Financial Econometrics
Shanghai Jiao Tong University
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Empirical Exercise 4B
With Solutions

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Reference: Stock, J.H. and Watson, M.W., Introduction to Econometrics (4th Edition)

Data: `Growth.csv` *(Malta excluded)*

Empirical Exercise 6.2. Using the data set `Growth` described in Empirical Exercise E4.1, but excluding the data for Malta, carry out the following exercises.

(a) Construct a table that shows the sample mean, standard deviation, and minimum and maximum values for the series *Growth*, *TradeShare*, *YearsSchool*, *Oil*, *Rev_Coups*, *Assassinations*, and *RGDP60*. Include the appropriate units for all entries.

(b) Run a regression of *Growth* on *TradeShare*, *YearsSchool*, *Rev_Coups*, *Assassinations*, and *RGDP60*. What is the value of the coefficient on *Rev_Coups*? Interpret the value of this coefficient. Is it large or small in a real-world sense?

(c) Use the regression to predict the average annual growth rate for a country that has average values for all regressors.

(d) Repeat (c), but now assume that the country's value for *TradeShare* is one standard deviation above the mean.

(e) Why is *Oil* omitted from the regression? What would happen if it were included?

Solution:

Key Concepts for Multiple Regression

Multiple Regression Model:

$$Y_i = \beta_0 + \beta_1 X_{1i} + \beta_2 X_{2i} + \cdots + \beta_k X_{ki} + u_i$$

Interpretation of β_j:

The coefficient β_j measures the expected change in Y associated with a one-unit change in X_j, **holding all other regressors constant** (ceteris paribus).

Key Property of OLS:

The regression hyperplane passes through the point of means:

$$\bar{Y} = \hat{\beta}_0 + \hat{\beta}_1 \bar{X}_1 + \hat{\beta}_2 \bar{X}_2 + \cdots + \hat{\beta}_k \bar{X}_k$$

This means predicting $\hat{Y}$ at $X_j = \bar{X}_j$ for all j yields $\hat{Y} = \bar{Y}$.

(a) Summary Statistics

Variable	Units	Mean	SD	Min	Max
Growth	% per year	1.869	1.816	−2.812	7.157
TradeShare	ratio (0–1+)	0.542	0.228	0.141	1.128
YearsSchool	years	3.959	2.553	0.200	10.070
Rev_Coups	events/year	0.170	0.225	0.000	0.970
Assassinations	per million	0.282	0.494	0.000	2.467
RGDP60	1985 USD	3,130.8	2,523.0	367.0	9,895.0
Oil	0/1	0.000	0.000	0	0

Sample: 64 countries (1960–1995), Malta excluded.

Key Observations:

- Average GDP growth was 1.87% per year, ranging from −2.8% (decline) to +7.2%
- Trade share averages 0.54 (exports + imports = 54% of GDP)
- Political instability (Rev_Coups) averages 0.17 events per year
- Initial income (RGDP60) shows large variation: \$367 to \$9,895 per capita
- **Oil = 0 for all countries** in this sample—no variation

(b) Multiple Regression: Cross-Country Growth Regression

Model:

$$\text{Growth}_i = \beta_0 + \beta_1 \text{TradeShare}_i + \beta_2 \text{YearsSchool}_i + \beta_3 \text{Rev\_Coups}_i + \beta_4 \text{Assassinations}_i + \beta_5 \text{RGDP60}_i + u_i$$

This is a "Barro-style" cross-country growth regression, common in the empirical growth literature. It examines how trade openness, human capital, political stability, and initial income affect long-run economic growth.

Regression Output

	Coefficient	**Std. Error**	**t-statistic**	**p-value**
TradeShare	1.3408	0.9601	1.40	0.168
YearsSchool	0.5642	0.1431	3.94	0.000
Rev_Coups	−2.1504	1.1186	−1.92	0.059
Assassinations	0.3226	0.4880	0.66	0.511
RGDP60	−0.00046	0.00015	−3.06	0.003
Constant	0.6269	0.7830	0.80	0.427
$n = 64$,	$R^2 = 0.2911$,	$\bar{R}^2 = 0.2300$,	Root MSE = 1.594	

Coefficient on Rev_Coups

Answer: $\hat{\beta}_{\text{Rev\_Coups}} = -2.15$
Interpretation: Holding other variables constant, a one-unit increase in the number of revolutions and coups per year is associated with a **2.15 percentage point decrease** in average annual GDP growth.

Is This Large in a Real-World Sense?

To assess economic significance, consider the effect of a one standard deviation change:

$$\text{Effect of 1 SD} = \hat{\beta}_{\text{Rev\_Coups}} \times \text{SD(Rev\_Coups)} = -2.15 \times 0.225 = -0.48 \text{ pp}$$

Economic Significance Assessment:

- A 1 SD increase in political instability reduces growth by **0.48 percentage points**
- Given average growth of 1.87%, this represents a **26% reduction** in growth
- Over 35 years (1960–1995), this compounds to substantial income differences
- The coefficient is marginally significant ($p = 0.059$)

Verdict: The effect is **economically meaningful** but **statistically weak** (significant only at 10% level). Political instability appears to matter for growth, but the estimate is imprecise.

Other Notable Coefficients

- **YearsSchool** ($\hat{\beta} = 0.56$, $p < 0.001$): Human capital strongly predicts growth. Each additional year of schooling is associated with 0.56 pp higher growth.
- **RGDP60** ($\hat{\beta} = -0.00046$, $p = 0.003$): Evidence of **conditional convergence**—poorer countries grow faster, controlling for other factors. A \$1,000 higher initial income is associated with 0.46 pp lower growth.
- **TradeShare** ($\hat{\beta} = 1.34$, $p = 0.168$): Positive but **not significant**. Compare to simple regression in E4.1/E5.2 where trade was marginally significant.

(c) Prediction at Average Values

Question: Predict growth for a country with average values for all regressors.

OLS Property: The regression line passes through the point of means. Therefore:

$$\hat{Y}|_{X_j=\bar{X}_j \text{ for all } j} = \bar{Y}$$

Calculation

Setting all regressors at their sample means:

$$\begin{aligned}\widehat{\text{Growth}} &= 0.627 + 1.341(0.542) + 0.564(3.959) + (-2.150)(0.170) \\ &\quad + 0.323(0.282) + (-0.00046)(3130.8) \\ &= 1.869\%\end{aligned}$$

Predicted growth at mean values: 1.87%
This equals the sample mean of Growth, confirming the OLS property.

(d) Prediction: TradeShare One SD Above Mean

Question: Predict growth when TradeShare is one standard deviation above the mean, with all other variables at their means.

Setup

- TradeShare: $\bar{X} + \text{SD} = 0.542 + 0.228 = 0.771$
- All other variables: at their means

Calculation

The change in predicted growth comes only from TradeShare:

$$\Delta\widehat{\text{Growth}} = \hat{\beta}_{\text{TradeShare}} \times \Delta\text{TradeShare} = 1.341 \times 0.228 = 0.306 \text{ pp}$$

New prediction:

$$\widehat{\text{Growth}} = 1.869 + 0.306 = 2.175\%$$

Predicted growth with TradeShare 1 SD above mean: 2.18%
This is **0.31 percentage points higher** than the prediction at mean values.
Interpretation: A country that is more open to trade (by 1 SD) is predicted to grow about 0.3 pp faster annually, holding other factors constant. However, this effect is *not statistically significant* ($p = 0.168$).

(e) Why is Oil Omitted?

Examining the Oil Variable

Variable	Mean	SD	Min	Max
Oil	0	0	0	0

All 64 countries have Oil = 0. There is **no variation** in this variable.

Technical Explanation

The OLS estimator is:

$$\hat{\boldsymbol{\beta}} = (\mathbf{X}'\mathbf{X})^{-1}\mathbf{X}'\mathbf{Y}$$

This requires $(\mathbf{X}'\mathbf{X})$ to be invertible. For a variable X_j with $\text{Var}(X_j) = 0$:

- The column of $\mathbf{X}$ corresponding to X_j is constant (all zeros)
- This column is perfectly collinear with other columns (or adds no information)
- $(\mathbf{X}'\mathbf{X})$ becomes **singular** (not invertible)
- OLS cannot be computed

What Happens If Oil Is Included?

When we attempt to include Oil, Stata displays:

```
note: oil omitted because of collinearity.
```

Answer: Oil is omitted because it has **no variation** in this sample (all countries have Oil = 0).
Technical reason: When $\text{Var}(X) = 0$, OLS cannot estimate the coefficient because:

1. We cannot observe how Y changes when X changes if X never changes
2. Mathematically, $(\mathbf{X}'\mathbf{X})$ is singular when a column has zero variance

If included: Stata automatically drops Oil and displays "`oil omitted because of collinearity`." The remaining coefficients are unchanged.

Note: This differs from the full Growth dataset, which includes oil-exporting countries. Malta was excluded due to its outlier status (extremely high trade share), not because of Oil.

Summary: Key Results

Variable	Coefficient	SE	t-stat	Significant?
TradeShare	1.341	0.960	1.40	No
YearsSchool	0.564	0.143	3.94	Yes (1%)
Rev_Coups	−2.150	1.119	−1.92	Marginal (10%)
Assassinations	0.323	0.488	0.66	No
RGDP60	−0.00046	0.00015	−3.06	Yes (1%)

$R^2 = 0.291$, $\bar{R}^2 = 0.230$, $n = 64$

The Big Picture

1. **Determinants of Growth:** Human capital (YearsSchool) and initial income (RGDP60) are the strongest predictors of cross-country growth differences. Political instability (Rev_Coups) has an economically meaningful but statistically imprecise negative effect.

2. **Trade and Growth:** Once we control for other factors, the trade-growth relationship becomes weaker and insignificant. This contrasts with the simple regression (E4.1) and suggests the bivariate relationship may partly reflect omitted variables.

3. **Conditional Convergence:** The negative coefficient on RGDP60 supports the convergence hypothesis—poorer countries grow faster, conditional on human capital and political stability.

4. **Prediction at Means:** OLS predictions at mean values equal the sample mean of Y, a fundamental property of least squares.

5. **Zero-Variance Variables:** Variables with no variation cannot be included in regression. OLS requires variation in X to identify how Y responds to changes in X.

6. **Model Fit:** $R^2 = 0.29$ means these five variables explain about 29% of cross-country growth variation. Substantial unexplained variation remains, reflecting the complexity of economic development.

Calculations performed using Stata. See accompanying `EE_4B_solution.do` *file.*