EMPIRICAL INDUSTRIAL ORGANIZATION (ECO 310)

Fall 2022 – Victor Aguirregabiria

SOLUTION TO PROBLEM SET 1

Due on Sunday, October 2, before 11:59pm via Quercus

The total number of marks is 200.

PROBLEM 1. [70 points]. Consider an industry for an homogeneous product. Firms use capital and labor to produce output according to a Cobb-Douglas technology with parameters α_L and α_K and Total Factor Productivity (TFP) A. Suppose that firms are price takers in the input markets for labor and capital. Let W_L and W_K be the price of labor and capital, respectively.

QUESTION 1.1. (20 points). Derive the expression for the cost function of a firm $C(Y)$ as a function of output Y, the technological parameters α_L and α_K, TFP, and input prices. Explain in detail the different steps in your derivation.

ANSWER. The cost function $C(Y)$ is defined as the minimum cost of producing the amount of output Y:

$$C(Y) \quad = \quad \left[\begin{array}{c} \min\limits_{\{L,K\}} W_L\, L + W_K\, K \\ \\ \text{subject to: } Y = A\, L^{\alpha_L}\, K^{\alpha_K} \end{array} \right]$$

Or using a Lagrange representation:

$$C(Y) \quad = \quad \min_{\{\lambda,L,K\}} W_L\, L + W_K\, K + \lambda \left[Y - A\, L^{\alpha_L}\, K^{\alpha_K} \right]$$

where λ is the Lagrange multiplier of the restriction. The marginal conditions of optimality with respect to labor and capital are:

$$\left\{ \begin{array}{rcl} W_L - \lambda\, \alpha_L\, \dfrac{Y}{L} & = & 0 \\ W_K - \lambda\, \alpha_K\, \dfrac{Y}{K} & = & 0 \end{array} \right.$$

Solving for the amount of inputs, We can write these equations as:

$$\left\{ \begin{array}{rcl} L & = & \lambda\, Y\, \dfrac{\alpha_L}{W_L} \\ K & = & \lambda\, Y\, \dfrac{\alpha_K}{W_K} \end{array} \right.$$

The marginal condition of optimality with respect to λ is:

$$Y - A\, L^{\alpha_L}\, K^{\alpha_K} = 0$$

Therefore, we have the following system of three equations with three endogenous unknowns (L, K, λ):

$$\begin{cases} L &= \lambda\, Y\, \dfrac{\alpha_L}{W_L} \\ K &= \lambda\, Y\, \dfrac{\alpha_K}{W_K} \\ Y &= A\, L^{\alpha_L}\, K^{\alpha_K} \end{cases}$$

To solve this system, we plug the first two equations into the third one. We get:

$$Y \;=\; A \left(\lambda\, Y\, \frac{\alpha_L}{W_L}\right)^{\alpha_L} \left(\lambda\, Y\, \frac{\alpha_K}{W_K}\right)^{\alpha_K}$$

In this equation, the only endogenous unknown λ. Then, we solve for the endogenous λ in terms of the exogenous variables to get:

$$\lambda = A^{\frac{-1}{\alpha}}\, Y^{\frac{1-\alpha}{\alpha}} \left(\frac{W_L}{\alpha_L}\right)^{\frac{\alpha_L}{\alpha}} \left(\frac{W_K}{\alpha_K}\right)^{\frac{\alpha_K}{\alpha}}$$

with $\alpha = \alpha_L + \alpha_K$. Plugging this equation into the first order conditions for labor and capital, we have:

$$\begin{cases} W_L\, L &= \lambda\, Y\, \alpha_L = \alpha_L \left(\dfrac{Y}{A}\right)^{\frac{1}{\alpha}} \left(\dfrac{W_L}{\alpha_L}\right)^{\frac{\alpha_L}{\alpha}} \left(\dfrac{W_K}{\alpha_K}\right)^{\frac{\alpha_K}{\alpha}} \\ W_K\, K &= \lambda\, Y\, \alpha_K = \alpha_K \left(\dfrac{Y}{A}\right)^{\frac{1}{\alpha}} \left(\dfrac{W_L}{\alpha_L}\right)^{\frac{\alpha_L}{\alpha}} \left(\dfrac{W_K}{\alpha_K}\right)^{\frac{\alpha_K}{\alpha}} \end{cases}$$

Finally, by definition, the cost function $C(Y)$ is equal to the cost $W_L\, L + W_K\, K$ when inputs are chosen to minimize the cost of producing Y unit of output. Then, adding up the previous expressions for $W_L\, L$ and $W_K\, K$ we get:

$$C(Y) = \alpha \left(\frac{Y}{A}\right)^{\frac{1}{\alpha}} \left(\frac{W_L}{\alpha_L}\right)^{\frac{\alpha_L}{\alpha}} \left(\frac{W_K}{\alpha_K}\right)^{\frac{\alpha_K}{\alpha}}$$

QUESTION 1.2. (20 points). For this question 1.2, suppose that $\alpha_L = 0.5$ and $\alpha_K = 0.4$. Obtain the values of the following elasticities. Explain your answer.

- **[a.] Elasticity of cost with respect to output.**
- **[b.] Elasticity of cost with respect to TFP.**
- **[c.] Elasticity of cost with respect to the price of labor.**
- **[d.] Elasticity of cost with respect to the price of capital.**
- **[e.] Elasticity of output with respect to labor.**
- **[f.] Elasticity of output with respect to TFP.**

ANSWER. To obtain the elasticities, it is very convenient to take logarithms in both sides of the cost function to represent all the variables in logs. Remember that if we have a log-linear relationship between two variables, say A and B, such that $\log(A) = \alpha + \beta \log(B)$, the parameter β represents the elasticity of variable A with respect to variable B.

NOTE: This is not part of the answer to this question, but it is a good opportunity to prove this property of a linear in logs equation. To prove this, note that by differentiating both sides of this equation we have that:

$$d(\log(A)) \;=\; d(\alpha + \beta\ \log(B)) \;=\; \beta\, d(\log(B))$$

Taking into account the derivative of the logarithm function, we have that:

$$\frac{dA}{A} \;=\; \beta\, \frac{dB}{B}$$

Solving for β we get:

$$\beta \;=\; \frac{dA}{dB}\,\frac{B}{A}$$

which is the definition of elasticity of A with respect to B.

Applying logarithms to both sides of the cost function, we have:

$$\log(C) = \log(\alpha) + \frac{1}{\alpha}\log(Y) - \frac{1}{\alpha}\log(A) + \frac{\alpha_L}{\alpha}\log(W_L) - \frac{\alpha_L}{\alpha}\, log(\alpha_L) + \frac{\alpha_K}{\alpha}\log(W_K) - \frac{\alpha_K}{\alpha}\log(\alpha_K)$$

Similarly, applying logs to the production function.

$$\log(Y) = \log(A) + \alpha_L\ \log(L) + \alpha_K\ \log(K)$$

(a) Elasticity of cost with respect to output $= \dfrac{1}{\alpha} = \dfrac{1}{0.5 + 0.4} = 1.11.$

(b) Elasticity of cost with respect to TFP $= \dfrac{-1}{\alpha} = \dfrac{-1}{0.5 + 0.4} = -1.11.$

(c) Elasticity of cost with respect to the price of labor $= \dfrac{\alpha_L}{\alpha} = \dfrac{0.5}{0.5+0.4} = 0.55$.

(d) Elasticity of cost with respect to the price of capital $= \dfrac{\alpha_K}{\alpha} = \dfrac{0.4}{0.5+0.4} = 0.44$.

(e) Elasticity of output with respect to labor $= \alpha_L = 0.50$.

(f) Elasticity of output with respect to TFP $= 1.00$

Suppose that the output market in this industry is competitive: firms are price takers. The demand function is linear with the following form: $P = 1000 - 10\,Q$, where P is the market price of output, and Q is the aggregate output from all the firms in the market. Suppose that $\alpha_L = 0.25$ and $\alpha_K = 0.25$, and input prices are $W_L = 1$ and $W_K = 1$. Suppose also that each firm has a fixed cost (the cost of fixed land) that is exogenous and equal to 10.

NOTE. In this question, there is a third input that is land. We can consider that the production function is: $Y = A\,L^{\alpha_L}\,K^{\alpha_K}\,(Land)^{\alpha_{Land}}$. Since the Land input is the same for all the firms, we can consider, without lost of generality, that firms employ one unit of land. That is $Land = 1$ such that $Y = A\,L^{\alpha_L}\,K^{\alpha_K}\,(1)^{\alpha_{Land}} = A\,L^{\alpha_L}\,K^{\alpha_K}$. Since Land is fixed, it is not chosen optimally to minimize costs. Therefore, the fixed cost of land is $W_{Land} * Land = W_{Land} * 1$, that we assume is equal to 10. This fixed cost can be added to the cost function from labor and capital we have obtained above in Question 1.1.

QUESTION 1.3. (10 points). Taking into account the values of the parameters as established above, write the expression for the profit function of a firm (revenue minus cost) as a function of the market price of output, P, a firm's output, Y_i, and its TFP, A_i.

ANSWER. First, the total cost of firm i is now:

$$C(Y_i) = \alpha\,\left(\frac{Y_i}{A_i}\right)^{\frac{1}{\alpha}}\,\left(\frac{W_L}{\alpha_L}\right)^{\frac{\alpha_L}{\alpha}}\,\left(\frac{W_K}{\alpha_K}\right)^{\frac{\alpha_K}{\alpha}} + 10$$

where the value 10 comes from the fixed cost of Land. A firm's revenue is $P\,Y_i$. To obtain a firm's cost function, note that: $\alpha = \alpha_L + \alpha_K = 0.25 + 0.25 = 0.5$; $\dfrac{1}{\alpha} = \dfrac{1}{0.5} = 2$; $\dfrac{W_L}{\alpha_L} = \dfrac{1}{0.25} = 4$; and $\dfrac{W_K}{\alpha_K} = \dfrac{1}{0.25} = 4$. Therefore, we have:

$$C(Y_i) = 0.5\,\left(\frac{Y_i}{A_i}\right)^2\,(4)^{0.5}\,(4)^{0.5} + 10 = 2\,\left(\frac{Y_i}{A_i}\right)^2 + 10$$

Putting together the revenue and the cost function, we have the profit function:

$$\pi_i = P\,Y_i - 2\,\left(\frac{Y_i}{A_i}\right)^2 - 10$$

QUESTION 1.4. (10 points). Using the condition "price equal to marginal cost", obtain the optimal amount of output of a firm as a function of the market price, P, and the firm's TFP, A_i. Explain your derivation.

ANSWER. The marginal cost of a firm in this industry is:

$$MC_i = C'(Y_i) = 4\,\frac{Y_i}{A_i^2}$$

Therefore, the marginal condition of profit maximization is:

$$P = 4\,\frac{Y_i}{A_i^2}$$

Solving for output, we get:

$$Y_i = A_i^2\,\frac{P}{4}$$

A firm's optimal amount of output increases with market price and with its own TFP.

QUESTION 1.5. (10 points). A firm is active in the market (i.e., it offers a positive amount of output) only if its profit is greater or equal than zero. Using this condition show that a firm is active in this industry only if its TFP is greater than a threshold value that depends on market price P. Obtain the expression for this threshold value as a function of price. Explain your derivation. Interpret the result.

ANSWER. Solving the optimality condition $Y_i = A_i^2\,\frac{P}{4}$ into the profit function, we get:

$$\begin{aligned}\pi_i &= P * \frac{P}{4} * A_i^2 - 2\left(\frac{\frac{P}{4}\,A_i^2}{A_i}\right)^2 - 10\\ &= \frac{1}{8}\,(P\,A_i)^2 - 10\end{aligned}$$

Then, the condition for positive profit, $\pi_i \geq 0$, is equivalent to:

$$\frac{1}{8}\,(P\,A_i)^2 - 10 \geq 0$$

Operating in this inequality, we obtain that this condition is equivalent to $(P\,A_i)^2 \geq 80$, and to $P\,A_i \geq \sqrt{80}$. Finally, given that market price is strictly positive, the condition becomes:

$$A_i \geq \sqrt{80}/P$$

The threshold value for TFP is $\sqrt{80}/P$.

Interpretation: Only firms with TFP greater or equal than $\sqrt{80}/P$ find profitable to operate in this industry. When output price P increases (e.g., because an exogenous increase in product demand), the threshold value $\sqrt{80}/P$ declines and less efficient (lower TFP) firms decide to enter in the market. When output price P declines (e.g., because an exogenous reduction in product demand), the threshold value $\sqrt{80}/P$ increases and the less efficient (lower TFP) firms decide to exit the market such that only the most efficient firms are active. According to this condition, the average TFP in the industry is countercyclical: it declines in periods of demand expansion, and increases in periods of demand contraction.

PROBLEM 2. [130 points]. The datafile *spanish_dairy_farms.dta* contains annual information from 247 dairy farmers in the region of Asturias (Spain) between 1993 and 1998. The dataset includes information on the production of milk in physical units, the number of cows, the amount of feed, labor, and land. Consider a Cobb-Douglas function for the production of milk in terms of the following inputs: cows, feed, labor, and land.

$$MILK = A * COWS^{\alpha_C} \, FEED^{\alpha_F} \, LABOR^{\alpha_L} \, LAND^{\alpha_D}$$

Use this dataset to implement the following estimators and hypothesis tests. Provide the code in STATA and the table of estimation results.

QUESTION 2.1. (20 points).

- **QUESTION 2.1.(a) Write the production function in logarithms. Interpret it as a linear regression model.**

ANSWER. Taking logarithms in the two sides of the equation for the production function, we get:

$$m_{it} = \alpha_0 + \alpha_C \, c_{it} + \alpha_F \, f_{it} + \alpha_L \, \ell_{it} + \alpha_D \, d_{it} + \omega_{it}$$

where $m \equiv \ln(MILK)$, $c \equiv \ln(COWS)$, $f \equiv \ln(FEED)$, $\ell \equiv \ln(LABOR)$, $d \equiv \ln(LAND)$, and $\alpha_0 + \omega = \ln(A)$.

The intercept parameter α_0 represents the mean value of log-TFP $\ln(A)$. That is, $\alpha_0 = \mathbb{E}(\ln(A_{it}))$. And ω_{it} represents the deviation of log-TFP $\ln(A_{it})$ with respect to that mean. That is, $\omega_{it} = \ln(A_{it}) - \mathbb{E}(\ln(A_{it}))$. Therefore, by definition, ω_{it} is a zero mean random variable.

The slope parameters α_C, α_F, α_L, and α_D represent the causal effects on log-output of a unit change in a log-input. For instance, α_C is the causal effect on the logarithm of milk of a unit change in the logarithm of the number of cows.

- **QUESTION 2.1.(b). OLS estimator in model with time dummies. Comment the results.**

ANSWER.

CODE

```
gen m = ln(milk)
gen c = ln(cows)
gen f = ln(feed)
gen l = ln(labor)
gen d = ln(land)
reg m c f l d i.year
```

OUTPUT FROM STATA

```
. reg m c f l d i.year

      Source |       SS           df       MS      Number of obs   =     1,482
-------------+----------------------------------   F(9, 1472)      =   3304.20
       Model |  584.232785         9  64.9147539   Prob > F        =    0.0000
    Residual |   28.919066     1,472  .019646105   R-squared       =    0.9528
-------------+----------------------------------   Adj R-squared   =    0.9525
       Total |  613.151851     1,481  .414012053   Root MSE        =    .14016

------------------------------------------------------------------------------
           m | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
           c |   .6011047   .0196493    30.59   0.000     .5625611    .6396482
           f |   .4445645   .0110807    40.12   0.000     .4228287    .4663002
           l |   .0261117   .0131427     1.99   0.047     .0003314     .051892
           d |    .023508   .0112188     2.10   0.036     .0015014    .0455146
             |
        year |
        1994 |   .0168455   .0126486     1.33   0.183    -.0079658    .0416567
        1995 |   .0308689   .0127479     2.42   0.016      .005863    .0558749
        1996 |   .0289237   .0128381     2.25   0.024     .0037409    .0541066
        1997 |   .0242806   .0129171     1.88   0.060    -.0010574    .0496185
        1998 |   .0343129   .0130118     2.64   0.008     .0087894    .0598365
             |
       _cons |   4.944329   .0783404    63.11   0.000     4.790658       5.098
------------------------------------------------------------------------------
```

COMMENTS ON RESULTS

i. Not surprisingly, the technology is very intensive in cows and feed. A 100% increase in the number of cows implies a 60.1% increase in the production of milk. A 100% increase in the amount of feed implies a 44.4% increase in the production of milk.

Both effects are statistically significant at standard significant levels: p-values of the null hypothesis that the parameter is zero are smaller than 0.001 (0.1%).

ii. Labor and land have a much smaller contribution to the production of milk, with elasticities of 0.026 and 0.023, respectively. Their effects are statistically significant at 5% significance level.

iii. The R-square coefficient is quite large: these four inputs – and the time dummies – explain more than 95% of the sample variation in log-output.

iv. However, we expect this OLS estimator to be biased because endogeneity, i.e., correlation between the regressors (observed inputs) and the error term (unobserved log-TFP).

- **QUESTION 2.1.(c) Test the null hypothesis $\alpha_C + \alpha_F + \alpha_L + \alpha_D = 1$. Comment the results.**

ANSWER. This null hypothesis represents the condition that the production function has Constant Returns to Scale. Also, under this condition, the Cost Function $C(Y)$ is linear in the amount of output Y, and therefore the Marginal Cost function is constant, i.e., it does not depend on the amount of output produced.

CODE

```
test c + f + l + d = 1
```

OUTPUT FROM STATA

```
. test c + f + l + d = 1

 ( 1)  c + f + l + d = 1

       F(  1,  1472) =   57.76
            Prob > F =    0.0000
```

COMMENTS ON RESULTS

i. The sum of the parameter estimates is $\widehat{\alpha} = \widehat{\alpha}_C + \widehat{\alpha}_F + \widehat{\alpha}_L + \widehat{\alpha}_D = 0.601 + 0.444 + 0.026 + 0.023 = 1.090$, which is only slightly greater than 1.0.

ii. These parameters are quite precisely estimated such that even small deviations from the hypothesis value, 1.0, may be statistically significant. This is exactly the case, as shown in the result of the F-test. The p-value of the null hypothesis is smaller than 0.0001 (smaller than 0.01%), so that the null hypothesis is rejected under standard significance levels such as 1%.

iii. According to the result of this test, we can reject the null hypothesis of CRS in favor of Increasing Returns to Scale (IRS). Note that IRS implies that marginal cost is a decreasing function of the amount of output Y.

iv. Again, it is important to keep in mind that this OLS estimator can be biased because endogeneity. Positive correlation between observed inputs and unobserved log-TFP can generate an upward bias in our estimate of α and spurious evidence in favor of IRS.

QUESTION 2.2. (20 points).

- **QUESTION 2.2.(a) Fixed Effects estimator with time dummies. Comment results.**

ANSWER. The regression model is:

$$m_{it} = \alpha_0 + \alpha_C\, c_{it} + \alpha_F\, f_{it} + \alpha_L\, \ell_{it} + \alpha_D\, d_{it} + \gamma_t + \eta_i + u_{it}$$

where the variables are in logarithms. We eliminate the individual effect η_i by transforming the model in deviations with respect to firm-means:

$$\widetilde{m}_{it} = \alpha_C\, \widetilde{c}_{it} + \alpha_F\, \widetilde{f}_{it} + \alpha_L\, \widetilde{\ell}_{it} + \alpha_D\, \widetilde{d}_{it} + \widetilde{\gamma}_t + \widetilde{u}_{it}$$

where $\widetilde{m}_{it} = m_{it} - \overline{m}_i$, $\widetilde{c}_{it} = c_{it} - \overline{c}_i$, $\widetilde{f}_{it} = f_{it} - \overline{f}_i$, $\widetilde{\ell}_{it} = \ell_{it} - \overline{\ell}_i$, $\widetilde{d}_{it} = d_{it} - \overline{d}_i$, $\widetilde{\gamma}_t = \gamma_t - \overline{\gamma}$, and $\widetilde{u}_{it} = u_{it} - \overline{u}_i$, and the variables $\overline{m}_i$, $\overline{c}_i$, $\overline{f}_i$, $\overline{\ell}_i$, and $\overline{d}_i$, are sample means for firm i. We apply OLS to this model. We account for the time effects $\widetilde{\gamma}_t$ by including time (year) dummies: one for each year, except one.

CODE

```
xtset farm year
xtreg m c f l d i.year, fe
```

OUTPUT FROM STATA

```
. xtreg m c f l d i.year, fe

Fixed-effects (within) regression               Number of obs     =      1,482
Group variable: farm                            Number of groups  =        247

R-squared:                                      Obs per group:
     Within  = 0.8518                                         min =          6
     Between = 0.9593                                         avg =        6.0
     Overall = 0.9493                                         max =          6

                                                F(9,1226)         =     782.69
corr(u_i, Xb) = 0.4863                          Prob > F          =     0.0000

------------------------------------------------------------------------------
           m | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
           c |   .6381144   .0237788    26.84   0.000     .5914627     .684766
           f |    .308092   .0132185    23.31   0.000     .2821587    .3340254
           l |   .0348793   .0221855     1.57   0.116    -.0086466    .0784051
           d |    .041037   .0154412     2.66   0.008      .010743     .071331
             |
        year |
        1994 |   .0328663   .0071257     4.61   0.000     .0188863    .0468463
        1995 |   .0613626   .0074819     8.20   0.000     .0466839    .0760412
        1996 |   .0719311   .0080065     8.98   0.000      .056223    .0876391
        1997 |   .0752593   .0084287     8.93   0.000      .058723    .0917956
        1998 |   .0939261   .0089216    10.53   0.000     .0764227    .1114295
             |
       _cons |   6.211865    .115847    53.62   0.000     5.984584    6.439145
-------------+----------------------------------------------------------------
     sigma_u |  .14501737
     sigma_e |   .0775565
         rho |  .77759291   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(246, 1226) = 14.56                  Prob > F = 0.0000
```

COMMENTS ON RESULTS

i. Compared to the OLS estimates in Question 2.1.(b), the main change is a substantial reduction in the coefficient α_F for Feed, from 0.444 to 0.308. There is also a small increase in the parameter estimates from the other inputs.

ii. The sum of all the α parameters is now 1.021 which is smaller than the OLS estimate of 1.090 in Question 2.1.(b). This is consistent with the interpretation that the individual effects η_i generate an upward bias in the OLS estimates because they are positively correlated with observed inputs, especiall with the input Feed.

iii. As we expect, standard errors of the estimates are larger compared to the ones for

OLS estimates in Question 2.1.(b). However, the estimates of the parameters are still precise / informative.

- **QUESTION 2.2.(b) Test null hypothesis $\alpha_C + \alpha_F + \alpha_L + \alpha_D = 1$. Comment results.**

ANSWER. Again, this null hypothesis corresponds to the condition for CRS.

CODE

```
test c + f + l + d = 1
```

OUTPUT FROM STATA

```
. test c + f + l + d = 1

 ( 1)  c + f + l + d = 1

       F(  1,  1226) =    0.52
            Prob > F =    0.4702
```

COMMENTS ON RESULTS

i. The sum of the parameter estimates is $\widehat{\alpha} = \widehat{\alpha}_C + \widehat{\alpha}_F + \widehat{\alpha}_L + \widehat{\alpha}_D = 0.638 + 0.308 + 0.034 + 0.041 = 1.021$, which is only slightly greater than 1.0.

ii. The F-test provides a p-value of the null hypothesis equal to 0.470. This is pretty large p-value, and much larger than standard significance levels such as 1%, 5%, or 10%. Therefore, this test shows strong evidence in support of the null hypothesis of CRS.

iii. CRS (or DRS) is more plausible than IRS. This result is consistent with the conjecture that the unobserved individual effects η_i create an endogeneity problem, upward bias in OLS estimates, and spurious evidence in favor of IRS.

- **QUESTION 2.2.(c) Test the null hypothesis of no time-invariant unobserved heterogeneity: $\eta_i = 0$ for every firm i. Comment the results.**

ANSWER. The test of the null hypothesis of no time-invariant unobserved heterogeneity ($\eta_i = 0$ for every firm i) is the F-test at the bottom of the table of "xtreg ... , fe" estimates. The p-value of this test is practically zero. Therefore, we clearly reject the null hypothesis of no time-invariant unobserved heterogeneity.

QUESTION 2.3. (30 points).

- **QUESTION 2.3.(a) Fixed Effects - Cochrane-Orcutt estimator with time dummies. Comment the results.**

ANSWER. We apply the Cochrane-Orcutt estimator to eliminate endogeneity problems due to the serial correlation in the transitory shock u_{it}. Suppose that u_{it} follows an AR(1) process such that $u_{it} = \rho\ u_{it-1} + a_{it}$, where a_{it} is not serially correlated. The term u_{it-1} can be known to the farmer when choosing inputs at period t, and therefore it can be correlated with observed inputs.

We can obtain a quasi-first difference transformation of the model (equation at period t minus ρ times equation at period $t-1$). This implies the following equation:

$$m_{it} = \beta_1\ m_{i,t-1} + \beta_2\ c_{it} + \beta_3\ c_{i,t-1} + \beta_4\ f_{it} + \beta_5\ f_{i,t-1} + \beta_6\ \ell_{it} + \beta_7\ \ell_{i,t-1} + \beta_8\ d_{it} + \beta_9\ d_{i,t-1} + \eta_i^* + \gamma_t^* + a_{it}$$

with $\beta_1 = \rho$, $\beta_2 = \alpha_C$, $\beta_3 = -\rho\alpha_C$, $\beta_4 = \alpha_F$, $\beta_5 = -\rho\alpha_F$, $\beta_6 = \alpha_L$, $\beta_7 = -\rho\alpha_L$, $\beta_8 = \alpha_D$, $\beta_9 = -\rho\alpha_D$. The FE Cochrane-Orcutt estimator is the FE estimator in this equation. Or equivalently, it is the OLS estimator in the following equation in deviations with respect to firm-specific means:

$$\widetilde{m}_{it} = \beta_1\ \widetilde{m}_{i,t-1} + \beta_2\ \widetilde{c}_{it} + \beta_3\ \widetilde{c}_{i,t-1} + \beta_4\ \widetilde{f}_{it} + \beta_5\ \widetilde{f}_{i,t-1} + \beta_6\ \widetilde{\ell}_{it} + \beta_7\ \widetilde{\ell}_{i,t-1} + \beta_8\ \widetilde{d}_{it} + \beta_9\ \widetilde{d}_{i,t-1} + \widetilde{\gamma}_t^* + \widetilde{a}_{it}$$

CODE

```
xtreg m l.m c l.c f l.f l l.l d l.d i.year, fe
```

OUTPUT FROM STATA

```
. xtreg m l.m c l.c f l.f l l.l d l.d i.year, fe

Fixed-effects (within) regression               Number of obs      =      1,235
Group variable: farm                            Number of groups   =        247

R-squared:                                      Obs per group:
     Within  = 0.8176                                         min =          5
     Between = 0.9701                                         avg =        5.0
     Overall = 0.9607                                         max =          5

                                                F(13,975)          =     336.12
corr(u_i, Xb) = 0.6356                          Prob > F           =     0.0000

------------------------------------------------------------------------------
           m | Coefficient  Std. err.      t    P>|t|     [95% conf. interval]
-------------+----------------------------------------------------------------
           m |
         L1. |   .1168351   .0307641     3.80   0.000     .0564636    .1772066
             |
           c |
         --. |   .5971121   .0279707    21.35   0.000     .5422225    .6520018
         L1. |  -.0936723   .0335423    -2.79   0.005    -.1594957   -.0278489
             |
           f |
         --. |   .2705934   .0147769    18.31   0.000     .2415953    .2995915
         L1. |   .0202181   .0167341     1.21   0.227     -.012621    .0530572
             |
           l |
         --. |    .042604   .0251035     1.70   0.090    -.0066591    .0918671
         L1. |  -.0628986   .0273874    -2.30   0.022    -.1166436   -.0091535
             |
           d |
         --. |   .0345773   .0165979     2.08   0.037     .0020057     .067149
         L1. |   .0198115    .018085     1.10   0.274    -.0156786    .0553016
             |
        year |
       1995  |   .0230554   .0067789     3.40   0.001     .0097525    .0363583
       1996  |   .0302282   .0075446     4.01   0.000     .0154226    .0450338
       1997  |   .0325802   .0083558     3.90   0.000     .0161828    .0489776
       1998  |   .0505107   .0090447     5.58   0.000     .0327614    .0682599
             |
       _cons |   5.483237   .2418905    22.67   0.000     5.008551    5.957923
-------------+----------------------------------------------------------------
     sigma_u |  .14484609
     sigma_e |  .07170482
         rho |  .80317024   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0: F(246, 975) = 3.27                    Prob > F = 0.0000
```

COMMENTS ON RESULTS

i. The estimate of ρ (or equivalently, of β_1) is significantly different to zero. Therefore, there is evidence of serial correlation in the transitory shock.

ii. Compared to the Fixed Effect estimates in Question 2.2.(a), we see a substantial decline in the estimates of parameters α_C (0.597 compared to 0.638) and α_F (0.270 compared to 0.308). This is consistent with the conjecture that serial correlation in the transitory shock generates an endogeneity problem and an upward bias in parameter estimates.

iii. The sum of all the α parameters is now 0.943, which is smaller than the Fixed Effects estimate of 0.943 in Question 2.2.(a). Again, this is consistent with the interpretation that serial correlation in u_{it} generates an upward bias in the OLS estimates because they are positively correlated with $u_{i,t-1}$.

iv. The test of the null hypothesis of no time-invariant unobserved heterogeneity ($\eta_i = 0$ for every firm i) – the F-test at the bottom of the table of estimates – has a p-value practically equal to zero, and therefore, it clearly rejects the null hypothesis of no time-invariant unobserved heterogeneity.

- **QUESTION 2.3.(b) Test null hypothesis $\alpha_C + \alpha_F + \alpha_L + \alpha_D = 1$. Comment results.**

ANSWER. This null hypothesis corresponds to the condition for CRS.

CODE

```
test c + f + l + d = 1
```

OUTPUT FROM STATA

```
. test c + f + l + d = 1

 ( 1)  c + f + l + d = 1

       F(  1,   975) =    2.25
            Prob > F =    0.1336
```

COMMENTS ON RESULTS

i. The sum of the parameter estimates is $\widehat{\alpha} = \widehat{\alpha}_C + \widehat{\alpha}_F + \widehat{\alpha}_L + \widehat{\alpha}_D = \widehat{\beta}_2 + \widehat{\beta}_4 + \widehat{\beta}_6 + \widehat{\beta}_8 = 0.597 + 0.270 + 0.042 + 0.034 = 0.943$, which is smaller than 1.0.

ii. The F-test provides a p-value of the null hypothesis equal to 0.133. This is larger than standard significance levels such as 1%, 5%, or 10%. Therefore, this test shows evidence in support of the null hypothesis of CRS.

- **QUESTION 2.3.(c) Test the four over-identifying restrictions of the model. Comment the results.**

ANSWER. The model implies four restrictions on the parameter estimates β:

$$\beta_1 = -\beta_3/\beta_2 \quad ; \quad \beta_1 = -\beta_5/\beta_4 \quad ; \quad \beta_1 = -\beta_7/\beta_6 \quad ; \quad \beta_1 = -\beta_9/\beta_8$$

We can test these nonlinear restrictions jointly using the command "testnl" in Stata.

CODE.

```
testnl (_b[l.m] = -_b[l.c]/_b[c]) (_b[l.m] = -_b[l.f]/_b[f]) (_b[l.m] = -_b[l.l]/_b[l])
(_b[l.m] = -_b[l.d]/_b[d])
```

OUTPUT FROM STATA

```
. testnl (_b[l.m] = -_b[l.c]/_b[c]) (_b[l.m] =
> -_b[l.f]/_b[f]) (_b[l.m] = -_b[l.l]/_b[l])  (
> _b[l.m] = -_b[l.d]/_b[d])

  (1)  _b[l.m] = -_b[l.c]/_b[c]
  (2)  _b[l.m] = -_b[l.f]/_b[f]
  (3)  _b[l.m] = -_b[l.l]/_b[l]
  (4)  _b[l.m] = -_b[l.d]/_b[d]

              chi2(4) =       16.50
        Prob > chi2 =        0.0024
```

COMMENTS ON RESULTS

i. The p-value of the test is 0.0024, or equivalently 0.24%. This is smaller than the usual significance levels of 1% or 5%. Therefore, using this significance levels we would reject the null hypothesis of these restrictions.

ii. However, the evidence on these restrictions is mixed. If tests each restriction separately we get the following p-values:

`testnl (_b[l.m] = -_b[l.c]/_b[c])` has p-value = 0.3665.

`testnl (_b[l.m] = -_b[l.f]/_b[f])` has p-value = 0.0004.

`testnl (_b[l.m] = -_b[l.l]/_b[l])` has p-value = 0.1923.

`testnl (_b[l.m] = -_b[l.d]/_b[d])` has p-value = 0.2762.

There is strong support for 3 of the 4 restrictions.

QUESTION 2.4. (20 points).

- **QUESTION 2.4.(a) Arellano-Bond estimator with time dummies and non-serially correlated transitory shock. Comment the results.**

ANSWER. We estimate the model in first differences:

$$\Delta m_{it} = \alpha_C \, \Delta c_{it} + \alpha_F \, \Delta f_{it} + \alpha_L \, \Delta \ell_{it} + \alpha_D \, \Delta d_{it} + \Delta \gamma_t + \Delta u_{it}$$

using as instruments m_{it-2}, c_{it-2}, ℓ_{it-2}, d_{it-2}, and also lags of these variables before $t-2$. These instruments are valid only if u_{it} is not serially correlated, or what is equivalent, if Δu_{it} is serially correlated of first-order but not of second order or higher.

CODE. To implement this estimator, we can use the Stata command `xtabond`. First, note that you need to install this command in Stata using the following line of code:

```
ssc install xtabond2
```

Somme comments on the syntax of the `xtabond2` command.

[i.] Though the model is estimated in first differences, the syntax of the `xtabond` command is such that the dependent and explanatory variables are input in levels, i.e., `m c f l d`.

[ii.] The part `gmm(., lag())` of the command determines the set instruments. We use lags $t-2$ and further of log-milk, lof-cows, log-feed, log-labor, and log-land: `gmm(m c f l d, lag(2 .))`

[iii.] The part `iv()` of the command determines the regressors which are exogenous, in our case only the time dummies: `iv(i.year)`

[iv.] We use the option `noleveleq` to choose the Arellano-Bond estimator (the default of this command is the System GMM estimator).

[v.] We use the option `robust` to obtain standard errors that are robust of serial correlation and heteroscedasticity.

```
xtabond2 m c f l d i.year, gmm(m c f l d, lag(2 .))  iv(i.year) robust noleveleq
```

OUTPUT FROM STATA

```
. xtabond2 m c f l d i.year, gmm(m c f l d, lag(2 .)) iv(i.year) robust noleveleq
Favoring space over speed. To switch, type or click on mata: mata set matafavor speed,
1993b.year dropped due to collinearity
Warning: Two-step estimated covariance matrix of moments is singular.
  Using a generalized inverse to calculate robust weighting matrix for Hansen test.
  Difference-in-Sargan/Hansen statistics may be negative.

Dynamic panel-data estimation, one-step difference GMM
------------------------------------------------------------------------------
Group variable: farm                            Number of obs      =      1235
Time variable : year                            Number of groups   =       247
Number of instruments = 55                      Obs per group: min =         5
Wald chi2(0)  =         .                                      avg =      5.00
Prob > chi2   =         .                                      max =         5
------------------------------------------------------------------------------
             |               Robust
           m | Coefficient  std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
           c |   .4458857   .1275443     3.50   0.000     .1959034     .695868
           f |   .2568898   .0684461     3.75   0.000     .1227379    .3910417
           l |   .0586217   .0656332     0.89   0.372    -.0700169    .1872603
           d |   .0429985   .0624748     0.69   0.491    -.0794498    .1654469
             |
        year |
        1994 |   .0478243    .011832     4.04   0.000      .024634    .0710145
        1995 |   .0874454   .0198401     4.41   0.000     .0485595    .1263313
        1996 |   .1147483   .0291529     3.94   0.000     .0576096     .171887
        1997 |   .1289608    .033991     3.79   0.000     .0623397     .195582
        1998 |   .1566481   .0402553     3.89   0.000     .0777491     .235547
------------------------------------------------------------------------------
Instruments for first differences equation
  Standard
    D.(1993b.year 1994.year 1995.year 1996.year 1997.year 1998.year)
  GMM-type (missing=0, separate instruments for each period unless collapsed)
    L(2/5).(m c f l d)
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =  -4.80  Pr > z =  0.000
Arellano-Bond test for AR(2) in first differences: z =  -0.53  Pr > z =  0.599
------------------------------------------------------------------------------
Sargan test of overid. restrictions: chi2(46)   = 117.47  Prob > chi2 =  0.000
  (Not robust, but not weakened by many instruments.)
Hansen test of overid. restrictions: chi2(46)   =  62.89  Prob > chi2 =  0.049
  (Robust, but weakened by many instruments.)
```

COMMENTS ON RESULTS

i. Relative to the Fixed Effect + Cochrane-Orcutt estimates, Arellano-Bond estimates of parameters α_C and α_F are substantially smaller. This is consistent with the argument that there is still some bias in the FE-CO which is corrected using instrumental variables.

ii. However, relative to the Fixed Effect + Cochrane-Orcutt estimates, Arellano-Bond estimates are much less precise: standard errors are substantially larger, and confidence intervals much wider. The estimates seem less informative than FE-CO.

iii. The test of serial correlation "Arellano-Bond test for AR(2) in first differences" tests for the null hypothesis $E(\Delta u_{it}\ \Delta u_{it-2}) = 0$. The p-value of this test is 0.599. There is strong support for the null hypothesis. According to this test, there is no evidence of serial correlation in u_{it}, such that instruments m_{it-2}, c_{it-2}, f_{it-2}, ℓ_{it-2}, and d_{it-2} are valid.

iv. According to Hansen test, the null hypothesis of the validity of the over-identifying restrictions (more instruments than endogenous variables) has a p-value of 4.9%, which provides additional support for this estimator.

v. In summary, the estimates make economic sense, and the specification tests support the validity of the instruments. However, the estimates are very imprecise.

- **QUESTION 2.4.(b) Test null hypothesis $\alpha_C + \alpha_F + \alpha_L + \alpha_D = 1$. Comment results.**

ANSWER. This null hypothesis corresponds to the condition for CRS.

CODE

```
test c + f + l + d = 1
```

OUTPUT FROM STATA

```
. test c + f + l + d = 1

 ( 1)  c + f + l + d = 1

           chi2(  1) =    2.22
         Prob > chi2 =    0.1362
```

COMMENTS ON RESULTS

i. The sum of the parameter estimates is $\widehat{\alpha} = \widehat{\alpha}_C + \widehat{\alpha}_F + \widehat{\alpha}_L + \widehat{\alpha}_D = 0.445 + 0.256 + 0.058 + 0.042 = 0.801$, which is substantially smaller than 1.0.

ii. The F-test provides a p-value of the null hypothesis equal to 0.136. This is larger than the standard significance levels such as 1%, 5%, or 10%. Therefore, this test shows evidence in support of the null hypothesis of CRS.

iii. However, the main reason why we cannot reject the null hypothesis of CRS in favor of DRS is because these IV estimates are very imprecise.

QUESTION 2.5. (30 points).

- **QUESTION 2.5.(a) Arellano-Bond estimator with time dummies and AR(1) transitory shock. Comment the results.**

ANSWER. Suppose that u_{it} follows an AR(1) process such that $u_{it} = \rho\, u_{it-1} + a_{it}$, where a_{it} is not serially correlated. Since the transitory shock u_{it} is serially correlated, the Arellano-Bond instruments are not valid in the equation in first differences. However, we can transform the model taking a quasi-first difference (as we did for the Cochrane-Orcutt) estimator, such that we can obtain a model where the "new" transitory shock is a_{it}, which is not serially correlated. The model after the quasi-first difference is:

$$m_{it} = \beta_1\, m_{i,t-1} + \beta_2\, c_{it} + \beta_3\, c_{i,t-1} + \beta_4\, f_{it} + \beta_5\, f_{i,t-1} + \beta_6\, \ell_{it} + \beta_7\, \ell_{i,t-1} + \beta_8\, d_{it} + \beta_9\, d_{i,t-1} + \eta_i^* + \gamma_t^* + a_{it}$$

with $\beta_1 = \rho$, $\beta_2 = \alpha_C$, $\beta_3 = -\rho\alpha_C$, $\beta_4 = \alpha_F$, $\beta_5 = -\rho\alpha_F$, $\beta_6 = \alpha_L$, $\beta_7 = -\rho\alpha_L$, $\beta_8 = \alpha_D$, $\beta_9 = -\rho\alpha_D$. Then, in this model we can apply first differences. The equation that we estimate is:

$$\Delta m_{it} = \beta_1 \Delta m_{i,t-1} + \beta_2 \Delta c_{it} + \beta_3 \Delta c_{i,t-1} + \beta_4 \Delta f_{it} + \beta_5 \Delta f_{i,t-1} + \beta_6 \Delta \ell_{it} + \beta_7 \Delta \ell_{i,t-1} + \beta_8 \Delta d_{it} + \beta_9 \Delta d_{i,t-1} + \Delta$$

We estimate this model using a instrumental variables (GMM) estimator using as instruments m_{it-2}, c_{it-2}, f_{it-2}, ℓ_{it-2}, d_{it-2}, and lags before $t-2$. Note that these instruments are valid in this transformed model.

CODE. To implement this estimator, we can use the command `xtabond2`. The only difference with respect to the code in Question 2.4.(a) is in the set of regressors. Now, we need to include the first lags of m, c, f, ℓ, and d as regressors. The set of instruments is the same, and the other options of the command are also the same. Remember that in the syntax of this command the variables are input in levels though the estimation is in first differences (the command makes the transformation for us).

```
xtabond2 m l.m c l.c f l.f l l.l d l.d i.year, gmm(m c f l d, lag(2 .))  iv(i.year)
robust noleveleq
```

OUTPUT FROM STATA

```
. xtabond2 m l.m c l.c f l.f l l.l d l.d i.year, gmm(m c f l d, lag(2 .)) iv(i.year) robust noleveleq
Favoring space over speed. To switch, type or click on mata: mata set matafavor speed, perm.
1993b.year dropped due to collinearity
1998.year dropped due to collinearity
Warning: Two-step estimated covariance matrix of moments is singular.
  Using a generalized inverse to calculate robust weighting matrix for Hansen test.
  Difference-in-Sargan/Hansen statistics may be negative.

Dynamic panel-data estimation, one-step difference GMM
------------------------------------------------------------------------------
Group variable: farm                            Number of obs      =       988
Time variable : year                            Number of groups   =       247
Number of instruments = 54                      Obs per group: min =         4
Wald chi2(0)  =         .                                      avg =      4.00
Prob > chi2   =         .                                      max =         4
------------------------------------------------------------------------------
             |               Robust
           m | Coefficient  std. err.      z    P>|z|     [95% conf. interval]
-------------+----------------------------------------------------------------
           m |
         L1. |   .2969986   .0695288     4.27   0.000     .1607246    .4332726
             |
           c |
         --. |   .5554785   .1435523     3.87   0.000     .2741211    .8368359
         L1. |  -.1969684   .1203653    -1.64   0.102    -.4328801    .0389432
             |
           f |
         --. |   .2394646   .0665232     3.60   0.000     .1090815    .3698476
         L1. |  -.0008452   .0342317    -0.02   0.980     -.067938    .0662477
             |
           l |
         --. |   .0377628   .0694506     0.54   0.587    -.0983579    .1738836
         L1. |  -.0704425   .0763357    -0.92   0.356    -.2200576    .0791727
             |
           d |
         --. |    .025434   .0568726     0.45   0.655    -.0860342    .1369022
         L1. |   .0229353   .0260171     0.88   0.378    -.0280573    .0739279
             |
        year |
       1994  |  -.0384685   .0326928    -1.18   0.239    -.1025451    .0256081
       1995  |  -.0215207   .0243181    -0.88   0.376    -.0691832    .0261419
       1996  |  -.0181296   .0154473    -1.17   0.241    -.0484058    .0121467
       1997  |  -.0178497   .0094993    -1.88   0.060     -.036468    .0007686
------------------------------------------------------------------------------
Instruments for first differences equation
  Standard
    D.(1993b.year 1994.year 1995.year 1996.year 1997.year 1998.year)
  GMM-type (missing=0, separate instruments for each period unless collapsed)
    L(2/5).(m c f l d)
------------------------------------------------------------------------------
Arellano-Bond test for AR(1) in first differences: z =  -6.12  Pr > z =  0.000
Arellano-Bond test for AR(2) in first differences: z =   0.93  Pr > z =  0.354
------------------------------------------------------------------------------
Sargan test of overid. restrictions: chi2(41)   =  80.00  Prob > chi2 =  0.000
  (Not robust, but not weakened by many instruments.)
Hansen test of overid. restrictions: chi2(41)   =  51.16  Prob > chi2 =  0.133
  (Robust, but weakened by many instruments.)
```

COMMENTS ON RESULTS

i. The estimate of ρ (equivalently, β_1) is significantly greater than zero. There is evidence of positive correlation in the transitory shock.

ii. Parameter estimates make economic sense. But as for the previous Arellano-Bond estimator, the are not very precisely estimated.

iii. The test of serial correlation "Arellano-Bond test for AR(2) in first differences" tests for the null hypothesis $E(\Delta a_{it}\ \Delta a_{it-2}) = 0$. The p-value of this test is 0.354. The null hypothesis cannot be rejected using the standard significance levels (i.e., p-value is greater than 10%). This implies that we cannot reject that a_{it} is not serially correlated, and therefore that the instruments are valid.

iv. Hansen test of over-identifying restrictions from having more instruments than parameters β has a p-value of 0.354. There is strong evidence in favor of the validity of the instruments.

- **QUESTION 2.5.(b) Test null hypothesis $\alpha_C + \alpha_F + \alpha_L + \alpha_D = 1$. Comment results.**

ANSWER. This null hypothesis corresponds to the condition for CRS.

CODE

```
test c + f + l + d = 1
```

OUTPUT FROM STATA

```
. test c + f + l + d = 1

 ( 1)  c + f + l + d = 1

           chi2(  1) =    0.87
         Prob > chi2 =    0.3521
```

COMMENTS ON RESULTS

i. The sum of the parameter estimates is $\widehat{\alpha} = \widehat{\alpha}_C + \widehat{\alpha}_F + \widehat{\alpha}_L + \widehat{\alpha}_D = 0.555 + 0.239 + 0.037 + 0.025 = 0.856$, which is substantially smaller than 1.0.

ii. The F-test provides a p-value of the null hypothesis equal to 0.352. This is larger than the standard significance levels such as 1%, 5%, or 10%. Therefore, this test shows evidence in support of the null hypothesis of CRS.

iii. However, the main reason why we cannot reject the null hypothesis of CRS in favor of DRS is because these IV estimates are very imprecise.

- **QUESTION 2.5.(c) Test the four over-identifying restrictions of the model. Comment the results.**

ANSWER. The model implies four restrictions on the parameter estimates β:

$$\beta_1 = -\beta_3/\beta_2 \quad ; \quad \beta_1 = -\beta_5/\beta_4 \quad ; \quad \beta_1 = -\beta_7/\beta_6 \quad ; \quad \beta_1 = -\beta_9/\beta_8$$

We can test these nonlinear restrictions jointly using the command "testnl" in Stata.

CODE.

```
testnl (_b[l.m] = -_b[l.c]/_b[c]) (_b[l.m] = -_b[l.f]/_b[f]) (_b[l.m] = -_b[l.l]/_b[l])
(_b[l.m] = -_b[l.d]/_b[d])
```

OUTPUT FROM STATA

```
. testnl (_b[l.m] = -_b[l.c]/_b[c]) (_b[l.m] = -_b[l.
> f]/_b[f]) (_b[l.m] = -_b[l.l]/_b[l])  (_b[l.m] = -_
> b[l.d]/_b[d])

  (1)  _b[l.m] = -_b[l.c]/_b[c]
  (2)  _b[l.m] = -_b[l.f]/_b[f]
  (3)  _b[l.m] = -_b[l.l]/_b[l]
  (4)  _b[l.m] = -_b[l.d]/_b[d]

              chi2(4) =        4.33
          Prob > chi2 =        0.3627
```

COMMENTS ON RESULTS

i. The p-value of the test is 0.3627, or equivalently 36.27%. This is much larger than the usual significance levels of 1% or 5%. Therefore, using this significance levels we cannot reject the null hypothesis of these restrictions. In fact, there is strong support in favor of these restrictions.

QUESTION 2.6. (10 points). Based on the previous results, select your preferred estimates of the production function. Explain your choice.

ANSWER. The different specification tests provide strong support for the Arellano-Bond estimator with AR(1) error. In that sense, this is the estimator that better deals with simultaneity / endogeneity problems, and the specification tests support the assumptions and the validity of the instrumental variables. Howeverm, these parameter estimates are quite imprecise. If a researcher weights more the precision of the estimates, then the FE-CO estimator seems also a reasonable choice.

*** NOTE. Here it is not so important which estimator you choose, but the arguments you use to select that estimator.

DO FILE

```
clear
// ————————————————————————
// eco310_problem_set_1_question_2_2022.do
// Victor Aguirregabiria
// October 2, 2022
// ————————————————————————

// ————————————————————————
// 1. Reading data
// ————————————————————————

// In Line 15 of this code, the replicator needs to specify
// the folder address where the Stata datafile is located

cd "folder address"
use "spanish_dairy_farms.dta"

// ————————————————————————
// 2. Opening log file to copy results
// ————————————————————————

capture log close
// In Line 27 of this code, the replicator needs to specify
// the folder address where the log file with the results
// will be saved

cd "folder address"
log using "eco310_problem_set_1_question_2_2022.log", replace

// ————————————————————————
// 3. Construction of variables
// ————————————————————————

gen m = ln(milk)
gen c = ln(cows)
gen f = ln(feed)
gen l = ln(labor)
gen d = ln(land)

// ————————————————————————————————
// 4. Question 2.1(b): OLS estimator with time dummies
// ————————————————————————————————

reg m c f l d i.year
```

```
// ————————————————————————————————
// 5. Question 2.1(c): Test of Constant Returns to Scale
// based on OLS estimation
// ————————————————————————————————

test c + f + l + d = 1

// ————————————————————————————————————————-
// 6. Question 2.2(a): Fixed Effects estimator with time dummies
// ————————————————————————————————————————-

xtset farm year
xtreg m c f l d i.year, fe

// ————————————————————————————————————————-
// 7. Question 2.2(b): Test of Constant Returns to Scale
// based on Fixed Effects estimation
// ————————————————————————————————————————-

test c + f + l + d = 1

// ————————————————————————————————————————-
// 8. Question 2.3(a): Fixed Effects - Cochrane-Orcutt estimation
// ————————————————————————————————————————-

xtreg m l.m c l.c f l.f l l.l d l.d i.year, fe

// ————————————————————————————————
// 9. Question 2.3(b): Test of Constant Returns to Scale
// based on Fixed Effects - Cochrane-Orcutt estimation
// ————————————————————————————————

test c + f + l + d = 1

// ————————————————————————————————————————-
// 10. Question 2.3(c): Test of Over-Indentifying Restrictions
// in Cochrane-Orcutt estimation
// ————————————————————————————————————————-

testnl (_b[l.m] = -_b[l.c]/_b[c]) (_b[l.m] = -_b[l.f]/_b[f]) (_b[l.m] = -_b[l.l]/_b[l]) (_b[l.m]
= -_b[l.d]/_b[d])

// ————————————————————————
// 11. Question 2.4(a): Arellano-Bond: No AR(1)
// ————————————————————————

xtabond2 m c f l d i.year, gmm(m c f l d, lag(2 .)) iv(i.year) robust noleveleq
```

```
// ————————————————————————————————
// 12. Question 2.4(b): Test of Constant Returns to Scale
// based on Arellano-Bond-No AR(1) estimation
// ————————————————————————————————

test c + f + l + d = 1

// ————————————————————————————
// 13. Question 2.5(a): Arellano-Bond: AR(1)
// ————————————————————————————

xtabond2 m l.m c l.c f l.f l l.l d l.d i.year, gmm(m c f l d, lag(2 .)) iv(i.year) robust noleveleq

// ————————————————————————————————
// 14. Question 2.5(b): Test of Constant Returns to Scale
// based on Arellano-Bond-AR(1) estimation
// ————————————————————————————————

test c + f + l + d = 1

// ————————————————————————————————————-
// 15. Question 2.5(c): Test of Over-Indentifying Restrictions
// in AR(1) transformation
// ————————————————————————————————————-

testnl (_b[l.m] = -_b[l.c]/_b[c]) (_b[l.m] = -_b[l.f]/_b[f]) (_b[l.m] = -_b[l.l]/_b[l]) (_b[l.m] = -_b[l.d]/_b[d])

log close
```