Agricultural Production and Technological Change

Advanced Producer Theory and Analysis: The Production of Perennials

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AREC 705: Week 2

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French & Matthews Overview

French, B.C. & Matthews, J.L. (1971). A Supply Response Model for Perennial Crops. *American Journal of Agricultural Economics, 53(3)*: 478–490.

Contributions – what question(s) is the paper addressing? –

Category – theoretical? empirical? case study? meta-study? –

Conclusions – what are the results? –

Context – what are related papers? who are the authors? –

Methods – what methods are used to analyze the problem? –

French & Matthews Questions

French, B.C. & Matthews, J.L. (1971). A Supply Response Model for Perennial Crops. *American Journal of Agricultural Economics, 53(3)*: 478–490.

Why is the price response of perennial producers interesting to economists? –

Why do they model aggregate production (rather than individual)? –

Are there limitations to (or inaccuracies in) the conceptual framework? –

Are there limitations to (or inaccuracies in) the empirical modeling? –

Anything else of note? –

What Distinguishes Perennial and Annual Crop Production?

1. Long gestation period between initial input and first output.
2. Extended period of output flowing from the initial input.
3. Eventually a gradual deterioration of productivity.

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Annual plants have:

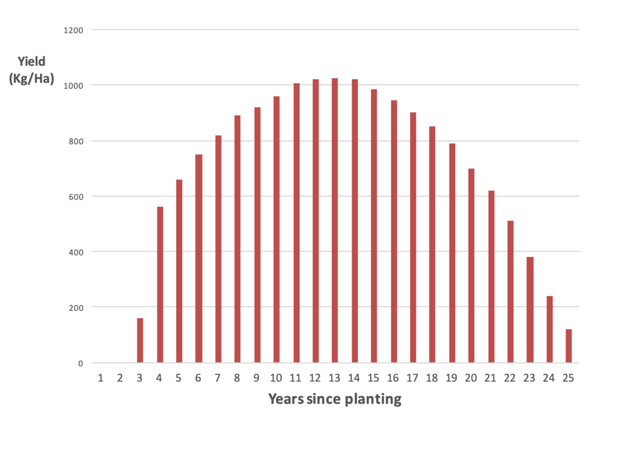
- A shorter initial gestation period (typically <3 months)
- A shorter output period (up to a few months)
- A fairly fast deterioration in productivity

What Distinguishes Perennial and Annual Crop Production?

1. Long gestation period between initial input and first output.
2. Extended period of output flowing from the initial input.
3. Eventually a gradual deterioration of productivity.

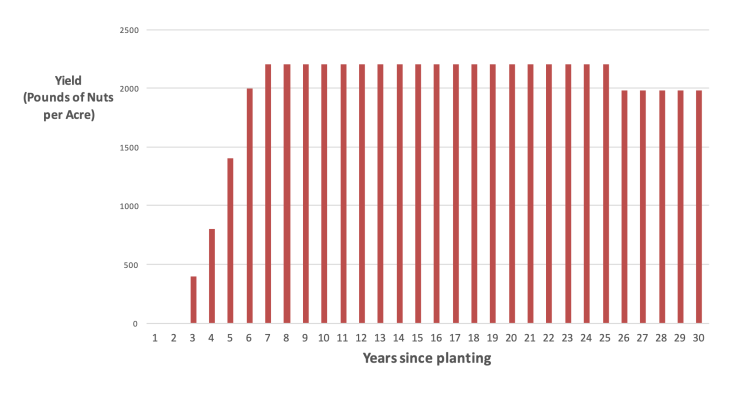
The durations of each of these stages differs by plant.

Cocoa in Ghana



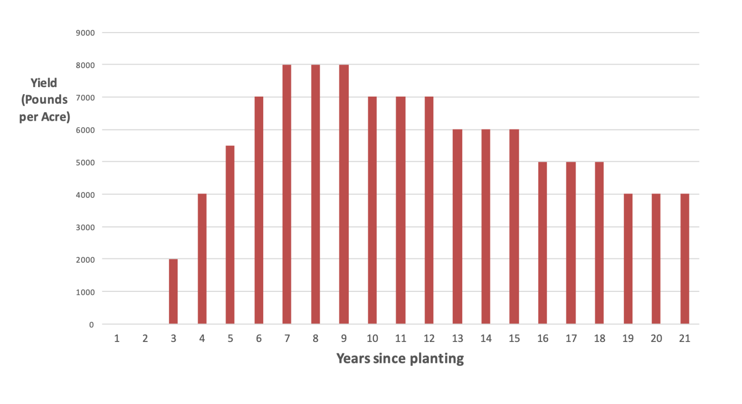
Mahrizal, Nalley, L. L., Dixon, B. L., & Popp, J. S. (2014). An optimal phased replanting approach for cocoa trees with application to Ghana. *Agricultural Economics, 45(3)*:291302. Source: Tregeagle & Simon (2018)

Almonds in California



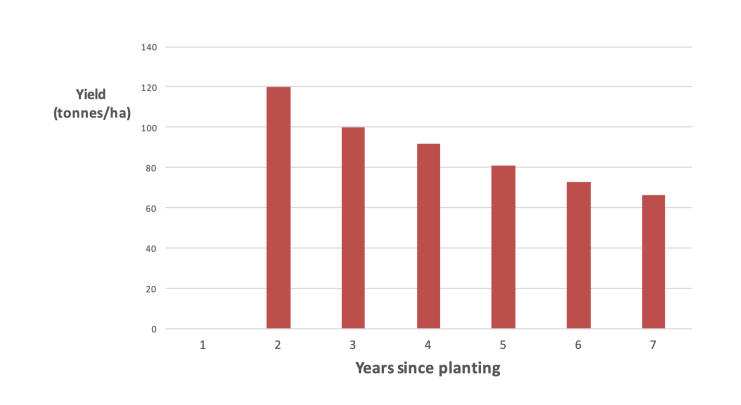
Klonsky, K., Livingston, P., & Tumber, K. (2016). Tree Loss Value Calculator - Almonds, Sacramento Valley. Source: Tregeagle & Simon (2018)

Blueberries in North Carolina



Safley, C.D., Cline, W.O., & Mainland, C.M. (2006). Evaluating the Profitability of Blueberry Production. Source: Tregeagle & Simon (2018)

Sugarcane in Brazil



Margarido, F. B. and Santos, F. (2012). Sugarcane Bioenergy, Sugar and Ethanol Technology and Prospects, Source: Tregeagle & Simon (2018)

What Distinguishes Perennial and Annual Crop Production?

1. Long gestation period between initial input and first output.
2. Extended period of output flowing from the initial input.
3. Eventually a gradual deterioration of productivity.

The optimal timing of new plantings and removals will depend on the specific yield curve of the plant.

Note that for annuals there are no removal decisions, and costs associated with removal are included in costs for next planting.

A Primer on Models of Supply Response

Before we go into the perennial planting model in French & Matthews...

The Nerlove Model

> *"Nerlove's famous formulation of agricultural supply response is certainly one of the most successful econometric models introduced into the literature."*
>
> *(Braulke 1982)*

Nerlove, M. (1956), "Estimates of elasticities of supply of selected agricultural commodities," *Journal of Farm Economics 38*:496-509.

Nerlove, M. (1958c), The Dynamics of Supply: Estimation of Farmers' Response to Price (Johns Hopkins University Press, Baltimore, MD).

The Nerlove Model of Agricultural Supply

$$A_t - A_{t-1} = \gamma(A_t^* - A_{t-1})$$
$$P_t^* - P_{t-1}^* = \beta(P_{t-1} - P_{t-1}^*)$$
$$A_t^* = \alpha_0 + \alpha_1 P_t^* + \alpha_2 Z_t + U_t$$

Where A_t and A_t^* are actual and "desired" area under cultivation at time t,
P_t and P_t^* are actual and "expected" price per crop unit at time t,
Z_t are observed, presumably exogenous factors,
and U_t are unobserved "latent" factors

β and γ are "coefficients of expectation and adjustment" reflecting the responses of expectations to observed prices and observed areas under cultivation in equilibrium areas.

The French & Bressler Model of Perennial Crop (Lemon) Production

$$\frac{N_t}{B_{t-1}} = b_0 + b_1\pi^*_{t-1} + b_2\frac{A_{t-1}}{B_{t-1}} + v_{t-1}$$

Where N_t is acres planted at time t,
B_{t-1} is bearing acres at time $t-1$,
π^*_{t-1} is long-run profit expectation at time $t-1$,
A_{t-1} is acres of bearing trees over an age that indicates likely removal (e.g., 25 years),
v_{t-1} accounts for the combined effect of other omitted variables

b_2 gives the effect of anticipated removals on the new plantings of trees.

π^*_{t-1} is approximated by $\frac{1}{5}\sum_{i=t-1}^{t-5}\pi_i$

The French & Bressler Model of Perennial Crop (Lemon) Production

$$\frac{R_t}{B_t} = a_0 + a_1\pi'_t + a_2\frac{A_t}{B_t} + \frac{K_t}{B_t} + u_{t-1}$$

Where R_t is acres removed at time t,
B_t is bearing acres at time t,
π'_t is short-run profit expectation at time t,
A_t is acres of bearing trees over an age that indicates likely removal (e.g., 25 years),
$\frac{K_t}{B_t}$ is acreage removed for urban expansion

a_2 gives the effect of anticipated removals on removals.

π'_{t-1} is approximated by current returns and $\frac{1}{5}\sum_{i=t-1}^{t-5}\pi_i$

$B_t = B_{t-1} + N_{t-5} - R_{t-1}$

Arak Overview

Arak, M. (1968). The price responsiveness of Sao Paulo coffee growers. Food Research Institute Studies 8, 211-223.

Contributions – what question(s) is the paper addressing? –

Category – theoretical? empirical? case study? meta-study? –

Conclusions – what are the results? –

Context – what are related papers? who are the authors? –

Methods – what methods are used to analyze the problem? –

The Arak Model

What is different about the Arak model of new plantings?

$$N_t^* = T_t^* - \sum_{-\infty}^{t-1} N_j$$

$$N_t = \gamma_1 D_t \left(T_t^* - \sum_{-\infty}^{t-1} N_j \right) + \gamma_2 \left(D_t - \lambda \right)$$

Where D_t is the percent of trees over ten years of age,
λ is a parameter representing the proportion of trees over 10 that indicate the tree stock is "relatively old"

The Arak Model

What parameter gives the price effect on new plantings?

$$T_t^* = a_0 + a_1 p_t \implies$$

$$N_t = c_0 + c_1 D_t + c_2(D_t p_t) + c_3(D_t \sum N_j)$$

Where

$$c_0 = -\gamma_2 \lambda$$

$$c_1 = \gamma_1 a_0 + \gamma_2 - \gamma_1 S_0$$

$$c_2 = \gamma_1 a_1$$

$$c_3 = -\gamma_1$$

The Arak Model

Removals – What are the two key roles of age in the plant removal decision?

Removals – how does age enter the removal decision model?

$$R_t^* = (d_0 + d_1 p_t + d_2 F_{t-1}) T_{t-1}^E$$

The Arak Model

Removals – What are the two key roles of age in the plant removal decision?

Removals – how does age enter the removal decision model?

$$R_t^* = (d_0 + d_1 p_t + d_2 F_{t-1}) T_{t-1}^E$$

Where T_{t-1}^e is the number of coffee trees in the age group for which the removal (rather than abandonment) is the rational alternative to the maintenance of the existing tree

F_{t-1} is an indicator for a frost occurrence

How to identify T_{t-1}^e?

The Arak Model

Abandonments – Why would coffee trees be abandoned rather than removed?

Abandonments – Is this relevant in the US (today)?

$$\frac{A_t}{T_{t-1}} = (b_1 + b_2 p_t)\frac{T^M_{t-1}}{T_{t-1}} + (b_3 + b_4 p_t)\frac{T^Y_{t-1}}{T_{t-1}} + b_0$$

The French & Matthews Model of Perennial Crop Production

What sets this model apart from prior work?

Are there any new variables in this model that were left out from prior work?

What framework does this model primarily pull from?

What are some key differences in the framework compared with others?

The French & Matthews Model of Perennial Crop Production

Desired Production and Acreage:

$$Q_t^* - Q_{t-1}^e = b_{11}(\pi_t^e - \pi_t^*) + b_{12}(\pi_{At}^e - \pi_{At}^*) + u_{1t}$$
$$A_t^* - A_{t-1} = b_{21}(\pi_t^e - \pi_t^*) + b_{22}(\pi_{At}^e - \pi_{At}^*) + b_{23}\Delta Y_t^e + u_{2t}$$

Where $Q_t^* =$ *desired* production,
$Q_{t-1}^e = Y_{t-1}^e A_{t-1} =$ *expected* average production,
$\pi_t^e =$ *expected* long-run profitability (per unit),
$\pi_t^* =$ normal long-run equilibrium profit (per unit),
$\pi_t^e =$ *expected* profitability per unit of product for the alternative land use,
$\pi_t^* =$ normal profitability per unit of product for the alternative land use,
$\Delta Y_t^e = Y_t^e - Y_{t-1}^e =$ change in expected yields,
u_{1t}, $u_{2t} =$ disturbance terms

The French & Matthews Model of Perennial Crop Production

Desired New Plantings:

$$N_t^* = A_{t+k}^* - A_{t-1} + R_{kt}^e - N_{kt-1}$$

Where N_t^* = *desired* acreage of new plantings desired by growers in year t,
k = the interval of time in years between initial planting and bearing,
R_{kt}^e = *expected* removals during the next k years,
$N_{kt-1} = \sum_{i=1}^{k} N_{t-1}$ = nonbearing but planted acreage, i.e., total acreage planted after year $t-k-1$

Actual New Plantings:

$$N_t = \alpha N_t^* + \beta(1-\alpha)N_{t-1} + e_t$$

The French & Matthews Model of Perennial Crop Production

Plug A_t^* and R_{kt}^e into N_t^* into N_t with $\beta = 0$ to arrive at...

Actual New Plantings:

$$N_t = b_{51}(\pi_t^e - \pi_t^*) + b_{52}(\pi_{At}^e - \pi_{At}^*) + b_{53}\Delta Y_t^e + b_{54}A_{t-1}^0 + b_{55}N_{kt-1} + b_{56}A_{t-1} + u_{5t}$$

Actual Removals:

$$R_t = b_{60} + b_{61}A_t^0 + b_{62}A_t^0(\pi_t^s - \pi_t^*) + b_{63}A_t^0(\pi_{At}^s - \pi_{At}^*) + b_{64}Z_t + b_{65}A_t + u_{6t}$$

Where R_t = acreage removed at the end of year t ,
A_t^0 = Acreage over a particular age (after which productivity declines),
π^s = short-run profit expectations,
Z_t = variable to account for institutional or physical factors of importance

The French & Matthews Model of Perennial Crop Production

Total Change in Acreage:

$$A_t - A_{t-1} = (1 - b_32)N_{t-k} - R_{t-k} + v_{1t}$$

Plug N_t and R_t^e into N_t^* to arrive at...

$$\begin{aligned} A_t - A_{t-1} = \; & b_{70} + b_{71}(\pi^e_{t-k} - \pi^*_{t-k}) + b_{72}(\pi^e_{At} - \pi^*_{At}) + b_{73}\Delta Y^e_{t-k} \\ & + b_{74}A^0_{t-k-1} + b_{75}A^0_{t-1} + b_{76}A^0_{t-1}(\pi^s_t - \pi^*_t) + b_{77}A^0_{t-1}(\pi^s_{At} - \pi^*_{At}) \\ & + b_{78}Z_{t-1} + b_{79}N_{kt-k-1} + b_{710}A_{t-k-1} + b_{711}A_{t-1} + u_{7t} \end{aligned}$$

The French & Matthews Model of Perennial Crop Production

Then make a bunch of assumptions and simplifications to generate measures of actual (rather than expected or desired) variables.

Then estimate the models with **what simplifications**?

What is the final estimating equation?

What are some limitations to all of these models?

The Nerlove Model of Agricultural Supply – Issues

"The statistical problems of estimating a model such as (1)-(3), particularly of identifying relevant observed exogenous variables, not subject to expectational lags, and problems due to serially correlated disturbances, are well known. In addition, the use of area cultivated, one input in the production process to represent planned output, the problem of choosing the relevant price or prices, and other issues of specification, such as the inclusion of expected yields, weather conditions, and price and yield variances to take account of elements of risk, have been widely discussed in the literature (see, for example, inter alia [Just (1974), Askari and Cummings (1976, 1977)])."

(Nerlove & Bessler 2001)

Assignments for Next Time

Advanced Producer Theory and Analysis I: Perennials

1. Wickens, M.R. & Greenfield, J.N. (1973). The Econometrics of Agricultural Supply: An Application to the World Coffee Market. *The Review of Economics and Statistics, 55(4)*: 433–440. https://www.jstor.org/stable/1925665
2. Devadoss, S. & Luckstead, J. (2010). An Analysis of Apple Supply Response. *International Journal of Production Economics, 124*: 265–271. https://www.sciencedirect.com/science/article/abs/pii/S0925527309004277

Wickens & Greenfield Overview

Wickens, M.R. & Greenfield, J.N. (1973). The Econometrics of Agricultural Supply: An Application to the World Coffee Market. *The Review of Economics and Statistics, 55(4)*: 433–440.

Contributions – what question(s) is the paper addressing? –

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Wickens & Greenfield Questions

Wickens, M.R. & Greenfield, J.N. (1973). The Econometrics of Agricultural Supply: An Application to the World Coffee Market. *The Review of Economics and Statistics, 55(4)*: 433–440.

Motivation – How does their motivation/hook/explanation of why this is important differ from the other papers we have discussed thus far? –

Contributions – why not use the Nerlove model (or other prior models)? –

Methods – why use an investment function rather than desired plantings? –

Methods – how does the model differ from the others we have covered? what variables are new? –

Wickens & Greenfield Model of Perennial Crop (Coffee) Production

The Investment Function:

$$q_t^p = \sum_{i=1}^{n} \delta(i, t) \, I_{t-i}$$

Where q_t^p is *potential* production,

I_{t-i} is the number of trees planted i years ago that have survived to year t,

$\delta(i, t)$ is the yield of those trees at time t,

Simplify so that $\delta(i, t) = \delta_i \rightarrow$ **why?**

Wickens & Greenfield Model of Perennial Crop (Coffee) Production

The Producer Maximization Problem:

$$V = \sum_{t=0}^{\infty} (1+r)^{-t} \left[\left(p_t^e - s_t^p \right) q_t^p - F_t - f(I_t) \right]$$

subject to:

$$q_t^p = \sum_{i=1}^{n} \delta_i I_{t-i}$$

Where V is *expected discounted* net revenue (i.e., NPV),
s_t^p is the expected unit cost of harvesting,
F_t are fixed costs,
$f(I_t)$ are (nonlinear, strictly increasing and convex) planting costs,
r is the rate of discount

Wickens & Greenfield Model of Perennial Crop (Coffee) Production

The FOCs:

$$\frac{\partial L}{\partial q_t^p} = (1+r)^{-t}\left(p_t^e - s_t^p\right) + \lambda_t = 0$$

$$\frac{\partial L}{\partial I_t} = (1+r)^{-t} f'(I_t) - \sum_{i=0}^{\infty} \lambda_{t+i}\delta_i = 0$$

$$\frac{\partial L}{\partial \lambda_t} = q_t^p - \sum_{i=0}^{\infty} \delta_i I_{t-i} = 0$$

$$\implies f'(I_t) = \sum_{i=0}^{\infty} (1+r)^{-i}\left(p_{t+i}^e - s_{t+i}^p\right)\delta_i$$

Investments (new plantings) are continued until the marginal cost of investing in one more tree equals NPV from the future production of that tree.

Wickens & Greenfield Model of Perennial Crop (Coffee) Production

Now need to make one assumption on functional form:

Assume $f(I_t)$ is quadratic, i.e., $f(I_t) = \alpha + \beta_0 I_t + \frac{1}{2}\beta_2 I_t^2 \implies$

$$\begin{aligned} f'(I_t) &= \;\; ?? \\ \implies I_t &= \;\; ?? \end{aligned}$$

And then begin the data problems...

The number of trees planted (I_t) is not typically observable, so we assume:

- All producers plant trees at density d
- Newly planted area (I_t^A) equals area observed at time t (A_t) minus area observed at time $t-1$ (A_{t-1}) plus area uprooted or abandoned (U_t), i.e., $I_t^A = A_t - A_{t-1} + U_t$ **why?**

Wickens & Greenfield Model of Perennial Crop (Coffee) Production

Then we arrive at an equation for observed changes in crop acreage (ΔA_t):

$$\Delta A_t = d\beta_0 + d\beta_1 R_t^e - U_t$$

Where

$$\Delta R_t^e = f'(I_t) = \sum_{i=0}^{\infty} (1+r)^{-i} \left(p_{t+i}^e - s_{t+i}^p\right) \delta_i$$

And the final estimated equation:

$$A_t = \alpha_0 + \sum_{i=1}^{m} \alpha_i A_{t-i} + \sum_{i=1}^{n} \beta_i p_{t-i} + u_t$$

How? What is Missing? What do each of the coefficients encompass?

Wickens & Greenfield Model of Perennial Crop (Coffee) Production

The Supply Functions:

$$q_t^p = \sum_{i=0}^{n} \delta_i I_{t-i}$$

$$I_t = \alpha_0 + \alpha_1 I_{t-1} + \alpha_2 p_t$$

$$q_t = \gamma_0 + \gamma_1 q_t^p + \sum_{i=0}^{m} \gamma_{i+2} p_{t-i} + \bar{\gamma} q_{t-1}$$

Where q_t is *actual* production.

Wickens & Greenfield Model of Perennial Crop (Coffee) Production

Plugging things in... we get the final reduced form supply equation:

$$q_t = \sum_{i=0}^{n} \beta_i p_{t-i} + (\bar{\gamma} + \alpha_1)\, q_{t-1} - \bar{\gamma}\alpha_1 q_{t-2} + \text{constant}$$

Where

$$\begin{aligned} \beta_i &= \gamma_2 + \alpha_2\gamma_1\delta_0 && i = 0 \\ &= \gamma_{i+2} + \alpha_2\gamma_1\delta_i - \alpha_1\gamma_{t+1} && i = 1, ..., m \\ &= \alpha_2\gamma_1\delta_{m+1} - \alpha_1\gamma_{m+1} && i = m+1 \\ &= \alpha_2\gamma_1\delta_i && i = m+2, ..., n \end{aligned}$$

Wickens & Greenfield Model of Perennial Crop (Coffee) Production

Finally, the main estimating equation:

$$q_t = \sum_{i=0}^{n+1} \beta_i^* p_{t-i} + (1 + \bar{\gamma} + \alpha_1)\, q_{t-1} - (\alpha_1 + \bar{\gamma} + \bar{\gamma}\alpha_1)\, q_{t-2} + \bar{\gamma}\alpha_1 q_{t-3}$$

Where

$$\beta_0^* = \beta_0$$

$$\beta_i^* = \beta_i - \beta_{i-1} \qquad i = 1, ..., n$$

$$\beta_{n+1} = -\beta_n$$

Why these changes? What is an Almon polynomial distributed lag? Why first differences in the coefficients?

Wickens & Greenfield Model of Perennial Crop (Coffee) Production

What are limitations to this model?

What are limitations to this model?

> *"This approach encounters several problems: (i) It is not possible to derive coefficients of the three structural equations from the reduced form. (ii) It is difficult to include non-price explanatory variables in the planting equation [if, for example, one term $\alpha_2 Z_t$ is added to the right-hand side of eq. (2) it appears as a distributed lag in eq. (4)]. (iii) The yield curves of perennial crops are not necessarily well approximated by the polynomial form used. Thus weights of lagged prices attained statistically could be quite different from the yield curve. And (iv), empirically, the sum of the coefficients for q_{t-1} and q_{t-2} seldom comes close to unity, which violates a theoretical constraint on this specification."*
>
> *(Akiyama & Trivedi 1987)*

Devadoss & Luckstead Overview

Devadoss, S. & Luckstead, J. (2010). An Analysis of Apple Supply Response. *International Journal of Production Economics*, *124*: 265–271.

Contributions – what question(s) is the paper addressing? –

Category – theoretical? empirical? case study? meta-study? –

Conclusions – what are the results? –

Context – what are related papers? who are the authors? –

Methods – what methods are used to analyze the problem? –

Devadoss & Luckstead Questions

Devadoss, S. & Luckstead, J. (2010). An Analysis of Apple Supply Response. *International Journal of Production Economics*, *124*: 265–271.

Data – what data does this paper use that prior work has not had access to? –

Context – what paper does this paper primarily borrow its conceptual framework/structural model from? –

Contributions – do you think there would be a more interesting or impactful way to frame this paper to heighten its contribution? –

Akiyama & Trivedi Model

Akiyama, T. & Trivedi, P.K. (1987). Vintage Production Approach to Perennial Crop Supply: An Application to Tea in Major Producing Countries. *Journal of Econometrics, 36*: 133–161.

> *The present paper reexamines some of the issues [to past models of perennial supplier behavior] and puts forward an alternative approach which has features absent from earlier work. For example, within our framework it becomes possible conceptually and empirically to distinguish between short-run and long-run elasticities and to identify the effects of local institutional features and incentives that play a key role in determining long-run resources. Our approach explains why supply elasticities cannot be treated as time-invariant and how the integration of the production and investment decisions of suppliers helps to understand better the supply response in total.*
>
> *(Akiyama & Trivedi)*

Akiyama & Trivedi Model

Akiyama, T. & Trivedi, P.K. (1987). Vintage Production Approach to Perennial Crop Supply: An Application to Tea in Major Producing Countries. *Journal of Econometrics*, *36*: 133–161.

> *Vintage capital frameworks allow to address the issue of replacement of obsolete capital goods and technologies. Such a mechanism was thought to generate original short and long-run dynamics compared to the traditional neoclassical growth model... Capital is non-malleable: while substitution between labor and capital is permitted ex-ante, it is not allowed once capital is installed. Capital goods embody the best available technology at the date of their construction and the number of workers operating them is "fixed by design".*
>
> *(Boucekkine, de la Croix, & Licandro 2011)*

Akiyama & Trivedi Model

Akiyama, T. & Trivedi, P.K. (1987). Vintage Production Approach to Perennial Crop Supply: An Application to Tea in Major Producing Countries. *Journal of Econometrics, 36*: 133–161.

$$Q(t) = \sum_{v} F\left[K(t, v), L(t, v)\right]$$

Where $Q(t)$ is total output,
$K(t, v)$ denotes 'capital' of vintage v used at time t,
$L(t, v)$ denotes 'labor'

Assignments for Next Time

Advanced Producer Theory and Analysis II: Optimal Planting Decisions

1. Working Paper (given in class)
2. Salo, S. & Tahvonen, O. (2001). On Equilibrium Cycles and Normal Forests in Optimal Harvesting of Tree Vintages. *Journal of Environmental Economics and Management*, *44*: 1–22. `https://www.sciencedirect.com/science/article/abs/pii/S0095069601912240`