

DUMMY VARIABLE REGRESSION MODELS

EE 325 (Ajarn Kaewkwan
Tangtipongkul)

- The Nature of Dummy Variables
- Caution in the use of Dummy Variable
- ANOVA
- The Dummy Variable Alternative to Chow Test
- Interaction Effects Using Dummy Variables
- The Use of Dummy Variable in Seasonal Analysis

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THE NATURE OF DUMMY VARIABLES

- Qualitative variables or nominal scale variables
- E.g. religion, sex, nationality, geographical region, etc.
- Variables that assume such 0 and 1 values

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DUMMY VARIABLE REGRESSION MODELS

$$Y_i = \beta_1 + \beta_2 X_i + \alpha D_i + u_i$$

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$$Y_i = \beta_1 + \beta_2 X_i + \alpha D_i + u_i$$

Y_i = total consumption (thousand baht)

X_i = total income (thousand baht)

$D_i = \begin{cases} 1 & \text{male} \\ 0 & \text{female} \end{cases}$

u_i = residual term

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$$E(Y_i | D_i = 0) = \beta_1 + \beta_2 X_i + \alpha(0) = \beta_1 + \beta_2 X_i$$

$$E(Y_i | D_i = 1) = \beta_1 + \beta_2 X_i + \alpha(1) = (\beta_1 + \alpha) + \beta_2 X_i$$

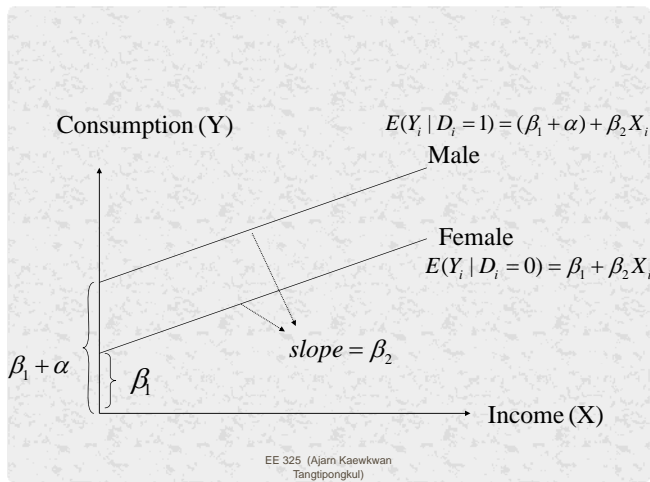
$$E(Y_i | D_i = 1) - E(Y_i | D_i = 0) = \alpha$$

The difference between mean total consumption of male and female is equal α

$\alpha > 0$ when the mean total consumption of male is more than female

$\alpha < 0$ when the mean total consumption of male is less than female

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$$H_0 : \alpha = 0$$

$$H_1 : \alpha \neq 0$$

$$\hat{Y}_i = 2.34 + 0.83X_i + 0.44D_i$$

$$t^* = (2.18)(10.44) \quad (5.26)$$

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CAUTION IN THE USE OF DUMMY VARIABLE

- If a qualitative variable has m categories, introduce only $(m-1)$ dummy variables
- The category for which no dummy variable is assigned is known as the **base, benchmark, control, comparison, reference, or omitted category**
- The intercept value represents the mean value of the benchmark category

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- The coefficient attached to the dummy variables in

$$Y_i = \beta_1 + \beta_2 D_{2i} + \beta_3 D_{3i} + u_i$$

are known as the **differential intercept coefficients**

- If a qualitative variable has more than one category, the choice of the benchmark category is strictly up to the researcher

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• Dummy variable trap

There is a way to circumvent this trap by introducing as many dummy variables as the number of categories of that variable, provided we do not introduce the intercept in such a model

$$Y_i = \beta_1 D_{1i} + \beta_2 D_{2i} + \beta_3 D_{3i} + u_i$$

We do not fall into the dummy variable trap, as there is no longer perfect collinearity

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- Which is a better method of introducing a dummy variable: (1) introduce a dummy for each category and omit the intercept term or (2) include the intercept term and introduce only $(m-1)$ dummies, where m is the number of categories of the dummy variable?

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REGRESSION WITH A MIXTURE OF QUANTITATIVE AND QUALITATIVE REGRESSORS: THE ANCOVA MODELS

- Example 9.3 Teacher's salary in relation to region and spending on public school per pupil

$$Y_i = \beta_1 + \beta_2 D_{2i} + \beta_3 D_{3i} + \beta_4 X_i + u_i$$

Y_i = average annual salary of public school teachers in state (\$)

X_i = spending on public school per pupil (\$)

$D_{2i} = 1$, if the state is in the Northeast or North Central
 = 0, otherwise

$D_{3i} = 1$, if the state is in the South
 = 0, otherwise

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Source	SS	df	MS			
Model	1.1204e+09	3	373457549	Number of obs =	51	
Residual	1.1309e+09	47	24062057.9	F(3, 47) =	15.52	
Total	2.2513e+09	50	45025787.3	Prob > F =	0.0000	
				R-squared =	0.4977	
				Adj R-squared =	0.4656	
				Root MSE =	4905.3	

salary	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
spending	2.340429	.359225	6.52	0.000	1.617761 3.063096
d2	-2954.127	1862.576	-1.59	0.119	-6701.146 792.8921
d3	-3112.195	1819.873	-1.71	0.094	-6773.306 548.9165
_cons	28694.92	3262.521	8.80	0.000	22131.57 35258.26

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$$\hat{Y}_i = 28,694.918 - 2,954.127D_{2i} - 3,112.194D_{3i} + 2.3404X_i$$

$$se = (3262.521) \quad (1862.576) \quad (1819.873) \quad (0.3592)$$

$$t = (8.795)^* \quad (-1.586)** \quad (-1.710)** \quad (6.515)^*$$

$$R^2 = 0.4977$$

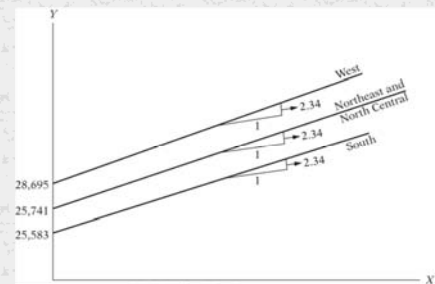
where * indicates p values less than 5 percent

** indicates p values greater than 5 percent

As these results suggest, ceteris paribus: as public expenditure goes up by a dollar, on average, a public school teacher's salary goes up by about \$2.34

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- Controlling for spending on education, we now see that the differential intercept coefficient is not significant for either the Northeast and North Central region or for the South.



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THE DUMMY VARIABLE ALTERNATIVE TO CHOW TEST

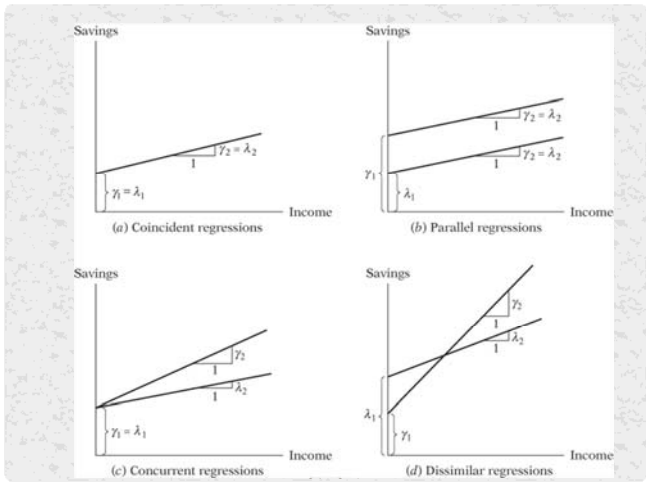
Chow Test – examine the structural stability of a regression model

- **Coincident regressions** – both the intercept and the slope coefficients are the same in the two regressions
- **Parallel regressions** – only the intercepts in the two regressions are different but the slopes are the same

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- **Concurrent regressions** – the intercepts in the two regressions are the same, but the slopes are different
- **Dissimilar regressions** – both the intercepts and slopes in the two regressions are different

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EXAMPLE

$$Y_t = \alpha_1 + \alpha_2 D_t + \beta_1 X_t + \beta_2 (D_t X_t) + u_t$$

Y = savings

X = income

t = time

D = 1 for observations in 1982-1995

= 0, otherwise

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TABLE 9.2
Savings and Income Data, United States, 1970-1995

Source: *Economic Report of the President*, 1997, Table B-25, p. 332.

Observation	Savings	Income	Dum
1970	61	727.1	0
1971	68.6	790.2	0
1972	63.6	855.3	0
1973	89.6	965	0
1974	97.6	1054.2	0
1975	104.4	1159.2	0
1976	96.4	1273	0
1977	92.5	1401.4	0
1978	112.6	1580.1	0
1979	130.1	1769.5	0
1980	161.8	1973.3	0
1981	199.1	2200.2	0
1982	205.5	2347.3	1
1983	167	2522.4	1
1984	235.7	2810	1
1985	206.2	3002	1
1986	196.5	3187.6	1
1987	168.4	3363.1	1
1988	189.1	3640.8	1
1989	187.8	3894.5	1
1990	208.7	4166.8	1
1991	246.4	4343.7	1
1992	272.6	4613.7	1
1993	214.4	4790.2	1
1994	189.4	5021.7	1
1995	249.3	5320.8	1

Note: Dum = 1 for observations beginning in 1982. Otherwise Savings and income figures are in \$100 million.

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$$E(u_t) = 0$$

Mean savings function for 1970-1981

$$E(Y_t | D_t = 0, X_t) = \alpha_1 + \beta_1 X_t$$

Mean savings function for 1982-1995

$$E(Y_t | D_t = 1, X_t) = (\alpha_1 + \alpha_2) + (\beta_1 + \beta_2) X_t$$

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Source	SS	df	MS			
Model	88079.8327	3	29359.9442	Number of obs =	26	
Residual	11790.2539	22	535.920634	F(3, 22) =	54.78	
Total	99870.0867	25	3994.80347	Prob > F =	0.0000	
				R-squared =	0.8819	
				Adj R-squared =	0.8658	
				Root MSE =	23.15	

savings	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
income	.0803319	.0144968	5.54	0.000	.0502673 .1103964
dum	152.4786	33.08237	4.61	0.000	83.86992 221.0872
incdum	-.0654694	.0159824	-4.10	0.000	-.098615 -.0323239
_cons	1.016115	20.16483	0.05	0.960	-40.80319 42.83542

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$$Y_t = \alpha_1 + \alpha_2 D_t + \beta_1 X_t + \beta_2 (D_t X_t) + u_t$$

$$\hat{Y}_t = 1.0161 + 152.4786 D_t + 0.0803 X_t + 0.0655 (D_t X_t)$$

$$se = (20.1648) (33.0824) (0.0144) (0.0159)$$

$$t = (0.0504) ** (4.6090) (5.5413) * (-4.0963) *$$

$$R^2 = 0.8891$$

where * indicates p values less than 5 percent

** indicates p values greater than 5 percent

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Savings function for 1970-1981

$$\hat{Y}_t = 1.0161 + 0.0803X_t$$

Savings function for 1982-1995

$$\hat{Y}_t = (1.0161 + 152.4786) + (0.0803 - 0.0655)X_t \\ = 153.4947 + 0.0148X_t$$

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- The Chow test does not explicitly tell us which coefficient, intercept, or slope is different or whether both are different in two periods.
- That is, one can obtain a significant Chow test because the slope only is different or the intercept only is different or both are different

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INTERACTION EFFECTS USING DUMMY VARIABLES

- Interaction between the two qualitative variables

$$Y_i = \alpha_1 + \alpha_2 D_{2i} + \alpha_3 D_{3i} + \alpha_4 (D_{2i} D_{3i}) + \beta X_i + u_i$$

Y = hourly wage in dollars

X = education (years of schooling)

$D_{2i} = 1$ if female, 0 otherwise

$D_{3i} = 1$ if nonwhite and non-Hispanic, 0 otherwise

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$$E(Y_i | D_{2i} = 1, D_{3i} = 1, X_i) = (\alpha_1 + \alpha_2 + \alpha_3 + \alpha_4) + \beta X_i$$

which is the mean hourly wage function for female nonwhite/ non-Hispanic workers

α_2 = differential effect of being a female

α_3 = differential effect of being a nonwhite/non-Hispanic

α_4 = differential effect of being a female nonwhite/non-Hispanic

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THE USE OF DUMMY VARIABLE IN SEASONAL ANALYSIS

- **Deseasonalization** or **Seasonal Adjustment** - the process of removing the seasonal component from a time series
- **Important Economic time series** such as the unemployment rate, the consumer price index (CPI), the producer price index (PPI), etc.

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EXAMPLE

TABLE 9.3

Quarterly Data on
Appliance Sales (in
thousands) and
Expenditure on
Durable Goods
(1978-1 to 1985-4V)

Source: Business Statistics and
Survey of Current Business,
Department of Commerce
(various issues).

	DISH	DISP	FRIG	WASH	DUR	DISH	DISP	FRIG	WASH	DUR
841	798	1317	1271	252.6	480	706	943	1036	247.7	
957	837	1615	1295	272.4	530	582	1175	1019	249.1	
999	821	1662	1313	270.9	557	659	1269	1047	251.8	
960	858	1295	1150	273.9	602	837	973	918	262	
894	837	1271	1289	268.9	658	867	1102	1137	263.3	
851	838	1555	1245	262.9	749	860	1344	1167	280	
863	832	1639	1270	270.9	827	918	1641	1230	288.5	
878	818	1238	1103	263.4	858	1017	1225	1081	300.5	
792	868	1277	1273	260.6	808	1063	1429	1326	312.6	
589	623	1258	1031	231.9	840	955	1699	1228	322.5	
657	662	1417	1143	242.7	893	973	1749	1297	324.3	
699	822	1185	1101	248.6	950	1096	1117	1198	333.1	
675	871	1196	1181	258.7	838	1086	1242	1292	344.8	
652	791	1410	1116	248.4	884	990	1684	1342	350.3	
628	759	1417	1190	255.5	905	1028	1764	1323	369.1	
529	734	919	1125	240.4	909	1003	1328	1274	356.4	

Note: DISH = dishwashers; DISP = garbage disposers; FRIG = refrigerators; WASH = washing machines; DUR = durable goods expenditure, billions of 1982 dollars.

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SALES OF REFRIGERATORS OVER THE SAMPLE PERIOD

$$Y_i = \alpha_1 D_{1t} + \alpha_2 D_{2t} + \alpha_3 D_{3t} + \alpha_4 D_{4t} + u_t$$

$Y_i =$ Sales of refrigerators (in thousands)
 $D = \begin{cases} 0 & \text{otherwise} \\ 1 & \text{the relevant quarter} \end{cases}$

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$$\hat{Y}_t = 1,222.125D_{1t} + 1,467.500D_{2t} + 1,569.750D_{3t} + 1,160.000D_{4t}$$

$$t = (20.3720) \quad (24.4622) \quad (26.1666) \quad (19.3364)$$

$$R^2 = 0.5317$$

The average sales of refrigerators (in thousands of units in each season (i.e., quarter)

The average sales of refrigerators in the first quarter in thousands of units, is about 1,222

The average sales of refrigerators in the second quarter in thousands of units, is about 1,468

The average sales of refrigerators in the third quarter in thousands of units, is about 1,570

The average sales of refrigerators in the fourth quarter in thousands of units, is about 1,160

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TABLE 9.4

U.S. Refrigerator Sales (thousands), 1978-1985 (quarterly)

Source: Business Statistics and Survey of Current Business, Department of Commerce (various issues).

	FRIG	DUR	D ₂	D ₃	D ₄	FRIG	DUR	D ₂	D ₃	D ₄
1317	252.6	0	0	0	0	943	247.7	0	0	0
1615	272.4	1	0	0	0	1175	249.1	1	0	0
1662	270.9	0	1	0	0	1269	251.8	0	1	0
1295	273.9	0	0	1	0	973	262.0	0	0	1
1271	268.9	0	0	0	0	1102	263.3	0	0	0
1555	262.9	1	0	0	0	1344	280.0	1	0	0
1639	270.9	0	1	0	0	1641	288.5	0	1	0
1238	263.4	0	0	1	0	1225	300.5	0	0	1
1277	260.6	0	0	0	0	1429	312.6	0	0	0
1258	231.9	1	0	0	0	1699	322.5	1	0	0
1417	242.7	0	1	0	0	1749	324.3	0	1	0
1185	248.6	0	0	1	0	1117	333.1	0	0	1
1196	258.7	0	0	0	0	1242	344.8	0	0	0
1410	248.4	1	0	0	0	1684	350.3	1	0	0
1417	255.5	0	1	0	0	1764	369.1	0	1	0
919	240.4	0	0	1	0	1328	356.4	0	0	1

Note: FRIG = refrigerator sales, thousands.
 DUR = durable goods expenditures, billions of 1982 dollars.
 D₂ = 1 in the second quarter, 0 otherwise.
 D₃ = 1 in the third quarter, 0 otherwise.
 D₄ = 1 in the fourth quarter, 0 otherwise.

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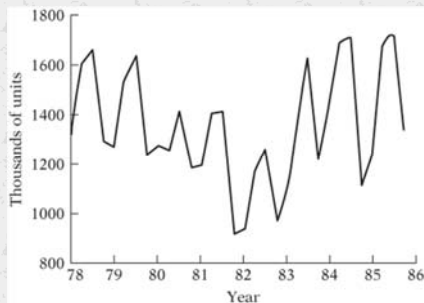
$$\hat{Y}_t = 1,222.1250 + 245.3750D_{2t} + 347.6250D_{3t} - 62.1250D_{4t}$$

$$t = (20.3720)^* \quad (2.8922)^* \quad (4.0974)^* \quad (-0.7322)^{**}$$

$$R^2 = 0.5318$$

p values <5% ** p values >5%

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$$Y_i = \beta_1 + \beta_2 X_{2i} + \alpha Sex_i + \gamma_1 Edu_{1i} + \gamma_2 Edu_{2i} + \lambda_1 (Sex_i Edu_{1i}) + \lambda_2 (Sex_i Edu_{2i}) + u_i$$

$Y_i =$ Consumption expenditure (thousand baht)

$X_i =$ Income (thousand baht)

$Sex_i = \begin{cases} 1 & \text{male} \\ 0 & \text{female} \end{cases}$

$Educ_{1i} = \begin{cases} 1 & \text{Bachelor degree} \\ 0 & \text{others} \end{cases}$

$Educ_{2i} = \begin{cases} 1 & \text{Master degree or higher} \\ 0 & \text{others} \end{cases}$

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$$\begin{aligned}
 E(Y_i | \text{Sex}_i = 0, \text{Edu}_{1i} = 0, \text{Edu}_{2i} = 0) &= \beta_1 + \beta_2 X_i \\
 E(Y_i | \text{Sex}_i = 0, \text{Edu}_{1i} = 1, \text{Edu}_{2i} = 0) &= (\beta_1 + \gamma_1) + \beta_2 X_i \\
 E(Y_i | \text{Sex}_i = 0, \text{Edu}_{1i} = 0, \text{Edu}_{2i} = 1) &= (\beta_1 + \gamma_2) + \beta_2 X_i \\
 E(Y_i | \text{Sex}_i = 1, \text{Edu}_{1i} = 0, \text{Edu}_{2i} = 0) &= (\beta_1 + \alpha) + \beta_2 X_i \\
 E(Y_i | \text{Sex}_i = 1, \text{Edu}_{1i} = 1, \text{Edu}_{2i} = 0) &= (\beta_1 + \alpha + \gamma_1 + \lambda_1) + \beta_2 X_i \\
 E(Y_i | \text{Sex}_i = 1, \text{Edu}_{1i} = 0, \text{Edu}_{2i} = 1) &= (\beta_1 + \alpha + \gamma_2 + \lambda_2) + \beta_2 X_i
 \end{aligned}$$

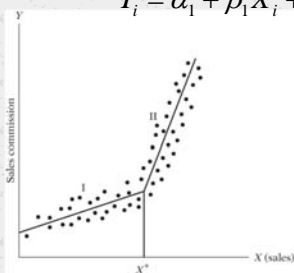
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$$E(Y_i | \text{Sex}_i = 0, \text{Edu}_{1i} = 1, \text{Edu}_{2i} = 0) - E(Y_i | \text{Sex}_i = 0, \text{Edu}_{1i} = 0, \text{Edu}_{2i} = 0) = \gamma_1$$

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PIECEWISE LINEAR REGRESSION

$$Y_i = \alpha_1 + \beta_1 X_i + \beta_2 (X_i - X^*) D_i + u_i$$



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where Y_i = sales commission

X_i = volume of sales generated by the sales person

X^* = threshold value of sales also known as a knot

$D_i = 1$ if $X_i > X^*$

$= 0$ if $X_i < X^*$

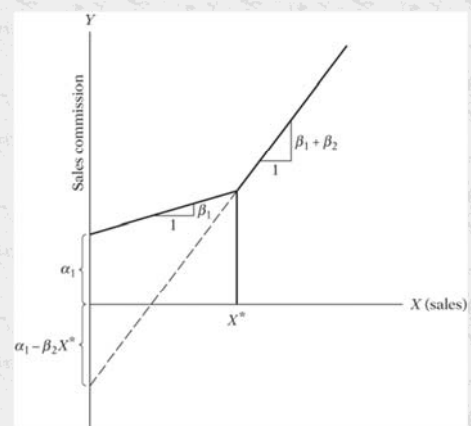
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Assuming $E(u_i) = 0$

$$E(Y_i | D_i = 0, X_i, X^*) = \alpha_1 + \beta_1 X_i$$

$$E(Y_i | D_i = 1, X_i, X^*) = \alpha_1 - \beta_2 X^* + (\beta_1 + \beta_2) X_i$$

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EXAMPLE

Total Costs in Relation to Output

TABLE 9.6
Hypothetical Data
on Output and
Total Cost

Total Cost, Dollars	Output, Units
256	1,000
414	2,000
634	3,000
778	4,000
1,003	5,000
1,839	6,000
2,081	7,000
2,423	8,000
2,734	9,000
2,914	10,000

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Source	SS	df	MS	Number of obs =
Model	8832644.9	2	4416322.45	10
Residual	238521.502	7	34074.5002	F(2, 7) = 129.61
Total	9071166.4	9	1007907.38	Prob > F = 0.0000
				R-squared = 0.9737
				Adj R-squared = 0.9662
				Root MSE = 184.59

	Coef.	Std. Err.	t	P> t	[95% Conf. Interval]
y					
x	.2791258	.0460081	6.07	0.001	.1703388 .3879177
xd	.0945	.0825524	1.14	0.290	-.1007054 .2897054
_cons	-145.7167	176.7341	-0.82	0.437	-563.6265 272.1932

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We are told that the total cost may change its slope at the output level of 5,500 units

$$\hat{Y}_i = -145.72 + 0.2791X_i^* + 0.0945(X_i - X_i^*)D_i$$

$$t = (-0.8245) \quad (6.0669) \quad (1.1447)$$

$$R^2 = 0.9737$$

$$X_i^* = 5,500$$

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- The marginal cost of production is about 28 cents per unit and although it is about 37 cents (28+9) for output over 5,500 units, the difference between the two is not statistically significant because the dummy variable is not significant at, say, the 5 percent level.
- For all practical purposes, then, one can regress total cost on total output, dropping the dummy variable

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SOME TECHNICAL ASPECT OF THE DUMMY VARIABLE TECHNIQUE

- The interpretation of Dummy variables in semilogarithmic regressions

$$\ln Y_i = \beta_1 + \beta_2 D_i + u_i$$

Y = hourly wage rate(\$)

$D = 1$ for female and 0 for male

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Wage function for male workers:

$$E(\ln Y_i | D_i = 0) = \beta_1$$

Wage function for female workers:

$$E(\ln Y_i | D_i = 1) = \beta_1 + \beta_2$$

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When we take antilog of β_1 , this represents the median hourly wages of male workers

When we take antilog of $(\beta_1 + \beta_2)$, we obtain the median hourly wages of female workers

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LOGARITHM OF HOURLY WAGES IN RELATION TO GENDER

$$\ln Y_i = 2.1763 - 0.2437D_i$$

$$t = (72.2943)(-5.5048)$$

$$R^2 = 0.0544$$

- Taking antilog of 2.1763, we find \$8.8136, which is the median hourly earnings of male workers, and taking the antilog of $(2.1763 - 0.2437 = 1.92857)$, we obtain \$6.8796, which is the median hourly earnings of female workers

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- We can obtain semielasticity for a dummy regressor
Take the antilog (to base e) of the estimated dummy coefficient and subtract 1 from it and multiply the difference by 100.

Take the antilog of -0.2437, you will obtain 0.78366. Subtracting 1 from this gives -0.2163. After multiplying this by 100, we get -21.63 percent, suggesting that a female worker's median salary is lower than that of her male counterpart by about 21.63%

EE 325 (Ajarn Kaewkwan
Tangtipongkul)

SOURCE

Gujarati, D.N. (2009) Basic Econometrics. 5th ed. Singapore, McGraw-Hill.

EE 325 (Ajarn Kaewkwan
Tangtipongkul)