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Fully calibrating regional models of agricultural supply under multiple constraints

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Motivation

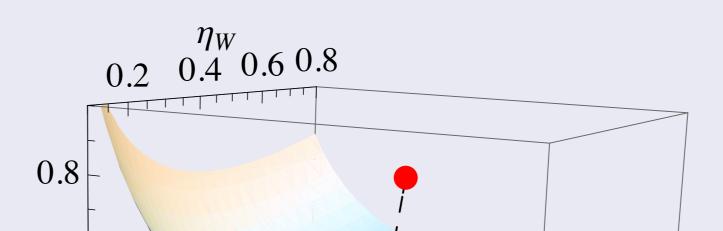
Model

- Positive mathematical programming (PMP) allows the exact calibration of agricultural production models against available economic information without the use of artificial flexibility constraints, while requiring minimal data.
- Calibration against the reference allocation (first-order calibration) is always feasible and can be achieved in many ways.
- Calibration against supply elasticity priors (second-order calibration) is not always feasible and, when it is feasible, is achieved in a unique way.

Using the calibration criterion to allow for calibration

When the prior $\bar{\eta}$ lies outside the calibration region, the analyst can modify the elasticity vector to satisfy the calibration criterion, while minimising the departure from $\bar{\eta}$, e.g., using generalised maximum entropy (GME).

Application to the data published in Howitt (1995): California region with I = 3 crops, K = 2 constraints and $\bar{\eta} = (\bar{\eta}_{Cotton}, \bar{\eta}_{Wheat}, \bar{\eta}_{Rice}) = (0.47, 0.40, 0.80).$



The criterion C^2 is violated for rice, the prior lying outside the

The optimisation program for the fixed-proportion technology and linear cost model for *I* crops and *K* constraints can be written as

$$\max_{\mathbf{x} \geq 0} \sum_{i} p_{i} \alpha_{i} x_{i}^{\delta_{i}} - (C_{i} + \lambda_{2i}) x_{i} \text{ subject to } \mathbf{A}\mathbf{x} = \mathbf{v} \quad [\boldsymbol{\lambda}].$$

- x_i: acreage of crop i
- *p_i*: price of crop *i*
- $\alpha_i \ge 0$: scale parameter of crop *i*
- $\delta_i \in (0, 1)$: returns to scale of crop *i*
- λ_{2i} : crop-specific adjustment cost
- C_i : per acre cost of activity *i*
- $\quad \lambda_k: shadow value of constraint k$
- \blacksquare $a_{k,i}$: constraint coefficient
- v_k : regional constraint k

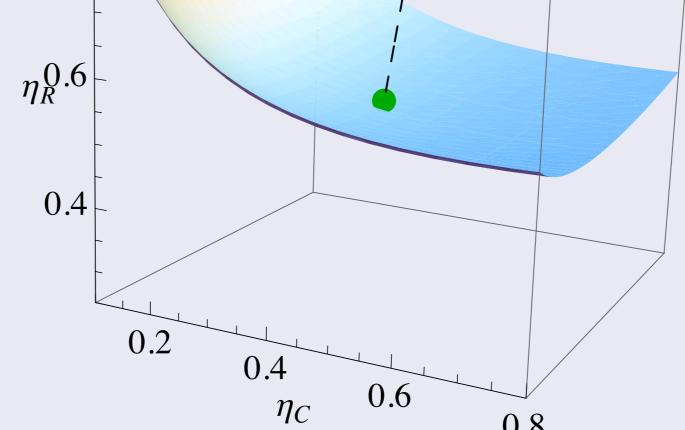


Figure: GME projection of $\bar{\eta}$ into the calibration region

- calibration region (red dot).
- Solving a GME program with equidistant supports for each crop, we find $\eta^{GME} = (0.43, 0.42, 0.55),$ lying within the calibration region (green dot).

The calibration system

The model can be calibrated in two steps. The analyst chooses

1 δ to replicate the set of prior elasticities $\bar{\eta}$ at the reference allocation, 2 α and λ_2 to replicate the reference allocation ($\bar{\mathbf{q}}, \bar{\mathbf{x}}, \bar{\lambda}$).

Applying the implicit function theorem, the calibration system for the supply elasticities is

 $\bar{\boldsymbol{\eta}} = \text{VecDiag} \left[\mathbf{D} (\mathbf{I}_I - \mathbf{A}^T (\mathbf{A} \boldsymbol{\Delta} \mathbf{A}^T)^{-1} \mathbf{A} \boldsymbol{\Delta}) \right]$

where VecDiag creates an *I*-vector out of the diagonal elements of an $I \times I$ matrix, Δ and \mathbf{D} are the $I \times I$ diagonal matrices with typical element $\frac{b_i}{\delta_i(1-\delta_i)}$

A tool to disaggregate $\bar{\eta}$ to the regional level

Even when the prior is compatible with the reference allocation, we can use the calibration criterion C^1 to generate regional variation in supply elasticities by maximizing the minimum distance of the regional elasticity to the calibration surface across regions, with the weighted sum of the regional elasticities replicating the prior $\bar{\eta}$.

Application to 3 regions of the California SWAP model: I = 16 crops and K = 1 constraint.

and $\frac{\delta_i}{1-\delta_i}$, respectively, with $b_i \equiv \frac{\bar{x}_i^2}{p_i \bar{q}_i}$.

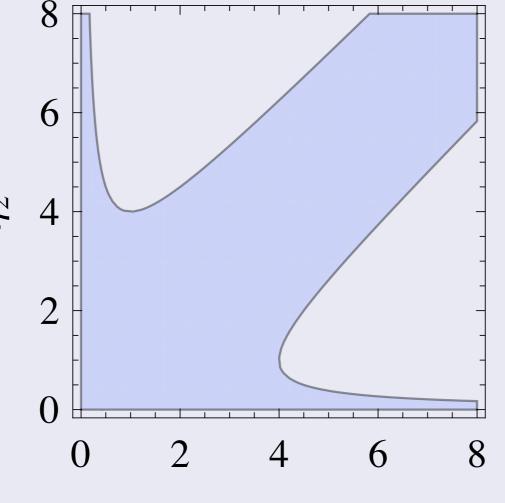
The calibration conditions

We show that the calibration system has at most one solution in (0, 1)^{*I*}.
 We derive the necessary and sufficient conditions under which an *acceptable* solution exists. The calibration criterion C^K for a model subject to K constraints delineates the set of supply elasticities *η* that are compatible with the reference allocation, i.e., such that the model exactly reproduces the prior *η* and the reference allocation (*q*, *x*, *λ*).

Calibration criterion C^1 :

$$orall i \quad B_i ar\eta_i < \sum_{j \in I_{-i}} B_j ar\eta_j \left(1 + rac{1}{a\eta_j}\right)^2$$
 so with $B_i \equiv a_{1,i}^2 b_i.$

Figure: Calibration region for I = 2 and K = 1



 η_1

	Regional	output	shares	Prior	Regional	elasticities	
Crop <i>i</i>	<i>W</i> ₁	<i>W</i> ₂	W ₃	$ar\eta$	$\hat{\eta}_{1}$	$\hat{\eta}_{2}$	$\hat{\eta}_{3}$
Almond, pistachio	0.37	0.22	0.41	0.19	0.14	0.10	0.29
Alfalfa	0.32	0.45	0.22	0.44	0.66	0.22	0.57
Corn	0.32	0.31	0.38	0.21	0.19	0.11	0.32
Cotton	0	0.74	0.26	0.50	-	0.41	0.75
Cucurbitaceae	0.11	0.89	0	0.05	0.08	0.05	-
Dry bean	0.40	0.48	0.13	0.13	0.20	0.07	0.17
Onion, garlic	0	1	0	0.11	-	0.11	-
Other dec. tree cr.	0.86	0.09	0.05	0.19	0.20	0.10	0.29
Other field cr.	0.10	0.58	0.33	0.63	0.95	0.40	0.95
Other truck cr.	0.22	0.52	0.26	0.11	0.17	0.06	0.17
Pasture	0.81	0.14	0.05	0.24	0.25	0.12	0.36
Process. tomato	0	0.67	0.33	0.55	-	0.42	0.83
Rice	0.02	0.93	0.06	0.48	0.72	0.46	0.72
Safflower	0	0.79	0.21	0.34	-	0.30	0.51
Subtrop. cr.	0.93	0.03	0.04	0.03	0.03	0.02	0.05
Vine	0	0.49	0.51	0.05	-	0.03	0.07

The regional variation in economic information can be exploited to generate regional variation in supply responses, even in the absence of region-specific elasticity priors.

• Calibration criterion C^2 :

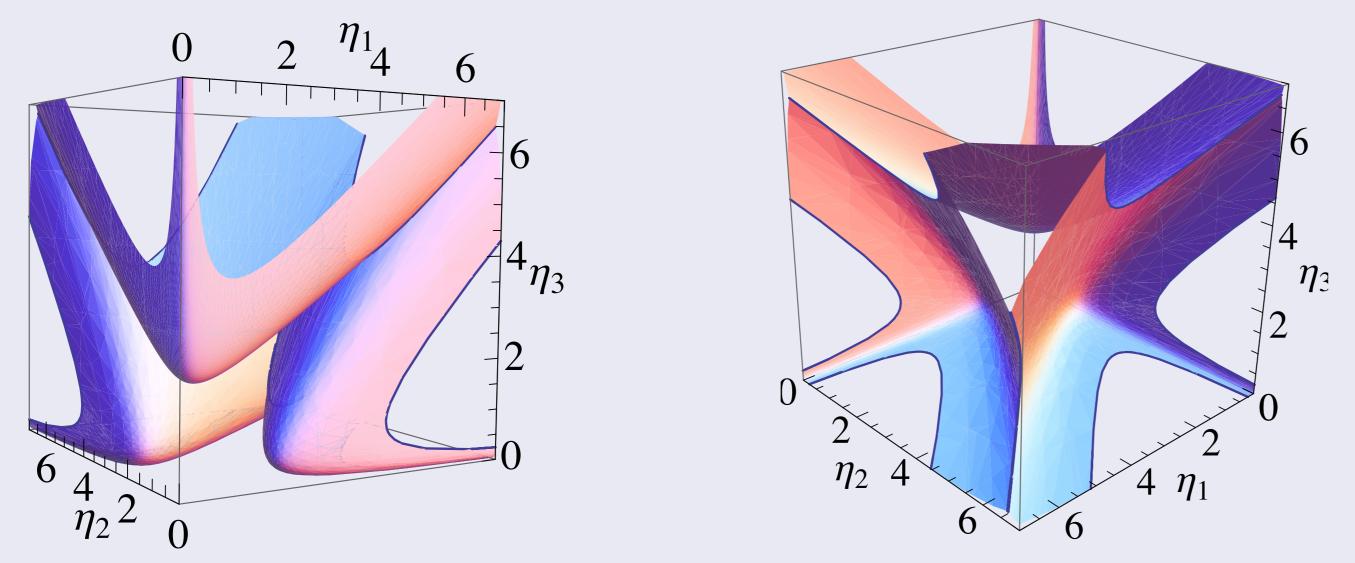


Figure: Calibration region for I = 3 and K = 2

Conclusion

Calibration against supply elasticity priors yields a unique solution, offering a clear advantage to simply using first-order calibration.
The calibration conditions allow the analyst to *ex ante* determine whether a prior *η* is compatible with the reference allocation (*q*, *x*, *λ*).
When the prior lies outside the calibration region, the analyst can use the calibration criterion to modify the elasticity vector in order to allow calibration, while minimising the departure from the prior.
The calibration criterion provides an information-based tool to disaggregate supply elasticities to the regional level—whether the prior satisfies the criterion or not.