changes in agricultural technologies, resource allocation or market dynamics

CONFORMAL PREDICTION



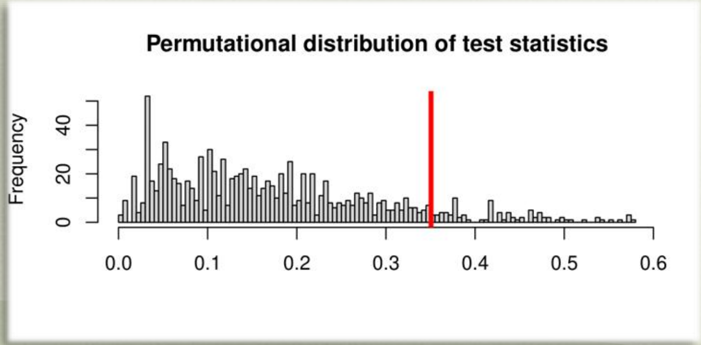
Conformal Intervals

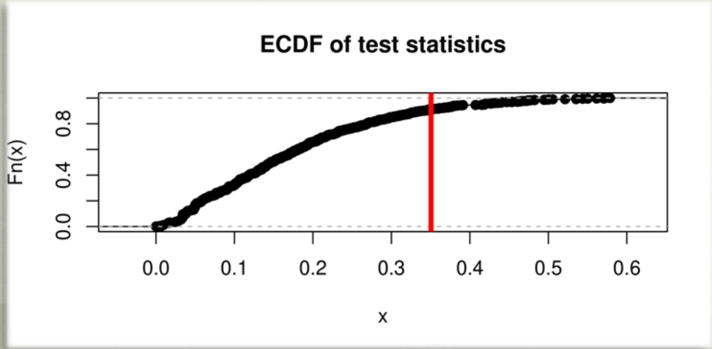
- Mahalanobis distance
- T prediction interval
- KNN distance

GAM

Multiple Permutation Tests $H_0: \beta_{Feed} = 0 \;\; vs \; H_1: \beta_{Feed} \neq 0$

to assess the significance of each covariate



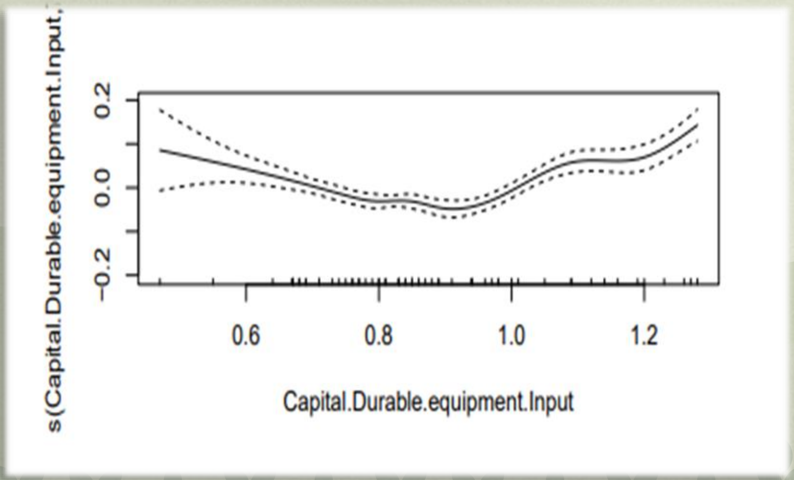


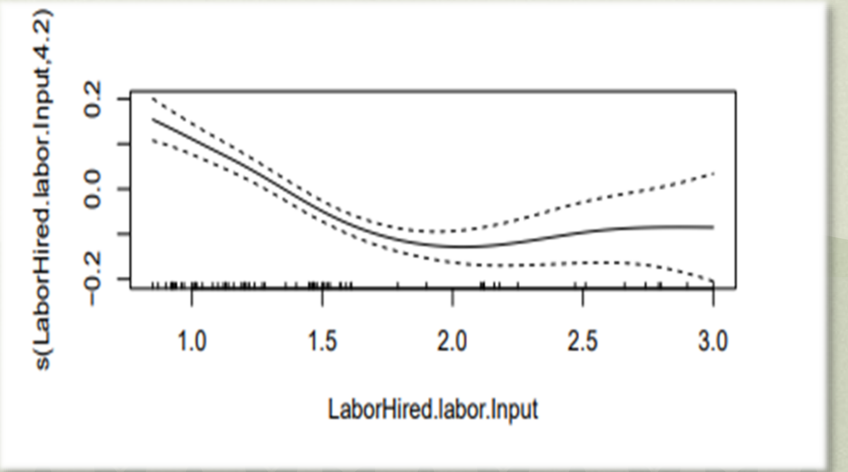
$$pval = 0.334$$

GAM

$$
\begin{aligned}
Total.Agricoltural.Output_i = \beta_0 &+ \beta_1 * Intermediate.Energy.Input_i \\
&+ \beta_2 * Intermediate.Pesticides.Input_i \\
&+ \beta_3 * Capital.Service.Buildings.Input_i : Period_i \\
&+ \beta_4 * Self.Employed.Unpaid.Family_i : Period_i \\
&+ f_1(Capital.Durable.Equipment.Input_i) \\
&+ f_2(Labor.Hired.Labor.Input_i) + \varepsilon_i
\end{aligned}
$$

$$\beta_1, \beta_2, \beta_{3,2} > 0$$
$$\beta_{3,1}, \beta_{4,1}, \beta_{4,2} < 0$$





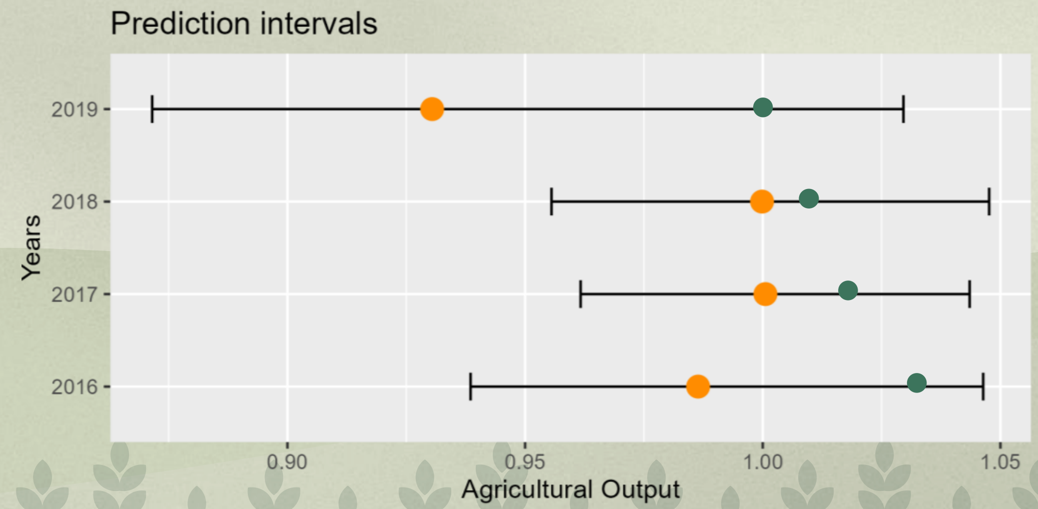
GAM

Prediction of years 2016-2019 using GAM covariates

+

Reverse Percentile (Bootstrap) intervals α=0.1

Comparison with true data

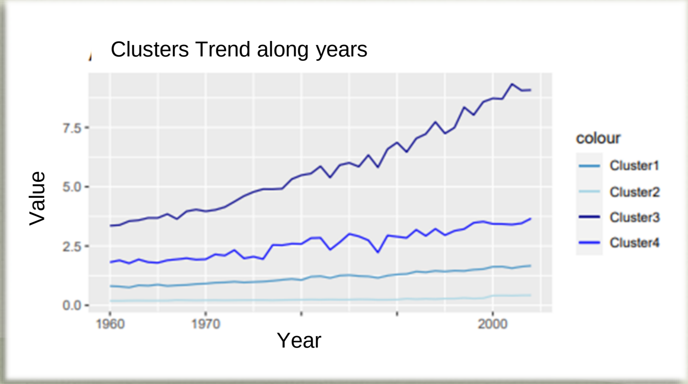


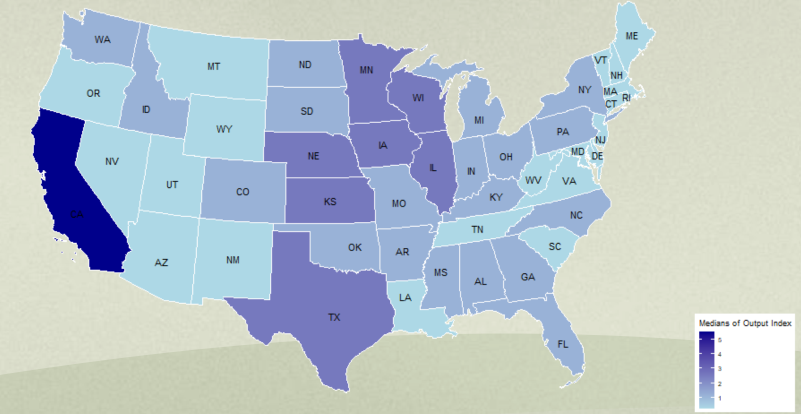
Prediction of 2019 underscores the challenge of accurately predicting outcomes when considering dynamic, external factors

SEQUENTIAL CLUSTERING

Sequential Clustering based on Agricultural Output Index

Identify **4 clusters** exhibiting similar patterns over years



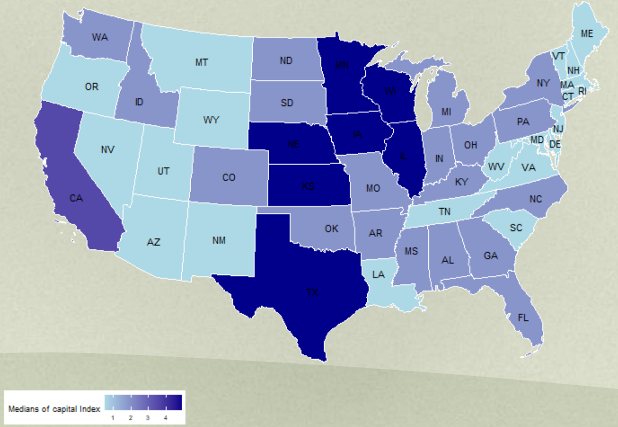


Singleton California has values significantly higher than those of other state

PERMUTATIONAL MANOVA

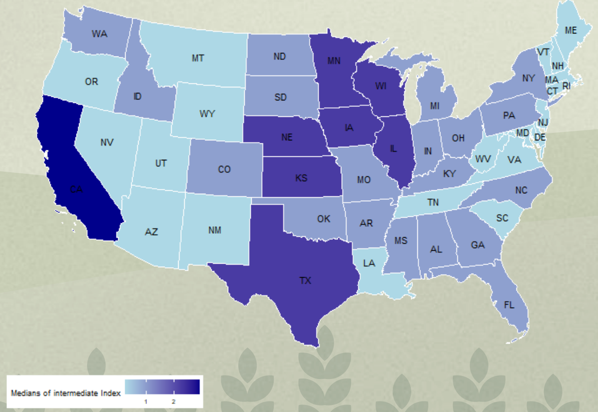
Permutational Manova Analysis on Capital Input, Labor Input and Intermediate Input

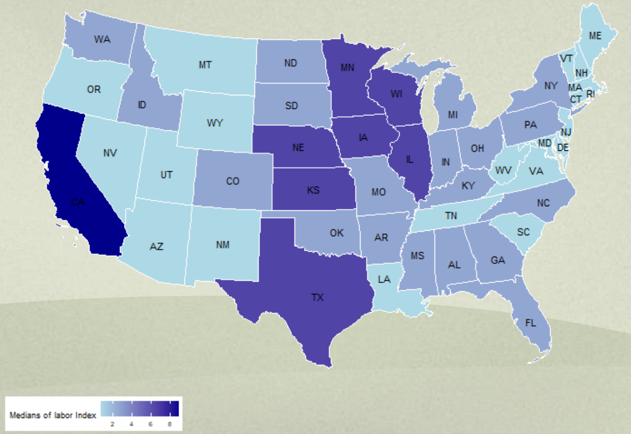
Clustering not only captures output distinctions but also reflects **statistically significant variations** in the use of inputs



Capital Input

Intermediate Input





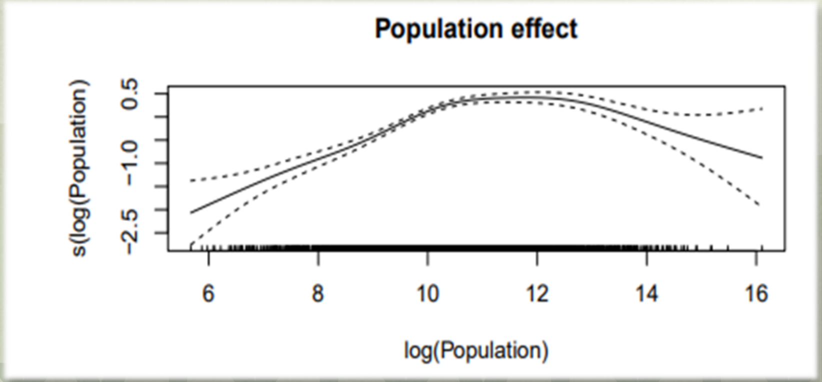
Labor Input

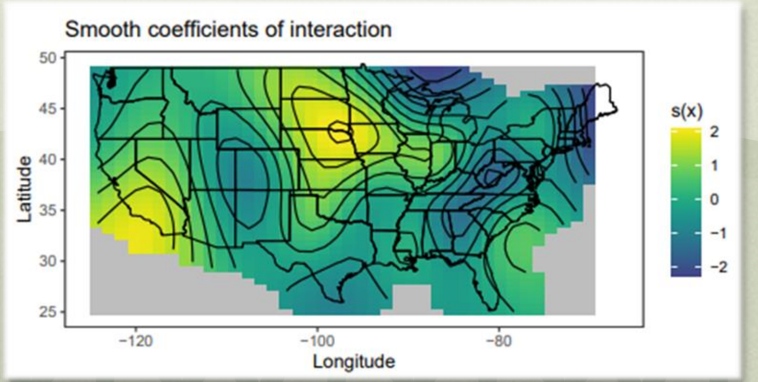
SPATIAL ANALYSIS

Spatial GAM to identify regions with the highest sales of agricultural commodities

Areas with **high sales** could indicate regions with a **strong demand** for agricultural commodities and a **higher necessity** for agricultural productivity

$$\log(Total\_Commodities\_Sales) = f_1(Latitude, Longitude) + f_2(\log(Population))$$





CONCLUSIONS

Conclusions

01

Changes In Input Usage

⬇

Permutational Tests

02

Primary drivers of the agricultural sector

⬇

GAM + Bootstraps Intervals

03

Spatial Agricultural Trends

⬇

Permutational Manova
+ Spatial GAM

Further Developments

- Include in the analysis external factors, such us weather conditions or characteristics of the soil
- Employ more sophisticated modeling techniques to understand complexity of the dynamics of agricultural systems

Thanks for your attention!

[redacted]

References

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- Wang et al. *Public r&d, private r&d, and us agricultural productivity growth: Dynamic and long-run relationships.* American journal of agricultural economics, 2013.

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