**Exercise Chapter 8**

1. How do models of endogenous growth differ from those that assume growth is exogenous?

The background to this question is the Solow model. The Solow model was developed to explain the stylised facts of growth in developed countries. These were that (taken from Solow 1970, pp.2-3):

(a) Real output per man (or per man hour) grows at a more or less constant rate over fairly long periods of time…. There is no clear systematic tendency for the rate of increase of productivity in this sense to accelerate or to slow down.

(b) The stock of real capital, crudely measured, grows at a more or less constant rate exceeding the rate of growth of labour input.

(c) The rates of growth of real output and the stock of capital goods tend to be about the same, so that the ratio of capital to output shows no systematic trend.

(d) The rate of profit on capital has a horizontal trend, apart from occasional violent changes associated with sharp variations in effective demand.

Solow is explicit that he is primarily concerned with explaining changes within a country rather than in explaining differences across countries. However his model as adapted by Mankiw, Romer and Weil (1992) has been used to discuss changes across countries as well as over time.

In Chapter 8 Section 8.4 we introduced the time series version of the model.

(8.3)

In its use in chapter 8 Table 8.1 we used a cross section version of the model as indeed Mankiw, Romer and Weil (1992) did in their paper. That raises additional econometric issues that we cover later in the book (see Sections III and VIII). For now we note that all these models if estimated by OLS assume the regressors, the saving rate and physical and human capital, are exogenous in the sense that these regressors are not correlated with the unobservables. We discuss in later chapters how to relax that assumption.

This version of the Solow model is described as one of exogenous growth because in the long run, with constant saving rates and rates of population growth, the long term rate of growth is given by the rate of technical progress, in equation (8.3). A model of endogenous growth would seek to explain that rate of technical progress.

It is important to note that the model written down in equation (8.3) does not allow us to distinguish between model of endogenous and exogenous growth. If for example we wished to hypothesise that investment affects the rate of technical progress we would need a more general specification and we do that much later in Chapter 25 Section 25.3. There is some ground to cover before we can tackle the econometric issues that arise in such a specification.

2. What evidence do you need to distinguish between the hypotheses of endogenous and exogenous growth?

Models of endogenous growth hypothesise that certain factors, for example human capital and research and development, affect long run income through their effect on growth rates. Note that in the Mankiw, Romer and Weil (1992) version of the Solow model human capital does not affect the long run growth rate but the long run level of income through factor accumulation. The long run growth rate is exogenously given.

As both investment in human capital and investment in research and development have been steadily increasing since at least the beginning of the twentieth century you might argue that we could look for evidence in whether growth rate have been increasing over time. This is exactly what a paper by Charles Jones seeks to do (Time Series Tests of Endogenous Growth Models, The Quarterly Journal of Economics, Vol. 110, No. 2 (May, 1995), pp. 495-525). Jones asks for the US and OECD countries if there is an evidence in the data if growth rates have been increasing. He finds none and concludes that

‘If we characterize endogenous growth theory by the prediction that permanent changes in policy variables lead to permanent changes in growth, then this lack of persistent changes in growth rates imposes a strong restriction on these models: either the variables that have permanent effects on growth exhibit little persistent change, or somewhat miraculously the movements in these variables have been offsetting’ (Page 521)

In the answer to the next question we exploit the cross section evidence to see if the investment rate or education impact on growth and we find they do which appears to be inconsistent with the Jones finding.

3. Use the macro data ‘Macro\_PEBLIF’ to show how growth rates have varied in the period since 1950. Suggest reasons for what you observe.

In the table below we report summary statistics for four measures of the annual growth rate. All are yearly averages, the first is based on annual data, the second on five-year differences, the third on ten-year differences and the four on forty-year differences which is the longest period we have in this data set for both physical and human capital. The chart below the table presents these measures of growth in graphic form.

As we would expect there is a much larger variance in annual growth rates than in those over longer period reflecting the problems posed by measurement error in the data. Considering both the five and ten year based data we see that the distribution of the growth rate is close to being normal. We discussed in Chapter 4 why a normal distribution may arise in the data (see pages 48-49) as a result of the sum of lots of different i.i.d random variables. That of course does not mean that we will not be able to find variables that determine growth but it does suggest that there may be many of them and we should not be surprised if a lot of the variation of growth remains unexplained.

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| . sum d1\_lrgdpch, d  Annual growth rate GDP per capita  -------------------------------------------------------------  Percentiles Smallest  1% -18.03134 -54.29509  5% -8.187886 -53.61197  10% -4.777429 -48.76183 Obs 5619  25% -.8332686 -44.99822 Sum of Wgt. 5619  50% 2.219136 Mean 1.857559  Largest Std. Dev. 6.448578  75% 4.88187 45.61568  90% 8.034044 49.24193 Variance 41.58416  95% 10.45272 55.41155 Skewness -.5830749  99% 19.3625 57.48756 Kurtosis 13.71547  . sum d5\_lrgdpch, d    Five year average annual growth rate GDP per capita  -------------------------------------------------------------  Percentiles Smallest  1% -7.850972 -14.27978  5% -4.00933 -11.92467  10% -2.329196 -11.51804 Obs 1037  25% .1731759 -10.16779 Sum of Wgt. 1037  50% 1.943126 Mean 1.821658  Largest Std. Dev. 3.400848  75% 3.678972 12.21365  90% 5.453471 12.41675 Variance 11.56577  95% 6.970429 19.91862 Skewness -.0594167  99% 10.34742 22.93369 Kurtosis 6.38449  . sum d10\_lrgdpch, d  Ten year average annual growth rate GDP per capita  -------------------------------------------------------------  Percentiles Smallest  1% -4.593226 -7.616482  5% -2.561619 -5.822298  10% -1.313929 -5.468181 Obs 520  25% .3821612 -5.42589 Sum of Wgt. 520  50% 1.887101 Mean 1.843226  Largest Std. Dev. 2.560092  75% 3.29294 8.931944  90% 5.088469 9.261215 Variance 6.554069  95% 5.975458 9.322326 Skewness -.0987426  99% 8.106404 10.57477 Kurtosis 3.652439  . sum d40\_lrgdpch, d  Forty year average annual growth rate GDP per  capita  -------------------------------------------------------------  Percentiles Smallest  1% -1.546112 -1.546112  5% -.9478462 -1.218287  10% -.284903 -1.050996 Obs 98  25% .7317563 -.9850605 Sum of Wgt. 98  50% 1.930251 Mean 1.784886  Largest Std. Dev. 1.518637  75% 2.795482 4.260983  90% 3.710646 4.595182 Variance 2.306258  95% 4.229699 5.390972 Skewness .0287303  99% 5.906276 5.906276 Kurtosis 2.721229 |

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We now consider how much of these differences in growth rates can be explained by physical and human capital. Note that the dependent variable in all the regressions below is the ten year annual average growth rate so we are choosing a quite different specification from that set out in equation (8.3) above.

This data is a pooled cross section so quite different from the data analysed in the Jones (1995) paper referred to above. In some respects the results are similar, the data show that growth rates have declined over time which is not readily squared with endogenous growth theories but it also shows that both physical and human capital have positive effects on growth rates which is what endogenous growth theories predict.

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| . reg d10\_lrgdpch year  Source | SS df MS Number of obs = 520  -------------+------------------------------ F( 1, 518) = 21.62  Model | 136.262898 1 136.262898 Prob > F = 0.0000  Residual | 3265.29906 518 6.30366615 R-squared = 0.0401  -------------+------------------------------ Adj R-squared = 0.0382  Total | 3401.56196 519 6.55406929 Root MSE = 2.5107  ------------------------------------------------------------------------------  d10\_lrgdpch | Coef. Std. Err. t P>|t| [95% Conf. Interval]  -------------+----------------------------------------------------------------  year | -.0393923 .0084726 -4.65 0.000 -.0560372 -.0227473  \_cons | 79.94903 16.79966 4.76 0.000 46.94519 112.9529  ------------------------------------------------------------------------------  . reg d10\_lrgdpch lki\_10 year  Source | SS df MS Number of obs = 520  -------------+------------------------------ F( 2, 517) = 49.85  Model | 549.886131 2 274.943065 Prob > F = 0.0000  Residual | 2851.67583 517 5.51581399 R-squared = 0.1617  -------------+------------------------------ Adj R-squared = 0.1584  Total | 3401.56196 519 6.55406929 Root MSE = 2.3486  ------------------------------------------------------------------------------  d10\_lrgdpch | Coef. Std. Err. t P>|t| [95% Conf. Interval]  -------------+----------------------------------------------------------------  lki\_10 | 1.146603 .1324084 8.66 0.000 .8864787 1.406728  year | -.0447679 .0079498 -5.63 0.000 -.0603857 -.02915  \_cons | 87.69245 15.74021 5.57 0.000 56.76981 118.6151  ------------------------------------------------------------------------------  . reg d10\_lrgdpch tyr15\_10 year  Source | SS df MS Number of obs = 356  -------------+------------------------------ F( 2, 353) = 32.37  Model | 329.364464 2 164.682232 Prob > F = 0.0000  Residual | 1795.93758 353 5.08764187 R-squared = 0.1550  -------------+------------------------------ Adj R-squared = 0.1502  Total | 2125.30204 355 5.98676632 Root MSE = 2.2556  ------------------------------------------------------------------------------  d10\_lrgdpch | Coef. Std. Err. t P>|t| [95% Conf. Interval]  -------------+----------------------------------------------------------------  tyr15\_10 | .2706474 .0446425 6.06 0.000 .1828486 .3584462  year | -.0754593 .0112638 -6.70 0.000 -.0976118 -.0533068  \_cons | 150.4688 22.30728 6.75 0.000 106.5969 194.3406  ------------------------------------------------------------------------------  . reg d10\_lrgdpch lki\_10 tyr15\_10 year  Source | SS df MS Number of obs = 356  -------------+------------------------------ F( 3, 352) = 31.31  Model | 447.643699 3 149.214566 Prob > F = 0.0000  Residual | 1677.65834 352 4.76607484 R-squared = 0.2106  -------------+------------------------------ Adj R-squared = 0.2039  Total | 2125.30204 355 5.98676632 Root MSE = 2.1831  ------------------------------------------------------------------------------  d10\_lrgdpch | Coef. Std. Err. t P>|t| [95% Conf. Interval]  -------------+----------------------------------------------------------------  lki\_10 | .9521954 .1911403 4.98 0.000 .5762748 1.328116  tyr15\_10 | .1269104 .0519567 2.44 0.015 .0247258 .2290951  year | -.068019 .0110038 -6.18 0.000 -.0896605 -.0463775  \_cons | 133.8634 21.84659 6.13 0.000 90.89718 176.8297  ------------------------------------------------------------------------------ |

4. Does your answer to Question 3 provide any evidence for or against theories of endogenous growth?

Our final paragraph to the previous question suggested we have evidence both for and against endogenous growth theories. How can they be reconciled?

The first point to note is that we do not yet have a model general enough to provide a formal test of whether investment rates do affect growth rates. As there are several econometric issues that need to be addressed before we can tackle that question on panel data that topic is not covered until Chapter 25.

It is however possible to reconcile the results with endogenous growth. The regressions in the table above suggest there is some general factor (correlated with time) reducing growth rates but that conditioning on that unknown general factor both forms of capital do impact positively on growth rates. That would be consistent with Jones’ results for as he acknowledges there might be factors offsetting the positive effects on investment on growth although he argues such an assumption is very implausible. If one did wish to argue along these lines it would obviously be rather important to establish what those factors correlated with time were that were reducing growth.

In summary the data provides evidence apparently consistent with endogenous growth and apparently inconsistent. More work is required before we can argue more strongly for or against its existence.