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Technical efficiency and technology adoption in beef cattle in Uruguay

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Agenda

Summary

Technical efficiency and technology adoption in beef cattle in Uruguay

- Measuring Technical Efficiency (ET) is important:
  - Benchmarking $\rightarrow$ management
  - Improve decision-making and policy design
  - Impact evaluation of policy interventions
- The eficciency literature:
  - It had exponential growth in empirical applications in the last 40 years [Lampe and Hilgers (2015)]
  - The theoretical literature has also been very dynamic [Fried et al. (2008), Kumbhakar et al. (2020a,2020b)]
  - There are few applications on beef farming with disaggregated data
- Contributions of this paper:
  - Estimating TE at the farm level in beef cattle farming with a new dataset with national and mandatory coverage, that allows linking TE with the use of technologies.
  - Exploring the determinants of livestock TE in Uruguay.

Motivation

- Contribution of the agricultural sector in Uruguay
  - Exports of agricultural-based goods($\approx \frac{3}{4}$)
  - Greater multiplier effect (6.22) [Terra et al. (2009)]
  - 13% of employment generated by agroindustries [Ackerman and Cortelezzi (2017)], with strong participation in the productive specialization of cities [Ackermann and Cortelezzi (2020)]
  - 92.8% national area.
    - ⋆ 59.5% of the national territory occupied by livestock
- Importance of efficiency and productivity
  - Huge and persistent gap between firms [Syverson (2011)].
    - ⋆ There are several empirical challenges in estimating productivity and TE [Griliches and Mairesse (1995), Aguirregabiria (2012), Fried et al. (2008), Syverson (2011)]
  - Productivity improvement:
    - ⋆ It is a matter of survival for firms
    - ⋆ It is a necessary condition for the economic development of countries.
  - Economic, social and environmental sustainability

Motivation

Partial livestock productivity

- Uruguay has partial livestock productivity estimates (kg/ha/year) per productive unit with administrative records of national and mandatory coverage
  - Livestock productivity with SNIG microdata (2010-2017) [Aguirre (2018)]
  - Partial productivity gaps with 2011 census data [Aguirre (2019)]
  - Evolution of partial livestock productivity with SNIG microdata (2005-2022)[Aguirre (2022a)]
  - Variability of partial livestock productivity with the EGN 2016 [Aguirre (2022b)]
- Although partial productivity has been used to assess as the outcome variable in impacts evaluations in beef cattle [Durán et al. (2018)], is not a good indicator to compare producers.

Literature

Technical efficiency in beef cattle farming

- While there is a growing literature on measuring technical efficiency in the agricultural sector [Bravo-Ureta et al. (2007)], there are few works on beef farming.
  - TE estimates in Uruguay
    - ★ DEA: Lanfranco and Buffa (2013), García Suárez and Lanfranco (2019)
    - ★ SPF García Suárez et al. (2018), Aguirre et al. (2021)
  - TE estimates for others countries
    - ★ SPF: Trestini (2006) , Qushim et al. (2013) ,Ozden and Armagan (2014)
    - ★ MFA: Gatti et al. (2015)
  - The papers differ in the universe they describe, the information they possess, and the methodology they use. In addition, livestock production systems differ in several key cleavages.
  - It is very challenging to compare the results of different studies in the beef cattle

Data

National Livestock Information System (SNIG) (mandatory and national traceability system)

- Animal stock declaration at 6/30
  - Number of animals by category (age, sex and destination)
  - Use and type of land tenure
- Movement and transit guides for any change of property or place

National Livestock Survey 2016 (EGN). National and representative random survey.

- Characteristics of the producer, production systems, applied technologies, use of inputs and services

Target sample 441 units

- Includes farmers: without dairy, without feedlots and with breeding cattle

Methodology

- SFM (stochastic frontier model) nest two models as special cases:
  - Deterministic: any deviation from the frontier is assumed to be inefficiency $v_i = 0$
  - Regression: any deviation from the boundaries is assumed to be part of the error $u_i = 0$

$$(SFM) \begin{cases} Y_i = f(X_i;\beta)e^{\epsilon_i} \ , \ i = 1,..,n \\ \epsilon_i = v_i - u_i \\ v_i \sim \mathcal{N}(0,\sigma_v^2) \\ u_i \sim \mathcal{F}^+(\mu_u,\sigma_u^2) \end{cases} \tag{1}$$

Methodology

$\epsilon = v_i - u_i, v_i \sim \mathcal{N}(0, \sigma_v^2),\ u_i \sim \mathcal{N}^+(\mu_i, \sigma_{u_i}^2)$		
	μ_i	$\sigma_{u_i}^2$
HN [Aigner et al. (1977)]	$\mu_i = 0$	$\sigma_{u_i}^2 = \sigma_u^2 \in \mathbb{R}^+$
TN [Stevenson (1980)]	$\mu_i = \mu \in \mathbb{R}$	$\sigma_{u_i}^2 = \sigma_u^2 \in \mathbb{R}^+$
KGM [Kumbhakar et al. (1991)]	$\mu_i = \delta Z_i$	$\sigma_{u_i}^2 = \sigma_u^2 \in \mathbb{R}^+$
CF [Caudill and Ford (1993)]	$\mu_i = \mu \in \mathbb{R}$	$\sigma_{u_i}^2 = e^{Z_i'\gamma}$
Wang [Wang (2002)]	$\mu_i = \delta Z_i$	$\sigma_{u_i}^2 = e^{Z_i'\gamma}$

- Estimation in one stage by ML
  - Assumptions: (1): $u_i, v_i \perp\!\!\!\perp x, z\ \forall x, z$; (2) u_i, v_i are independents
- Estimation of the inefficiency of the firm: $\hat{TE}_i = \mathbb{E}[e^{-\hat{u}_i} \mid \epsilon_i]$
- In Wang's model, the effect of contextual variables on expectation and the variance of inefficiency are non-linear. (APE)
- $LR = -2[In(L(H_0) - InL(H_1)]$. If $\theta \in Interior(\Theta), LR\ |_{H_0} \sim \chi_J^2$

Challenges

- ¿Heterogeneity?
  - ¿What is the target population?
  - ¿What are the outputs to consider?
    - ★ ¿Multi-product production function?
- ¿Identification problems?
  - ¿What is the functional form? $Q = F(K, L, M, \dots)$. ¿How to measure capital?
  - Variable Selection
  - Measurement errors
  - Omitted variables
  - Unobservable quality differences
- How to deal with inconsistent data? What to do with outliers?

Group	Variable	Definition
Y	CarneB	Livestock production (kg/año)
X	UGB	Bovine livestock units (UG)
	SupP	Land utilized for cattle production (ha)
	TrabajT	Total workers (equivalent annual working units)
Controls	RArMejo	% graze area with improvement
	CONEAT	Average Coneat index
	Región	One dummy per agreoclogical region
	OrientGan	A dummy variable per livestock orientation (1-ganadero, 2-mixto)
	OrientVac	A dummy variable per bovine orientation (1-Cria, 2-CC, 3-Inver)
	Suplem	A dummy variable if it supplemented cattle
Z	TipoSoc	A categorical variable that captures the legal status
	Tenencia	A categorical variable that captures the type of tenure
	VCriaConToro	Is the breeding cow with the bull all year round?
	InsemArtif	Did you perform artificial insemination?
	DiagActOv	Did you diagnose ovarian activity?
	DiagGestVS	Did you carry out a pregnancy diagnosis of served wombs?
	UtEscCCV	Do you regularly use an ESCCV to classify sows?
	DestPrec	Did you perform early weaning?
	DestTemp	Did you perform temporary weaning?
	VacPastJuntEnOtInv	Do bred (pregnant) cows and heifers graze together?
	DrVet	Did you receive veterinary technical assistance?
	IngAgr	Did you receive agronomic technical assistance?

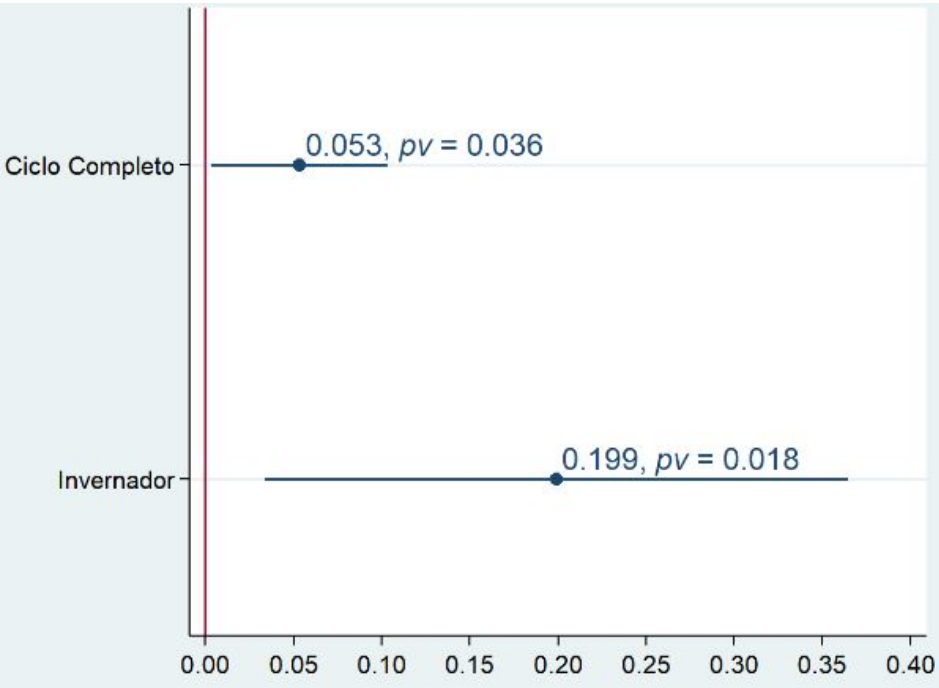
Result

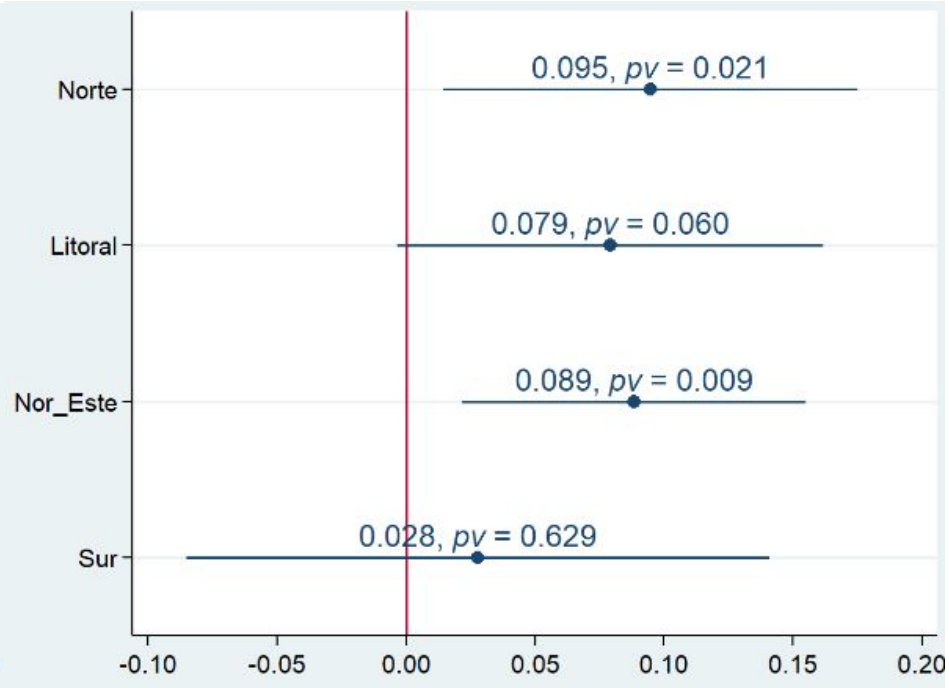
$$\begin{cases} y_i = \beta_0 + \sum_{i=1}^{K} \beta_i x_{ik} + \frac{1}{2} \sum_{i=1}^{K} \sum_{j=1}^{K} \beta_{ij} x_{ik} x_{jk} + \theta' C_i - u_i + v_i \ , \beta_{ij} = \beta_{ji} \\ v_i \sim \mathcal{N}(0, \sigma_v^2) \ , u_i \sim \mathcal{N}^+(Z_i' \delta, e^{Z_i' \gamma}) \end{cases}$$

- Following the bacon algorithm (blocked adaptive computationally efficient outlier nominators), not outlier are found
- The Wang translog model is the preferred specification according to the LR test

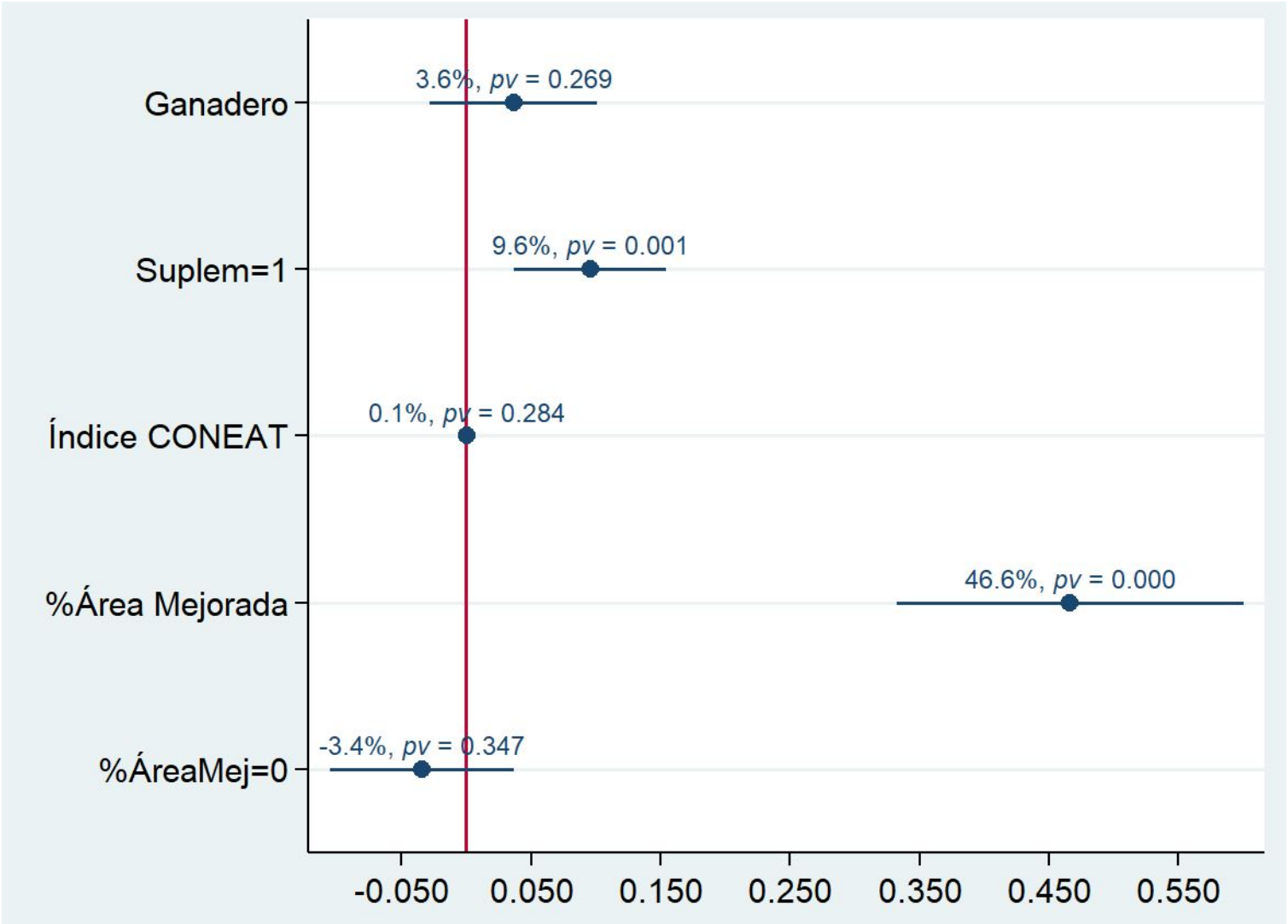
Results: control variables

- Significant at 10%: Región ($pv = 0.0725$), Ratio de área con mejoramientos 46,6% ($pv < 0.001$), Suplementación 9.57% ($pv = 0.001$), Orientación vacuna ($pv < 0.001$)
- Not significant at 10%: Orientación ganadera 3.6% (pv=0.2689), Índice CONEAT 0.06% (pv=0.284) y sin área con mejoramientos pastoriles -3.4% (pv=0.347)





Partial effects with control variables



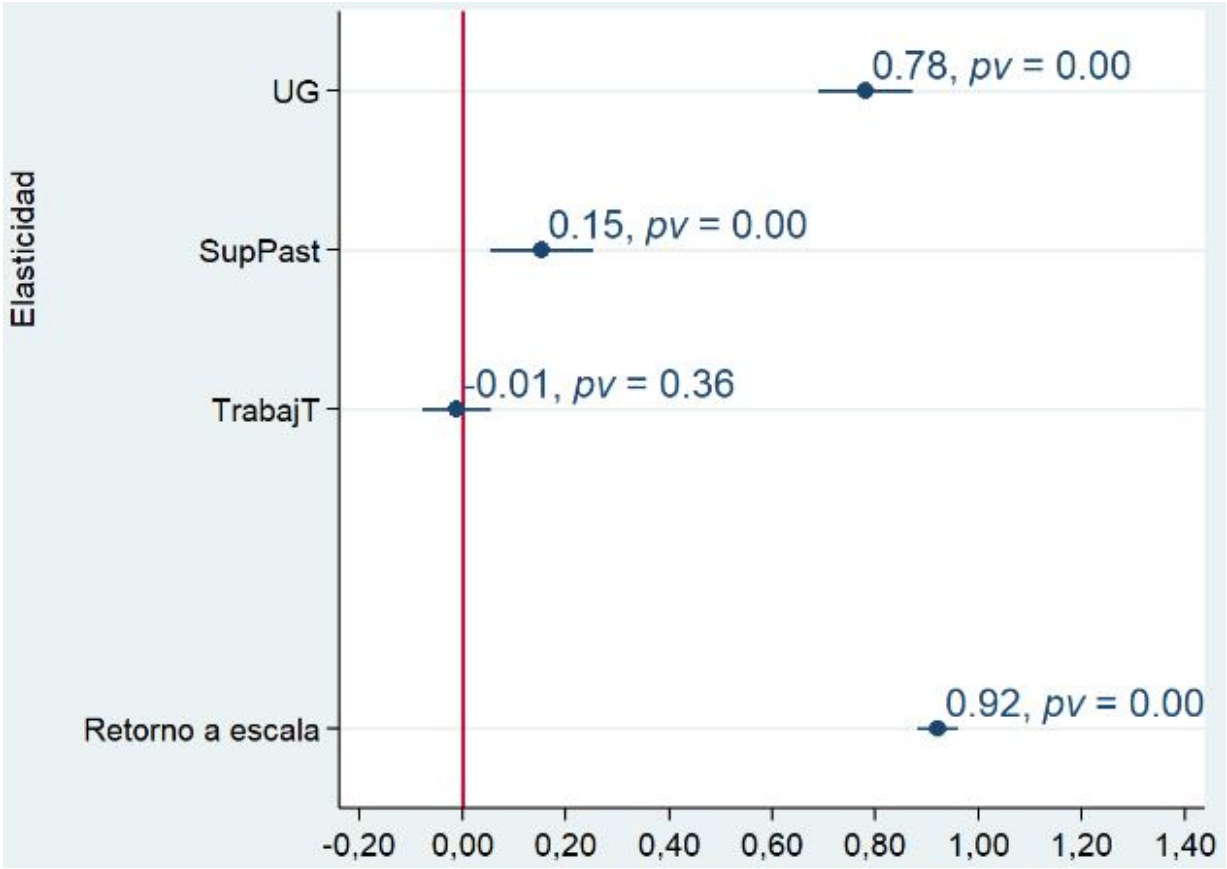
Distribution of technical efficiency

	Mean	SD	p10	p25	p50	p75	p90	p90/p10
TE	0.819	0.176	0.612	0.778	0.878	0.937	0.959	1.568

- Simple average 0.819
- Weighted mean 0.716
  - This implies that with the technology and resources available, through better management, it is possible to increase production in a $1/0.716 \approx 40\%$
  - Similar to previous works for Uruguay
    - ★ García Suárez et al. (2018) 77.38%
    - ★ García Suárez and Lanfranco (2019) 72.3%;
    - ★ Aguirre et al. (2019) 80.3%

Elasticities and returns to scale (Wang TL)

- Product input elasticities[1] and return to scale[2] at mean are computed



[1] $\varepsilon_{x_j}^{y} = \frac{\partial L(y)}{\partial L(x_j)} = \sum_j (\beta_j + \sum_k \beta_{jk} L(X_{ik}))$

[2] $RS(X_i) = \sum_j \varepsilon_{x_j}^{y}$

Contextual variables

	APE (inefficiency)	
	E(u)	V(u)
VCriaConToro	8.60%	3.60%
InsemArtif	-16.6%**	-12.3%***
DiagActOv	-3.80%	3.30%
DiagGestVS	-2.20%	-3.5%*
UtEscCCV	-5.50%	-1.90%
DestPrec	0.50%	-5.6%**
DestTemp	-6.50%	-1%
VacPastJuntEnOtInv	2.20%	0.50%
DrVet	-8.6%**	-5.4%**
IngAgr	-40.5%***	-8.7%**

*** p<0.01, ** p<0.05, * p<0.1.

APE standards errors with Wang´s model estimated by bootstrap with 1000 repetitions [Kumbhakar et al. (2015)]

APE

Land Tenure		APE (Inefficiency)	
		E(u)	V(u)
Owner	44.50%		
Tenant	9.20%	-2.90%	-12.1%**
Other forms	46.20%	10.30%	2.50%

Legal Status		APE (Inefficiency)	
		E(u)	V(u)
Natural person	44.50%		
Legal person without contract	9.30%	-22.2%**	-2.90%
Legal person with contract	46.20%	-15.5%***	-7.3%**

Comments and discussion

- This work allows progress in the estimation of TE in beef cattle with breeding herd and without feedlots in Uruguay
  - TE is a better indicator of farm management than partial productivity, since it allows controlling for the intensity in the use of inputs
  - As expected, the producers who receive technical assistance and implement the technologies for bovine breeding recommended by the academy achieve a better productive performance.
  - It is possible to increase beef production by 39.7% at the national level
- Analyzing the relevance of including the variable work in the TE estimate is relevant since said variable is not available in the SNIG data panel
  - It is observed that the elasticity is not significant, and when excluding this variable, the distribution of the TE changed very little.

Comments and discussion

- Although the objective of this document is to describe the expected value of the production function given a feature vector, strictly speaking the parameters cannot be interpreted as causal but rather as partial correlations.
  - Following Sickles and Zelenyuk (2019) parameter estimation can be inconsistent and biased for several reasons: omitted variable bias, endogenous treatment effect, simultaneity bias, parameter heterogeneity, measurement errors of the dependent and non-independent variable, non-random sampling, and bias survival.

Future steps

- Refinements and new questions
  - How to incorporate unobservable heterogeneity?,
  - How was the evolution of the livestock TFP? How can it be decomposed?
    - ★ Working with panel data models allows to address this problem
  - How to incorporate endogeneity?
    - ★ Two approaches: statistical (through the use of instrumental variables); the economic (incorporating constraints or deriving a structural model)

Thank you very much for your attention! Questions?

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