

Lecture 5: The Solow Model and Cross-Country Income Differences

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This lecture

- Recall how, in Lecture 3, we tried to account for cross-country income differences using our aggregate production function framework.
- In this lecture we'll re-do this measurement, but impose more structure than just an aggregate production function—we impose the structure implied by the Solow model.
 - With Cobb-Douglas production we have

$$k^* = \left(\frac{sA}{\delta} \right)^{\frac{1}{1-\alpha}} \quad \text{and} \quad y^* = A \left(\frac{sA}{\delta} \right)^{\frac{\alpha}{1-\alpha}} = A^{\frac{1}{1-\alpha}} \left(\frac{s}{\delta} \right)^{\frac{\alpha}{1-\alpha}}. \quad (1)$$

- Thus, through the lens of the Solow model, differences in y^* come from differences in A, s, δ (rather than A and k , as in our accounting in Lecture 3)
- We will proceed in two different ways:
 1. Regression analysis: Mankiw, Romer, Weil (1992)
 2. Calibration exercise: Hall and Jones (1999)

Outline

1. Regression analysis

Solow model and cross-country income regressions

Extension: Solow model with human capital

2. Calibration exercise

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1. Regression analysis

Solow model and cross-country income regressions

Extension: Solow model with human capital

2. Calibration exercise

Cross-country income regressions

- Let's take the log of the y^* equation in (1) for country j :

$$\begin{aligned}\ln y^{j*} &= \frac{1}{1-\alpha} \ln A^j + \frac{\alpha}{1-\alpha} \ln s^j - \frac{\alpha}{1-\alpha} \ln \delta^j \\ &= \text{constant} + \frac{\alpha}{1-\alpha} \ln s^j - \frac{\alpha}{1-\alpha} \ln \delta^j + \varepsilon^j\end{aligned}\quad (2)$$

Here, the second line splits the TFP term into a world average (constant) as well as a zero-mean country specific TFP effect ε^j .

- This expression suggests running a cross-country regression!

Aside: note how (2) uses the Solow model structure. What would the analogue of (2) using our production function perspective (Lecture 3) have looked like?

- That is the starting point of Mankiw-Romer-Weil (1992). They use a richer version of the Solow model featuring population growth, so their equation has “effective depreciation,”

$$n^j + \delta^j \quad \text{instead of} \quad \delta^j$$

- Actually they also have growth. More on this in the next lecture.

Cross-country income regressions

- MRW can measure s^j for each country j (how?).
- They also assume $\delta^j = \delta$ for all j , and use population growth n^j to obtain a measure of the effective depreciation for each country j .
- They however cannot measure the country's productivity ε^j .
 - So they assume ε^j is uncorrelated with s^j and effective depreciation.
 - This enables them to treat ε^j as noise.
 - We will come back to this assumption, but for now let's proceed with it.
- MRW then run a cross-country linear regression ...

Results

Number	Country	Sample			GDP/ adult		Growth 1960–1985		I/Y SCHOOL
		N	I	O	1960	1985	GDP	working age pop	
85	Portugal	1	1	1	2272	5827	4.4	0.6	22.5
86	Spain	1	1	1	3766	9903	4.9	1.0	17.7
87	Sweden	1	1	1	7802	15,237	3.1	0.4	24.5
88	Switzerland	1	1	1	10,308	15,881	2.5	0.8	29.7
89	Turkey	1	1	1	2274	4444	5.2	2.5	20.2
90	United Kingdom	1	1	1	7634	13,331	2.5	0.3	18.4
91	Barbados	0	0	0	3165		4.8		19.5
92	Canada	1	1	1	10,286	17,935	4.2	2.0	23.3
93	Costa Rica	1	1	0	3360	4492	4.7	3.5	14.7
94	Dominican Rep.	1	1	0	1939	3308	5.1	2.9	17.1
95	El Salvador	1	1	0	2042	1997	3.3	3.3	8.0

- N=“non-oil” sample. I=intermediate (quality data). O=OECD.

Aside: why ignore oil-producing countries?

- OECD has the most reliable data. But not much variation (similar countries). So focus on the intermediate sample.

Results

TABLE I
ESTIMATION OF THE TEXTBOOK SOLOW MODEL

Dependent variable: log GDP per working-age person in 1985			
Sample:	Non-oil	Intermediate	OECD
Observations:	98	75	22
CONSTANT	5.48 (1.59)	5.36 (1.55)	7.97 (2.48)
$\ln(I/GDP)$	1.42 (0.14)	1.31 (0.17)	0.50 (0.43)
$\ln(n + g + \delta)$	-1.97 (0.56)	-2.01 (0.53)	-0.76 (0.84)
$\bar{R}^2$	0.59	0.59	0.01

Ignore g = growth. Will return to this in the next lecture. Not important for our purposes here.

- Standard errors in parenthesis. If the coefficient is more than 2 standard errors away from zero, then it is statistically significant (at the 5% confidence level).
- R^2 describes the fraction of the variation in the dependent variable accounted for by the variation in right-hand regressors (as opposed to the residual ε^j).

Qualitative success of the basic Solow model

- Regression coefficients
 - The coefficient on the saving rate $s = I/GDP$ has the right sign.
 - The coefficient on depreciation also has the right sign.
 - The two coefficients are relatively close to each other in absolute value. (Recall that, in the model, they are supposed to have the same absolute value.)
- R^2 on the intermediate sample is very large, 59%.
 - Differences in saving and effective depreciation appear to account for the bulk of the cross-country income differences!!
 - However: negligible R^2 for the OECD. Does this make sense? Would you expect this to be smaller or larger than that for the full sample?
- From now on we focus on the intermediate sample, where the model seems to succeed.

How about the magnitudes?

- Our analysis of labor and capital shares suggested $\alpha = 1/3$.
- So (2) predicts not only the sign, but also **the magnitudes** of the coefficients. Plugging in $\alpha = 1/3$, we obtain

$$\ln y^{j*} = \text{constant} + \frac{1}{2} \ln s^j - \frac{1}{2} \ln \delta^j + \varepsilon^j.$$

- The estimated coefficient on $\ln s$ is 1.31. Much larger than $1/2$.
- Equivalently, this coefficient implies $\alpha \simeq 0.6$, which is too large.

Problem I: coefficients are too large

- Intuitively, observed differences in saving rates could explain cross-country income differences only if capital's share of income were much larger than the measured one.
- So this explanation attributes way too much importance to capital.
 - Tension between α that (i) makes sense for labor share (recall production function discussion) & (ii) is needed to explain y vs. s
 - How should we interpret this failure of the model?

Why does the regression have such good fit?

- To make sense of this, suppose the true model is:

$$\ln y^{j*} = \text{constant} + \frac{\alpha}{1-\alpha} \ln s^j - \frac{\alpha}{1-\alpha} \ln \delta^j + \underbrace{\beta^{other} X^{j,other}}_{\text{we called this } \varepsilon^j} + \tilde{\varepsilon}^j.$$

- Here, $X^{j,other}$ captures other factors that might affect the steady-state.
 - The true noise is given by $\tilde{\varepsilon}^j$, instead of our ε^j .
- What happens if $X^{j,other}$ is correlated with s^j ?

Why does the regression have such good fit?

- To make things extreme, suppose perfect correlation

$$\chi^{j,other} = b \ln s^j$$

for some $b \neq 0$.

E.g., an omitted factor is quality of capital & labor allocation across sectors (= productivity), and countries with high productivity also save a lot.

- Then, the equation can be rewritten as:

$$\ln y^{j*} = \text{constant} + \left(\frac{\alpha}{1-\alpha} + \beta^{other} b \right) \ln s^j - \frac{\alpha}{1-\alpha} \ln \delta^j + \tilde{\varepsilon}^j.$$

- If we ran a regression, we would find:

$$\text{estimated coefficient on } \ln s^j = \frac{\alpha}{1-\alpha} + \beta^{other} b.$$

- So we would be attributing the effect of other factors to savings.

Problem II: omitted variables

- This problem does not emerge if $X^{j,other}$ is uncorrelated with s^j . In that case, we might as well treat $\varepsilon^j = \beta^{other} X^{j,other} + \tilde{\varepsilon}^j$ as noise.

This is why MRW have to assume ε^j is uncorrelated with s^j .

- But is this a reasonable assumption? Would you expect $X^{j,other}$ to be correlated or uncorrelated with s^j in practice?

Outline

1. Regression analysis

Solow model and cross-country income regressions

Extension: Solow model with human capital

2. Calibration exercise

Solow model with human capital

- MRW recognize these problems with their basic analysis.
- To address them, they augment the Solow model with human capital.
 - **Human capital:** attributes that can be improved and that make labor more productive (education, training, health, ...).
 - Likely to be important for cross-country income differences, just as they are for within-country income inequality
 - Conceptually similar to capital, in that it can be accumulated.
 - Idea: including human capital may allow us to explicitly account for some of the omitted variables that go into the error term = it's as if we are measuring part of A^i
- Let's change the model to capture human capital accumulation ...

Solow model with human capital

- Suppose output is given by:

$$Y_t = AK_t^\alpha H_t^\beta L_t^{1-\alpha-\beta},$$

where H_t denotes **human capital** and $\alpha > 0, \beta > 0, \alpha + \beta < 1$.

- So human capital is treated as a separate factor of production.
 - This is somewhat unnatural but simpler for a regression analysis. Intuitively, it seems more natural that human capital improves labor, i.e., something like

$$Y_t = AK_t^\alpha (h_t L_t)^{1-\alpha}$$

where h_t is human capital per labor.

- We will study this alternative, more natural variant at the end of this lecture.

Solow model with human capital

- Households can invest in education as well as machines.
- As before, it is more convenient to work in intensive form. Define:

$$y_t = \frac{Y_t}{L_t} \text{ and } k_t = \frac{K_t}{L_t} \text{ and } h_t = \frac{H_t}{L_t}$$

and note that:

$$y_t = Ak_t^\alpha h_t^\beta.$$

- Accumulation rules
 - Suppose a constant fraction of output, $s_k y_t$, is invested in capital.
 - Also another constant fraction, $s_h y_t$, is invested in human capital.

This presumes that the same technology can be used to produce the current consumption good (“ice cream”), future physical capital (“machines”), and future human capital (“education”).

Solow model with human capital

- For simplicity, we continue to assume $n = 0$. The dynamics of the economy are then described by:

$$\begin{aligned}k_{t+1} &= s_k A k_t^\alpha h_t^\beta + (1 - \delta) k_t, \\h_{t+1} &= s_h A k_t^\alpha h_t^\beta + (1 - \delta) h_t.\end{aligned}$$

- This looks complicated. But conceptually similar to before. Starting with k_0, h_0 , can roll forward to solve $\{k_t, h_t\}_{t=0}^\infty$.
 - Before we had a single ordinary difference equation, with one initial condition. Now we have two single ordinary difference equations, with two initial conditions.
 - Before the steady state was a resting point k^* for the single type of capital. Now it is a resting point (k^*, h^*) for the two types capital.

Steady state with human capital

- How do we solve for the steady state? We plug $k_{t+1} = k_t = k^*$ and $h_{t+1} = h_t = h^*$ in the above two equations and solve them for (k^*, h^*) .
- There is again a trivial steady state with $k = h = 0$, we focus on the unique one with positive stocks. This is given by:

$$k^* = \left(\frac{A s_k^{1-\beta} s_h^\beta}{\delta} \right)^{1/(1-\alpha-\beta)} \quad \text{and} \quad h^* = \left(\frac{A s_k^\alpha s_h^{1-\alpha}}{\delta} \right)^{1/(1-\alpha-\beta)}.$$

And output per labor is given by $y^* = A (k^*)^\alpha (h^*)^\beta$.

- Direct channels (intuition?):
 - Higher s_k raises k^*
 - Higher s_h raises h^*
- Indirect channel: higher s_k now also raises h^* , and has a greater ultimate impact on output than before. On the next slide, the coefficient in front of $\ln s_k$ is bigger than $1/(1-\alpha)$...

Cross-country regressions with human capital

- These expressions imply

$$\begin{aligned}\ln y^{j*} &= \frac{\ln A^j}{1 - \alpha - \beta} + \frac{\alpha \ln s_k^j}{1 - \alpha - \beta} + \frac{\beta \ln s_h^j}{1 - \alpha - \beta} - \frac{(\alpha + \beta) \ln \delta^j}{1 - \alpha - \beta} \\ &= \text{constant} + \frac{\alpha \ln s_k^j}{1 - \alpha - \beta} + \frac{\beta \ln s_h^j}{1 - \alpha - \beta} - \frac{(\alpha + \beta) \ln \delta^j}{1 - \alpha - \beta} + \varepsilon^j.\end{aligned}$$

- The second line rewrites the TFP term as before. Assume ε^j is uncorrelated with s_k^j, s_h^j, δ^j as before. Then we can run a similar regression as before.
- But there is a measurement challenge. What is it?

How to measure human capital savings?

- The major challenge for running this regression is measuring s_h . Unlike s_k , human capital investments are hard to observe.
- Various challenges even if we (narrowly) focus on schooling.
- MRW's measure for s_h : fraction of working-age population (15+) attending school.
 - What is the intuition behind this proxy?
 - Clearly imperfect. But for statistical purposes, it suffices to find something that is proportional to s_h (a proxy). Can you prove this? What happens if it's a noisy proxy, i.e. there is measurement error in the independent variable? Remember prior econometrics classes.
- Their measure ranges from 0.4% – 12%.
 - Developed countries typically around 10% – 12% (almost everybody goes to secondary school and large fraction goes college, but still modest fraction of working-age population)
 - Sub-Saharan African countries typically around 0.4% – 1% (few attend secondary school, almost nobody goes to college)

TABLE II
ESTIMATION OF THE AUGMENTED SOLOW MODEL

Dependent variable: log GDP per working-age person in 1985		
Sample:	Non-oil	Intermediate
Observations:	98	75
CONSTANT	6.89 (1.17)	7.81 (1.19)
$\ln(I/GDP)$	0.69 (0.13)	0.70 (0.15)
$\ln(n + g + \delta)$	-1.73 (0.41)	-1.50 (0.40)
$\ln(SCHOOL)$	0.66 (0.07)	0.73 (0.10)
$\bar{R}^2$	0.78	0.77

Evaluating the MRW results

- The coefficient on $\ln s_k$ is still significant and large, $\simeq 0.7$.
- The coefficient on $\ln s_h$ is also significant and large, $\simeq 0.7$.
- The coefficient on $\ln(n + g + \delta)$ is roughly equal to the negative of the sum of the aforementioned two coefficients, as the theory predicts.
- R^2 (fit of regression) is very large, almost 80%.
- The coefficients on $\ln s_k$ and $\ln s_h$ together imply $\alpha \simeq \beta \simeq 0.3$.

Evaluating the MRW results

- These results suggest variation in savings rates and schooling rates can explain about 80% of income differences!
- Moreover, they make quantitative sense: implied share of capital, α , is now much closer to $1/3$.
- If these findings are reliable, they have big impact on how we should think about growth and cross-country inequality.
- But are the results reliable? Can you think of any problems?
Hint: Remember the problems without human capital.

Problem I: magnitudes

- MRW obtain a reasonable α . But how about β ?
- Hard to measure β . But arguably related to returns to schooling.
 - Suppose Chad increases schooling rate from 0.4% to 12%.
 - According to the estimates, $\ln(y^{Chad,*})$ rises by:

$$\frac{\beta}{1 - \alpha - \beta} (\ln(12\%) - \ln(0.4\%)) = 0.7 \times \ln 30 \simeq 2.38.$$

- This means, $y^{Chad,*}$ increases by a large factor $e^{2.38} \simeq 10.8$.

Problem I: magnitudes

- Micro estimates from the US: worker with one more year of schooling earns about 6-10% more than a comparable worker.
- Now return to our experiment of Chad increasing its average schooling by 12 years. Then the impact of schooling should be in the following ballpark:

$$\text{rough lower bound} \quad : \quad (1.06)^{12} = 2.01$$

$$\text{rough upper bound} \quad : \quad (1.1)^{12} = 3.14$$

- The implied impact factor, 10.8, is way too large.
- Equivalently, the implied β is too large (unless we are willing to assume large externalities, i.e., my h increases your productivity & wage by a lot.)

Problem II: omitted variables

- Another potential problem (as before) is omitted variable bias.
- Suppose the country-specific productivity shifter is given by

$$\varepsilon^j = \beta^{other} X^{j,other} + \tilde{\varepsilon}^j,$$

where $X^{j,other}$ are **omitted factors** that affect productivity.

- If $X^{j,other}$ is correlated with s_k^j and/or s_h^j , then as before we would be attributing the effects of other factors to saving or schooling.
- Can you think of $X^{j,other}$ that could be correlated with s_k^j, s_h^j ?

General problem with Solow model: saving rates are exogenous. In reality they depend on things like the return to savings.

How about including more variables?

- Easterly-Levine (2001) redo the analysis by including other variables that could be related to a country's productivity, e.g., country's region, whether it is in OECD ...
- They find these other variables are also significant in the regression.
- Controlling for them, the coefficients on $\ln s_k$, $\ln s_h$ fall considerably.

MRW results after including more variables

TABLE 4. MRW Least Squares Regression Including Regional, Oil, and OECD Dummy Variables

Variable	Coefficient	Standard error	
OECD	0.999172	0.126361	OECD dummy: OECD countries have higher income (suggests higher TFP)
East Asia	8.040507	0.212161	
South Asia	7.593671	0.184937	
Sub-Saharan Africa	7.636055	0.207923	Region Dummies: South Asia and Sub-Saharan Africa seem to have lower TFP
Western Hemisphere	8.285468	0.136361	
Middle East and North Africa	8.345100	0.192838	
Europe	8.222288	0.161656	
OIL	0.618785	0.179383	
$\ln(s_k) \leftarrow$ MRW	0.168531	0.095305	Coefficients on savings and schooling lower
$\ln(s_h) \leftarrow$ MRWH	0.433868	0.089235	
R^2	0.812286	Mean dependent	

Outline

1. Regression analysis

Solow model and cross-country income regressions

Extension: Solow model with human capital

2. Calibration exercise

Calibrating productivity differences

- So it seems like simple regressions on s_k and h (or s_h) are assigning too much importance to physical and human capital.
- Differences in TFP are arguably important—even after controlling for observable differences in human capital such as schooling.
- To quantify the importance of A relative to s_k and h we will now take the model to data in a different way.
 - Instead of regression, directly measure the inputs to production & back out A residually.
 - We essentially did a version of this in Lecture 3, when we use the production model to decompose y differences into k and a residual A .
- What's new now?
 1. We add human capital (= addt'l factor of production)
 2. We account for the effect of A on k , guided by the Solow model theory

Based on Hall and Jones (1999).

A production function with human capital

- Suppose the production function is given by:

$$Y_t = AK_t^\alpha (h_t L_t)^{1-\alpha}.$$

- Here, h_t can be thought of as human capital per labor.
 - Unlike in MRW, we assume h_t makes labor more productive (as opposed to being a factor in and of itself). This is more natural if you think of schooling as increasing skill.
- We can also write this in per-labor terms as follows,

$$y_t = Ak_t^\alpha h_t^{1-\alpha},$$

where $y_t = Y_t/L_t$ and $k_t = K_t/L_t$ as before.

How to measure human capital?

- To make the theory operational, we need a measure of h_t . As before, this is quite challenging for a variety of reasons.
- Let's focus on the part that is easier to measure: schooling. But how exactly should we relate h_t to schooling years?
 - Let's try to use the micro estimates to schooling as our guide.
 - Consider a person with one unit of labor and human capital h_t . How much would this person earn in our model?

Measuring human capital from schooling

- In the model, the person would earn

$$h_t \frac{\partial Y_t}{\partial L_t} = h_t w_t.$$

We see that human capital multiplies wages, since it raises effective labor.

- Recall: According to micro estimates, an additional year of schooling also multiplies earnings by $1 + \phi$ where $\phi \approx 6\%$ to 10% .
- Let E_t denote the average years of schooling per worker. Our model would be consistent with the estimates if we take

$$h_t = (1 + \phi)^{E_t}$$

Measuring human capital form schooling

- This provides an operational method to calculate h_t .
- Suppose $\phi = 8\%$. Then a country with 12 years more of schooling will have $1.08^{12} \simeq 2.51$ times human capital.
 - In principle you can also use different ϕ 's for different levels of schooling (e.g., ϕ for earlier education generally thought to be higher). We'll abstract from that.
 - Also note that, by just using the micro estimates, we are implicitly assuming the absence of any further externalities.
- Barro-Lee constructed an international data set for schooling. Their human capital index, included in the PWT data set, is equal to h_t , i.e., it incorporates ϕ and E_t .

Calibrating productivity differences

- In sum, we have the production function:

$$y_t = Ak_t^\alpha h_t^{1-\alpha}$$

where h_t have been measured using $h_t = (1 + \phi)^{E_t}$ and k_t has been measured using $k_t = (1 - \delta)k_{t-1} + i_t$, as usual.

- From now on, take the data for k_t and h_t as given.
- Normalizing countries by the US, we obtain:

$$\frac{y_t^j}{y_t^{US}} = \underbrace{\left(\frac{k_t^j}{k_t^{US}} \right)^{1/3}}_{\text{explained by capital}} \underbrace{\left(\frac{h_t^j}{h_t^{US}} \right)^{2/3}}_{\text{by human capital}} \overbrace{\frac{A^j}{A^{US}}}^{\text{residual explained by productivity}} \quad (3)$$

- Once we measure y_t^j/y_t^{US} , k_t^j/k_t^{US} , h_t^j/h_t^{US} , we can back out A^j/A^{US} .

Accounting for the endogeneity of capital

- This would be a slight extension of what we did in Lecture 3.
- But in the meantime we learned that, once we model k -accumulation, some of the k -differences that we observe are due to A -differences.
 - So the first attempt overstates the importance of k .
 - How can we correct for that?
- Recall that the steady state of the Solow model satisfies,

$$s^j y^{j*} = \delta^j k^{j*} \text{ which implies } \frac{s^j}{\delta^j} = \frac{k^{j*}}{y^{j*}}.$$

The ratio, k^{j*}/y^{j*} , is thus not affected by A^j . It is informative about factors that affect k^j directly (such as s^j, δ^j).

Accounting for the endogeneity of capital

- Recall that we have the production function,

$$y_t = Ak_t^\alpha h_t^{1-\alpha}$$

- Take to the power $1/(1-\alpha)$ and divide by $y_t^{\alpha/(1-\alpha)}$ to have,

$$y_t = A^{1/(1-\alpha)} \left(\frac{k_t}{y_t} \right)^{\alpha/(1-\alpha)} h_t$$

When $\alpha = 1/3$, we have

$$y_t = A^{3/2} \left(\frac{k_t}{y_t} \right)^{1/2} h_t$$

- This relates output to k_t/y_t ratio [which is actually independent of A , and only depends on savings rate/depreciation] and h_t .
 - Note that A will now appear more important—exponent $3/2$. This is the amplification channel from the last lecture.

Calibrating productivity differences

- Let us normalize by the US as before to obtain:

$$\frac{y_t^j}{y_t^{US}} = \underbrace{\left(\frac{k_t^j / y_t^j}{k_t^{US} / y_t^{US}} \right)^{1/2}}_{\text{explained by } s, \delta} \underbrace{\frac{h_t^j}{h_t^{US}}}_{\text{by human capital}} \underbrace{\left(\frac{A^j}{A^{US}} \right)^{3/2}}_{\text{residual explained by productivity}} . \quad (4)$$

- Let's see the results from Hall and Jones (1999) ...

Calibrating productivity differences

- Difference in 1988 between the US and Niger:

$$\underbrace{\text{differences in } y}_{\text{Factor of 35}} = \underbrace{\text{contribution from } k/y \text{ ratio } (s_k, \delta)}_{\text{Factor of 1.5}} \times \underbrace{\text{contribution from human capital } h}_{\text{Factor 3.1}} \times \underbrace{\text{contribution from residual-productivity}}_{\text{Residual factor 7.7}}$$

- Results are representative of rich and poor country differences.
- So A -differences account for very large differences. Larger than those accounted by s_k -differences and h -differences.
- Capital seems even less important than in Lecture 2. Why?
 - Because now some of the role of capital has been assigned to A (which itself led to capital accumulation).

Results from Hall and Jones (1999)

TABLE I
PRODUCTIVITY CALCULATIONS: RATIOS TO U. S. VALUES

Country	Y/L	Contribution from		
		$(K/Y)^{\alpha/(1-\alpha)}$	H/L	A
United States	1.000	1.000	1.000	1.000
Canada	0.941	1.002	0.908	1.034
Italy	0.834	1.063	0.650	1.207
West Germany	0.818	1.118	0.802	0.912
France	0.818	1.091	0.666	1.126
United Kingdom	0.727	0.891	0.808	1.011
Hong Kong	0.608	0.741	0.735	1.115
Singapore	0.606	1.031	0.545	1.078
Japan	0.587	1.119	0.797	0.658
Mexico	0.433	0.868	0.538	0.926
Argentina	0.418	0.953	0.676	0.648
U.S.S.R.	0.417	1.231	0.724	0.468
India	0.086	0.709	0.454	0.267
China	0.060	0.891	0.632	0.106
Kenya	0.056	0.747	0.457	0.165
Zaire	0.033	0.499	0.408	0.160

Taking Stock

Taking stock

1. What we learn from MRW:

- Basic Solow model **qualitatively** consistent with income differences. Likely endogeneity issues, as saving rate differences are highly correlated with income differences.
- Solow model with human capital is **quantitatively** more successful. But:
 - Regression analysis still suffers from omitted variables bias.
 - Implied magnitudes inconsistent w/ micro-returns to schooling.
- MRW regressions are likely to attribute effects of A to s_k, s_h .

2. What we learn from the calibration exercise:

- A -differences are key even after accounting for differences in saving and human capital.
- Big picture & policy implications: seems like you can't save your way to growth. Still need productivity gains, otherwise diminishing returns set in.

What next?

- Recall the two key questions we started with:

1. What explains long-run growth?
2. What explains cross-country income differences?

We've seen that capital accumulation can't deliver 1. and is of limited importance for 2., which instead calls for a key role of A

- Thus will need to dig deeper into A
 - Next: changes in A also needed to generate long-run growth, so A is key for both objectives
 - Thus: try to understand determinants of A —technological progress, institutions, ...
- In the middle we'll have one detour: replace the Solow model's exogenous savings decision with “optimal” savings.

Why? Endogenizing savings decisions is intrinsically interesting & will give us the tools needed to later endogenize the decisions that lead to A changing over time (+ key for business cycles).

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14.05 Intermediate Macroeconomics
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