Empirical Analysis of the Role of Energy in Economic Growth

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Abstract

*********** Add abstract ***********

Keywords: economic growth, energy, cobb-douglas, CES, LINEX

Caleb, put your LaTeX code here.

1. Cobb-Douglas Without Energy

Table 1: Cobb-Douglas parameters for 1980-2011 (US, UK, JP) or 1991-2011 (others). (Parameter estimates beneath symbol. 95% confidence bounds to left and right.)

		λ			α			β	
US	0.0087	0.0102	0.0116	0.21	0.27	0.34	0.66	0.73	0.79
UK	-0.0104	0.0097	0.0303	-0.25	0.44	1.12	-0.13	0.56	1.24
JP	0.0014	0.0048	0.0081	0.44	0.52	0.61	0.39	0.48	0.56
CN	-0.0405	0.0188	0.0779	0.11	0.71	1.32	-0.32	0.29	0.89
ZA	-0.0007	0.0008	0.0022	0.46	0.60	0.73	0.26	0.40	0.54
SA	-0.0159	-0.0123	-0.0087	0.21	0.45	0.68	0.32	0.55	0.78
IR	0.0032	0.0039	0.0045	0.49	0.60	0.70	0.30	0.40	0.51
TZ	-0.0039	0.0015	0.0068	0.50	0.73	0.95	0.05	0.27	0.50
ZM	0.0218	0.0249	0.0280	1.25	1.41	1.57	-0.57	-0.41	-0.25

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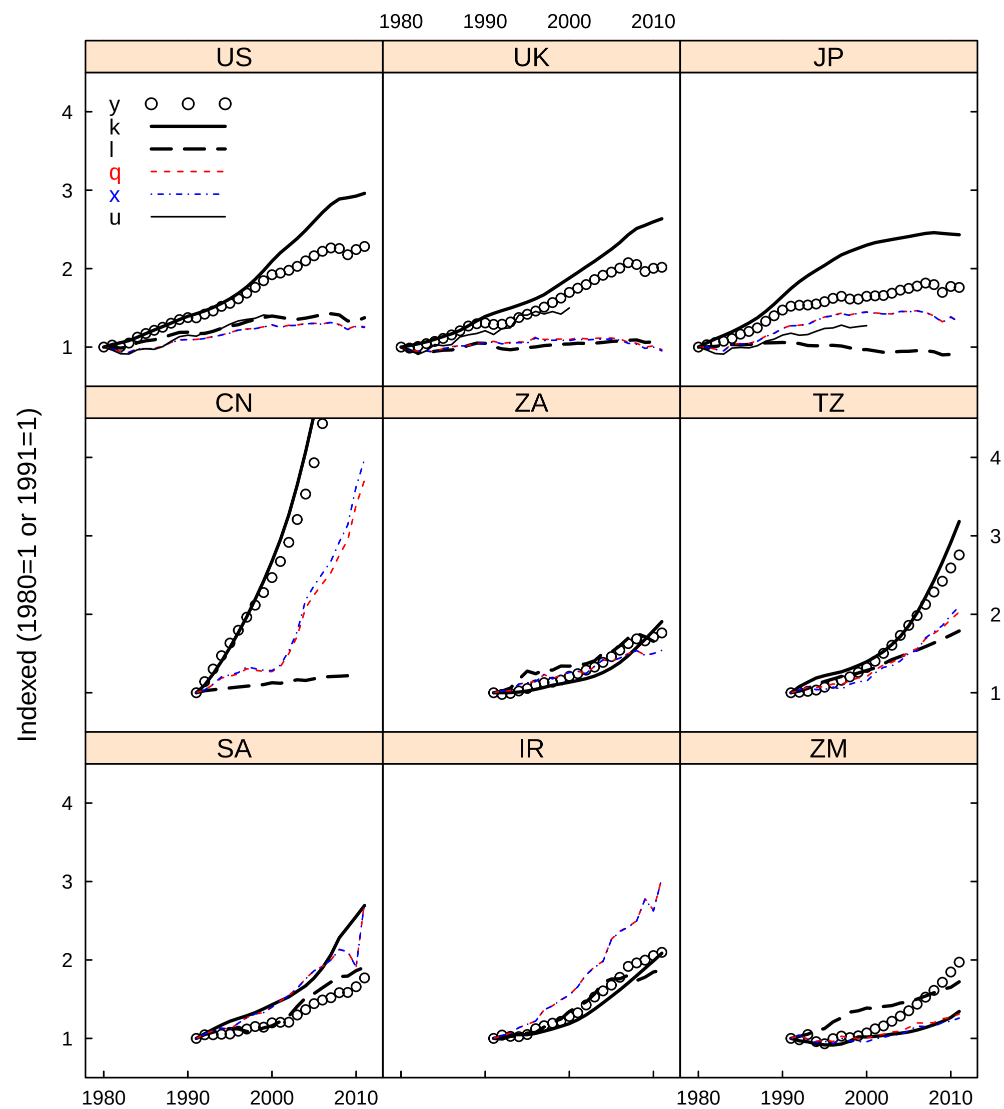

Figure 1: GDP (y), capital stock (k), labor (l), thermal energy (q), exergy (x), and useful work (u) for all economies. (China's indexed GDP and indexed capital stock rise to $y = 7.3$ and $k = 9.2$ in 2011.)

```r
usModel <- cobbDouglasModel("US")
coefs <- coef(usModel)
print(coef(usModel))
```

```
 lambda   alpha
0.01016 0.27418
```

```r
usPred <- predict(usModel)
class(usPred)
```

```
[1] "numeric"
```

```r
print(usPred)
```

```
 [1] 1.000 1.021 1.026 1.057 1.119 1.162 1.196 1.244 1.296 1.348 1.375
[12] 1.383 1.408 1.458 1.520 1.579 1.628 1.702 1.772 1.844 1.912 1.941
[23] 1.963 1.997 2.058 2.128 2.204 2.260 2.281 2.215 2.241 2.323
```

```r
data.frame(usPred)
```

```
   usPred
1   1.000
2   1.021
3   1.026
4   1.057
5   1.119
6   1.162
7   1.196
8   1.244
9   1.296
10  1.348
11  1.375
12  1.383
13  1.408
14  1.458
15  1.520
16  1.579
17  1.628
```

```
18  1.702
19  1.772
20  1.844
21  1.912
22  1.941
23  1.963
24  1.997
25  2.058
26  2.128
27  2.204
28  2.260
29  2.281
30  2.215
31  2.241
32  2.323
```

2. Cobb-Douglas With Energy

We can force α, β, and γ to be in $[0,1]$ by a reparameterization:

$$a \in [0,1], b \in [0,1], \alpha = \min(a,b), \beta = |b-a|, \gamma = 1 - \max(a,b)$$

2.1. Cobb-Douglas with Q

```
# Note that the anlaysis of ZA is taking a long time here. Need to figure out why.
CDqTables <- lapply(countries, cobbDouglasEnergyTable, energyType="Q")
```

```
print(CDqTables[["US"]], caption.placement="top")
print(CDqTables[["ZA"]], caption.placement="top")
# According to http://cran.r-project.org/web/packages/xtable/vignettes/xtableGalle
# be able to use the "sanitize.text.function" parameter to allow markup in column
# line is not working at the present time. --MKH, 18 Jan 2012.
# print(tableCDe, sanitize.text.function = function(x){x})

#print(tableAll, caption.placement="top")
```

2.2. Cobb-Douglas With X

```
# Note that the anlaysis of ZA is taking a long time here. Need to figure out why.
CDxTables <- lapply(countries, cobbDouglasEnergyTable, energyType="X")
```

```
print(CDxTables[["US"]], caption.placement="top")
print(CDxTables[["ZA"]], caption.placement="top")
```

2.3. Cobb-Douglas With U

```
CDuTables <- lapply(countries, cobbDouglasEnergyTable, energyType="U")
```

```
print(CDuTables[["US"]], caption.placement="top")
print(CDuTables[["ZA"]], caption.placement="top")
```

3. CES

```
cesData <- function(countryName, energyType){
  energyColumnName <- paste("i", energyType, sep="")
  # Load the data that we need.
  dataTable <- loadData(countryName)

  # Establish guess values for phi beta, zeta, lambda_L and lambda_E.
  phiGuess <- -20
  betaGuess <- 0.5 # a typical value for beta (exponent on labor)
  zetaGuess <- 0.0004 # a small value
  lambda_LGuess <- 0.007 #assuming no technical progress on the labor-capital port
  lambda_EGuess <- 0.008 #assuming no technical progress on the energy portion of

  # Runs a non-linear least squares fit to the data with constraints
  modelCES <- nls(iGDP ~ ((1-zeta) * (exp(lambda_L*iYear) * iCapStk^(1-beta) * iLa
                         + zeta*(exp(lambda_E*iYear) * iQ)^phi)^(1/phi),
                  algorithm = "port",
                  control = nls.control(maxiter = 500, tol = 1e-06, minFactor = 1
```

```
                                      printEval = FALSE, warnOnly = FALSE),
                   start = list(phi=phiGuess, beta=betaGuess, zeta=zetaGuess, lamb
                                lambda_E=lambda_EGuess),
                   lower = list(phi=-Inf, beta=0, zeta=0, lambda_L=-Inf, lambda_E=
                   upper = list(phi=0, beta=1, zeta=1, lambda_L=Inf, lambda_E=Inf)
                   data=dataTable)

aicCES <- AIC(modelCES, k=2) # Checks validity of the model. AIC stands for Akai
print(aicCES)

# Gives the nls summary table
summaryCES <- summary(modelCES) # Gives the nls summary table
print(summaryCES)

# Provides confidence intervals on phi, beta, zeta, lambda_L, and lambda_E. But,
ciCES <- confint(modelCES, level = ciLevel)
print(ciCES)

# Get the estimate for alpha
beta <- as.numeric(coef(modelCES)["beta"])
alpha <- 1.0 - beta
alpha.est <- deltaMethod(modelCES, "1 - beta") # Estimates alpha and its standar
print(alpha.est)

# Now calculate a confidence interval on alpha
dofCES <- summaryCES$df[2]
print(dofCES) # Gives the degrees of freedom for the model.
tvalCES <- qt(ciHalfLevel, df = dofCES); tvalCES
# Get confidence intervals for each parameter in the model
alphaCICES <- with(alpha.est, Estimate + c(-1.0, 1.0) * tvalCES * SE) # CI on al
print(alphaCICES)

# Assemble the data into data frames for the table.
estCES <- data.frame(phi = coef(modelCES)["phi"], alpha = alpha,
                     beta = coef(modelCES)["beta"], zeta = coef(modelCES)["zeta'
                     lambda_L = coef(modelCES)["lambda_L"], lambda_E = coef(mode
row.names(estCES) <- paste("CES with ", energyType, sep="")
```

```
  #print(estCES)
  # The [1] subscripts pick off the lower confidence interval
  lowerCES <- data.frame(phi = ciCES["phi","2.5%"], alpha = alphaCICES[1],
                         beta = ciCES["beta", "2.5%"], zeta = ciCES["zeta", "2.5%"
                         lambda_L = ciCES["lambda_L", "2.5%"], lambda_E = ciCES["l
  row.names(lowerCES) <- "- 95% CI"
  # The [2] subscripts pick off the lower confidence interval
  upperCES <- data.frame(phi = ciCES["phi","97.5%"], alpha = alphaCICES[2],
                         beta = ciCES["beta", "97.5%"], zeta = ciCES["zeta", "97.5
                         lambda_L = ciCES["lambda_L", "97.5%"], lambda_E = ciCES["
  row.names(upperCES) <- "+ 95% CI"

  # Now create the data for a table.
  dataCES <- rbind(upperCES, estCES, lowerCES)
  print(dataCES)
  return(dataCES)

  #xyplot( resid(modelCESQ) ~ fitted(modelCESQ) )
  #histogram( ~resid(modelCESQ) )
  #qqmath( ~resid(modelCESQ) )
}

####################################
# Creates a LaTeX printable table from the CES data. This function first calls ces
#
# countryName is a string containint the 2-letter abbreviation for the country, e.
# energyType is a string to be used in table captions reprsenting the type of ener
#
# returns a printable LaTeX table from xtable.
##
cesTable <- function(countryName, energyType){
  dataCESe <- cesData(countryName, energyType)
  tableCESq <- xtable(dataCESe, caption=paste(countryName, ", 1980-2011.", sep=""))
}
```

3.1. CES with Q

```
countryName <- "US"
energyType <- "Q"
tableCESq <- cesTable(countryName, energyType)

[1] -194

Formula: iGDP ~ ((1 - zeta) * (exp(lambda_L * iYear) * iCapStk^(1 - beta) *
    iLabor^beta)^phi + zeta * (exp(lambda_E * iYear) * iQ)^phi)^(1/phi)

Parameters:
          Estimate Std. Error t value Pr(>|t|)
phi      -3.96e+01   2.43e+01   -1.63   0.1144
beta      6.09e-01   3.45e-02   17.64  2.4e-16
zeta      2.09e-06   1.32e-05    0.16   0.8758
lambda_L  7.98e-03   6.68e-04   11.95  2.8e-12
lambda_E  8.57e-03   2.48e-03    3.45   0.0018

Residual standard error: 0.0105 on 27 degrees of freedom

Algorithm "port", convergence message: relative convergence (4)

Waiting for profiling to be done...

             2.5%      97.5%
phi            NA -10.290831
beta     0.514667   0.665371
zeta           NA         NA
lambda_L 0.006428   0.009152
lambda_E 0.000715   0.012468
         Estimate      SE
1 - beta   0.3911 0.03453
[1] 27
[1] 0.3202 0.4619
              phi  alpha   beta      zeta lambda_L lambda_E
+ 95% CI   -10.29 0.4619 0.6654        NA 0.009152 0.012468
CES with Q -39.64 0.3911 0.6089 2.085e-06 0.007979 0.008570
- 95% CI       NA 0.3202 0.5147        NA 0.006428 0.000715

#CESqTables <- lapply(countries, cesTable, energyType="Q")
```

```r
print(tableCESq, caption.placement="top")
```

Table 2: US, 1980-2011.

	phi	alpha	beta	zeta	lambda_L	lambda_E
+ 95% CI	-10.3	0.46	0.67		0.00915	0.01247
CES with Q	-39.6	0.39	0.61	0.000002	0.00798	0.00857
- 95% CI		0.32	0.51		0.00643	0.00071

```r
#print(CESqTables[["US"]], caption.placement="top")
#print(CESqTables[["ZA"]], caption.placement="top")
```