Introduction to Economics of Development

Technology, Innovation and Economic Growth

Some fun analysis of your exam results

1 . correlate exam1 quiz1 d_grad d_econ d_male d_sr d_miss2 d_lower d_undecided
(obs=40)

| exam1 quiz1 d_grad d_econ d_male d_sr d_miss2 > d_lower d_unde~d

examl	1.0000	_							
quizl	0.4483	1.0000							
d_grad	0.2056	0.1419	1.0000						
d_ēcon	0.3653	0.1186	0.3849	1.0000					
d_male	0.1277	0.0236	-0.1340	0.1741	1.0000				
d_sr	-0.0645	-0.1017	-0.1925	0.0667	0.2901	1.0000			
d_miss2	-0.0955	-0.1081	0.0658	0.0380	-0.0198	0.0380	1.0000		
d_lower	-0.2349	-0.0789	-0.2053	-0.3556	-0.1069	-0.3556	-0.1363	1.0000	
d_undecided	-0.3312	0.0407	-0.2313	-0.4006	-0.1985	-0.4006	-0.0386	0.6485	1.0000





Some fun analysis of your exam results

- 승규가는 위험하지만, 분만하거나는 가는 위하거에도 가득 받아갔어.

2	. reg examl	quiz1 d_econ d	_male						
	Source	55	df		MS		Number of obs	ä	40 5 24
	Model Residual	1074.91885 2462.98115	3 36	358. 68.	306284 416143		Prob > F R-squared		0.0042
	Total	3537.9	39	90.7:	153846		Root MSE	=	8.2714
- 2- 	examl	Coef.	std.	Err.	t	P> t	[95% Conf.	In	terval]
	quiz1 d_econ d_male _cons	 2.266255 6.630469 1.226393 71.3696	.7731 3.088 2.669 4.835	108 078 597 624	2.93 2.15 0.46 14.76	0.006 0.039 0.649 0.000	.6983139 .3675564 -4.1878 61.5625	3 1 6	.834197 2.89338 .640586 81.1767



Some fun analysis of your exam results

3 . reg exam1 quiz1 d_econ d_male d_lower d_miss2

Source	SS	df	MS		Number of obs	= 40 - 217
Model Residual	1125.86572 2412.03428	5 34	225.173143 70.9421848		Prob > F R-squared	= 0.0186 = 0.3182
 Total	3537.9	39	90.7153846		Root MSE	= 0.2180 = 8.4227
exam1	coef.	Std. B	Err. t	P> t	[95% Conf.	Interval]
quiz1 d_econ d_male d_lower d_miss2 _cons	2.19505 5.894872 1.089842 -2.344167 - <u>1.901724</u> 73.01251	.79359 3.3419 2.7232 3.228 3.5658 5.2944	906 2.77 927 1.76 232 0.40 511 -0.73 373 -0.53 136 13.79	0.009 0.087 0.692 0.473 0.597 0.000	.5822794 8967407 -4.444431 -8.90529 -9.148449 62.25292	3.80782 12.68648 6.624115 4.216957 5.345001 83.7721

Some Basic Concepts

• Labor productivity (LP): measured by output per labor-hour

Figure 1. Actual and Trend Changes in Output per Hour, NFPB Sector and Total Economy, 1950-2005





Some Basic Concepts

• Labor productivity: more recent US growth trend

Trend Productivity Growth (from Bob Gordon, 2/6/08)



Data: Gordon, Northwestern



Labor Productivity in OECD Countries



		La	bor Produc	Table tivity Gr	3 owth by (Country			
		1979-1995 1995-2003 Change							
	Total	Private	Difference	Total	Private	Difference	Total	Private	Difference
US	1.15	1.72	0.57	2.41	3.53	1.12	1.27	1.81	0.54
EU-15	2.38	2.87	0.49	1.66	1.95	0.29	-0.71	-0.92	-0.21
Tigers	2.38	2.91	0.53	3.98	4.79	0.81	1.60	1.88	0.28
Ireland	4.03	4.35	0.32	6.83	8.23	1.40	2.80	3.88	1.08
Finland	3.09	3.98	0.89	2.61	3.40	0.79	-0.49	-0.58	-0.09
Greece	0.93	1.38	0.45	2.94	3.32	0.38	2.01	1.94	-0.07
Middle	2.46	2.98	0.52	2.03	2.45	0.42	-0.43	-0.53	-0.10
Sweden	1.72	2.65	0.93	1.87	2.95	1.08	0.15	0.30	0.15
Austria	2.82	3.39	0.57	2.14	2.85	0.71	-0.68	-0.54	0.14
United Kingdom	2.42	2.95	0.53	2.22	2.70	0.48	-0.21	-0.25	-0.04
Germany	2.29	2.67	0.38	2.12	2.47	0.35	-0.16	-0.20	-0.04
Portugal	3.06	3.61	0.55	1.92	2.39	0.47	-1.14	-1.22	-0.08
France	2.75	3.38	0.63	1.87	2.10	0.23	-0.88	-1.28	-0.40
Tortoises	2.26	2.69	0.43	0.69	0.72	0.03	-1.57	-1.97	-0.40
Belgium	2.47	2.95	0.48	1.37	1.77	0.40	-1.10	-1.18	-0.08
Netherlands	2.05	2.34	0.30	1.18	1.63	0.45	-0.87	-0.71	0.16
Denmark	2.37	3.09	0.72	1.01	1.32	0.31	-1.37	-1.77	-0.41
Luxembourg	4.28	4.63	0.35	0.91	1.09	0.18	-3.37	-3.54	-0.17
Spain	2.63	2.97	0.34	0.72	0.64	-0.08	-1.91	-2.34	-0.42
Italy	2.06	2.48	0.42	0.51	0.46	-0.05	-1.55	-2.02	-0.47
Asian tigers	6.12	6.58	0.46	5.64	6.77	1.13	-0.47	0.19	0.67
Continental Europe	2.35	2.84	0.49	1.48	1.70	0.22	-0.86	-1.14	-0.28
	1 08	2 42	0.44	2.31	2.72	0.41	0.33	0.30	-0.03



Labor Productivity Growth: US vs. Europe



Labor Productivity Growth: US vs. Europe with longer history Ratio of Europe to the United States, Output per Capita and Output per Hour, selected years, 1820-2000







Some basic concepts

- Multi-Factor Productivity (MFP)
- Total Factor Productivity (TFP)
- They are the same, just different names
- The *growth rate* of TFP is measured as the growth rate of output less the growth rate of combined inputs of labor and capital.

$$Y = A \cdot F(K, L) = A \cdot K^{0.3} L^{0.2} \qquad \Rightarrow \quad g_y = w_K \cdot g_K + w_L \cdot g_L + g_a$$

For example:

1995: Y=100, K=50, L=20 2000: Y=130, K=80, L=25 g(Y)=30%, g(K)=60%, g(L)=50%

 \rightarrow g(TFP)=30%-(0.3)*60%-(0.2)*25%=7%, which is 1.4% per year on average.

Compare to 6% per year output growth, TFP accounts for 23% of total growth (1.4% / 6%) Now what about *share of growth rate* of capital and labor, respectively?

• TFP measures the productivity gain, aside from capital deepening and labor augmenting. It is the "Solow Residual" we mentioned before.

Longest-Run Economic Growth Once Again



Rough	World Ave	erages	
Year	Population	Income	althusian stagnation
-8000	5	\$500	
0	170	\$500	
1500	500	\$500	
1800	750	\$600	
1900	1500	\$1200	
2007	6300	\$7000	
		Towar	d a human world?
Period	Real GDP Growth	TFP Growth (1)	
-8000-0	0.04%	0.01%	
0-1500	0.07%	0.02%	
1500-1800	0.2%	0.09%	
1800-1900	1.38%	0.89%	
1900-2007	3.38%	2%	\sum
(1) alaba=0	2: hata=0.0		Where is the innovation?
(1) alpha=0.	.3; beta=0.2		
	1		
	Produ	ction function pa	rameters





Some basic concepts

• TFP level across countries





TFP Growth: Major Developed Economies

30% -20% -10% -0% -

Canada

US

UK

France Germany

Italy

Japan

	1960-1995 Ye	early Average	
Country	TFP growth %	Output growth %	Share of TFP growth
Canada	0.57	2.24	25%
US	0.76	2.11	36%
UK	0.8	1.89	42%
France	1.3	2.68	49%
Germany	1.32	2.66	50%
Italy	1.53	3.19	48%
Japan	2.65	4.81	55%
TFP gro	wth relative to out 1960-	out growth in G7 c 1995	ountries
40%			



TFP Growth: Asian Tigers

	1966-1	990 yearly average	
Country	TFP growth %	output growth %	Share of TFP growth
Singapore	0.2	8.7	2%
Korea	1.7	10.3	17%
Taiwan	2.6	9.4	28%
Hong Kon	g 2.3	7.3	32%
35% –		1966-1990	
30% -			
25% -			
20% -			
15% -			
10% -			
5% -			
0% +			
	Singapore	Korea Taiwar	n Hong Kong
	Singapore	Korea Taiwar	n Hong Kor

What's Happening 3/13/08





Dollar, Credit Roil Markets

Stocks dropped sharply as the dollar dropped below 100 yen for the first time and signs of trouble in the credit markets increased. An unexpected drop in U.S. retail sales compounded anxiety about the health of the broader economy. Gold futures moved above \$1000 an ounce.



Gold price, dollar per ounce, London PM fix



Jan-0Q/ul-0Q/an-01/ul-01/an-02/ul-02/an-03/ul-03/an-04/ul-04/an-05/ul-05/an-06/ul-06/an-07/ul-07/an-08



Recession Update

Most Economists Say Recession Has Arrived as Outlook Darkens

By PHIL IZZO March 13, 2008

The U.S. has finally slid into recession, according to the majority of economists in the latest Wall Street Journal economic-forecasting survey, a view that was reinforced by new data showing a sharp drop in retail sales last month.

"The evidence is now beyond a reasonable doubt," said Scott Anderson of Wells Fargo & Co., who was among the 71% of 51 respondents to say that the economy is now in a recession.

and of Capital Deepening, Country Onits a									5, 1900	-2004	a.	
		1980-95								1995-2004	1	
	LP	TFP	ICT TFP	Non-ICT TFP	ICT Capital Deepen	non-ICT Capital Deepen	LP	TFP	ICT TFP	Non-ICT TFP	ICT Capital Deepen	non-ICT Capital Deepen
United States	1.41	0.59	0.31	0.28	0.66	0.16	2.53	1.40	0.55	0.84	0.79	0.34
EU-15	2.34	1.16	0.20	0.96	0.42	0.76	1.46	0.64	0.26	0.38	0.46	0.36
Tigers												
Ireland	3.60	2.81	0.09	2.72	0.17	0.66	5.20	3.35	0.28	3.07	0.55	1.31
Finland	2.35	1.27	0.31	0.96	0.47	0.75	3.10	2.73	0.38	2.35	0.56	-0.18
Greece	0.10	-0.33	0.10	-0.43	0.10	0.32	2.90	1.86	0.40	1.46	0.38	0.67
Middle												
Sweden	1.59	0.58	0.31	0.27	0.49	0.51	2.60	1.60	0.39	1.21	0.75	0.25
Austria	1.64	0.55	0.14	0.40	0.40	0.69	2.30	1.04	0.29	0.74	0.47	0.79
United Kingdom	2.46	1.31	0.32	0.99	0.45	0.70	2.10	1.26	0.29	0.97	0.62	0.27
Germany	2.70	1.64	0.16	1.48	0.47	0.62	1.80	0.99	0.21	0.78	0.40	0.39
Portugal	2.37	1.58	0.16	1.42	0.24	0.55	1.60	0.40	0.29	0.11	0.47	0.75
France	2.39	0.92	0.12	0.79	0.29	1.18	2.10	1.01	0.20	0.80	0.32	0.75
Tortoises												
Belgium	2.09	0.94	0.30	0.64	0.69	0.46	1.90	1.06	0.44	0.62	0.70	0.09
Netherlands	1.72	0.93	0.18	0.75	0.44	0.35	0.80	0.40	0.38	0.02	0.39	-0.04
Denmark	2.35	1.11	0.34	0.77	0.64	0.59	1.80	0.31	0.41	-0.10	0.74	0.82
Luxembourg	3.13	1.74	0.28	1.47	0.76	0.63	1.40	0.49	0.33	0.16	0.42	0.51
Spain	2.78	1.61	0.20	1.41	0.32	0.85	0.00	-0.43	0.26	-0.69	0.27	0.14
Italy	1.99	0.91	0.21	0.70	0.35	0.73	0.50	-0.39	0.25	-0.64	0.41	0.50



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European Economy Snapshot

GDP (PPP) 2007		GDP (PPP)	13 🛌 Czech Republic	207,174	20,100
Member States	millions of	per capita 2007	14 🚺 Portugal €	190,882	18,300
European Union	12 172 536	24 700	15 E D enmark	171,298	30,900
1 Germany €	2 340 372	28 300	16 💳 Hungary	166,031	15,800
2 🚟 United Kingdom	1 847 105	29,300	17 ∎ Ireland €	157,070	36,200
3 EFrance €	1 744 444	27 200	18 🛨 Finland €	153,595	29,400
4 Italv €	1 500 475	25 200	19 💼 Slovakia	88,602	16,700
5 Spain €	1 121 961	25,200	20 🚃 Bulgaria	86,500	9,500
6 Netherlands €	530 564	32 600	21 🚃 Lithuania	50,241	14,900
7 Poland	525.277	13,500	22 💼 Slovenia €	44,040	22,400
8 ■ ■ Belaium €	319,867	29.700	23 📥 Latvia	33,630	14,500
9 Sweden	274.499	30,700	24 🚍 Luxembourg €	31,376	70,400
10 Austria €	264.472	31,800	25 💻 Estonia	23,919	17,900
11 🔚 Greece €	246.671	24.500	26 < Cyprus €	17,773	22,700
12 II Romania	208,220	10,000	27 * 📕 Malta €	7,824	19,100



TFP Growth: US vs. Europe



Some basic concepts

• Growth accounting: source of growth analysis

$$g_Y = (w_K \cdot g_K) + (w_L \cdot g_L) + \varepsilon$$
 "Solow Residual"

We have seen the residual can be just TFP growth:

 $g_{y} = W_{K} \cdot g_{K} + W_{L} \cdot g_{L} + g_{a}$

But TFP may be just part of the story.

The residual may also be due to other factors, one of such is institutions:

$$g_{y} = w_{K} \cdot g_{K} + w_{L} \cdot g_{L} + g_{a} + g_{z} + \varepsilon$$

What could be these institutions?



Growth Accounting: an example

DENISON: SOURCES OF GROWTH OF LABOR PRODUCTIVITY, 1950-62^a

		Of v	vhich			Of w	hich		
	Growth of Labor Productivity	Labor ^e	Capital	Residual (TFP)	Advance in Knowledge	Reduced Technology Gap and N.E.C.	Improved Resource Allocation	Economies of Scale	GDP per Man-hour (1950) ^b
Japan	6.45	0.77	1.17	4.57	1.	41	1.07	1.88	14
Italy	5.36	0.54	0.57	4.29	0.76	0.88	1.42	1.22	32
Germany	5.15	-0.12	0.93	4.43	0.75	0.83	1.00	1.59	33
France	4.80	0.37	0.76	3.67	0.76	0.74	0.95	1.00	44
The Netherlands	3.65	0.09	0.78	2.79	0.75	0.43	0.63	0.77	53
Norway	3.27	0.02	0.85	2.41	0.76	0.18	0.92	0.57	48
Belgium	2.64	0.36	0.28	2.02	0.76	0.07	0.51	0.51	50
Denmark	2.56	-0.11	0.77	1.94	0.75	-0.27	0.67	0.64	43
United States	2.15	0.22	0.60	1.36	0.75		0.29	0.36	100
United Kingdom	1.63	0.10	0.37	1.18	0.75	0.04	0.12	0.36	56

What's Happening 3/18/08



Fed Cuts Rates by 3/4 Point

A divided Fed cut interest rates by three-quarters of a percentage point to 2.25%, delivering less than the markets hoped for despite the magnitude of the move. The central bank highlighted growth risks, but discussed inflation concerns. (Statement)

The Federal Open Market Committee decided today to lower its target for the federal funds rate 75 basis points to 2-1/4%.

Recent information indicates that the outlook for economic activity has weakened further. Financial markets remain under considerable stress, and the tightening of the credit conditions and the deepening of the housing contraction are likely to weigh on economic growth over the next few quarters.



Unravel Growth Puzzle: New Wave

- Solow treated technology as exogenous, or falling off like "manna from heaven" (quote: economist magazine)
- Two promising routes to explain the "Solow Residual"
 - One is to find out besides technology what could be important in the residual. One of such is institutions. There could be others.
 - Another way is to explain how the technology came about in the first place. This has been done through enriching the original production function by incorporating some of the factors previously treated exogenously back into the function. This is the process of endogenizing.
- So theories like this are called *Endogenous Growth Theory* or *New Growth Theory* in comparison to Solow's neoclassical growth model. It was due to the seminal research done by Paul Romer (1990)

You can further listen to and read Romer's insights on economic growth at: <u>http://www.econtalk.org/archives/2007/08/romer_on_growth.html</u>



Unravel Growth Puzzle: New Wave

Previously we have:

$$Y = F(K, L)$$

Now we could

• separate labor into two kinds: one is unskilled, one is skilled

 $Y = F(K, L_H, L)$

• or divide capital into two kinds: physical capital and human capital

Y = F(K, H, L)

• There are many possibilities: you could also include R&D, technology spillover, etc.

Human Capital and Labor Productivity





log output per worker relative to the US









Human Capital and Personal Income



Note: All men and women ages 30–39, including those with no personal income, are included in these estimates. Source: Brookings tabulations of data from the Annual Social and Economic Supplement to the CPS, 1965–2006.



Technology Transfer, Adoption & Economic Growth

- Easterly outlined three vivid channels technology can transmit into economic growth
 - Leaks
 - Matches
 - Traps
- Matches and traps are different side of the same coin: one is positive externality and creates a *virtuous cycle*; the other is negative externality and it creates a *vicious cycle*.
- Another important implication from Easterly's analysis: technology is not something falling off from the sky, people need incentives:
 - to invest in R&D and invent new technology
 - to invest in human capital and education
 - to adopt technology and utilize them for their own benefits



From Technology to R&D

Figure 1 Evolution of the R&D intensity (DIRD/GDP) in Japan, in the USA and in Europe, 1981-2005



Source: OECD, MSTI (2007)



From Technology to R&D

Figure 2 R&D Intensity (DIRD/GDP) across the EU countries, the USA and Japan, 1991 and 2005



Source: OECD, MSTI (2007)



Incentives for R&D Investment

- Answer these questions:
 - What is the right incentive to give for firms (people) to engage in R&D, which involves huge initial investment, meanwhile the prospect of success is very remote and uncertain?
 - Given technology and knowledge's huge positive externalities, what could be done to solve the dilemma between the desire to make technology free or cheap to the public while avoid damaging the incentives to innovate, i.e., making profits by risk taking?
 - Looking back in human history, we're in an era full of ideas and creativities. We have created so many things we never dreamed before. Will human being run out of ideas, and next-generation-innovations become much harder than now, given the high level and huge stock of knowledge we have had?
 - Will technology also suffer diminishing returns? If so, what could be the policy to overcome this limit?



Competition, Innovation and Growth

The idea of "Creative Destruction"

Joseph Schumpeter:

"The process of industrial mutation.....that incessantly revolutionizes the economic structure from within, incessantly destroying the old one, incessantly creating a new one. This process of <u>Creative Destruction</u> is the essential fact about capitalism."

Creative destruction, or the "churn" process, removes vested old interests that are often less productive and detrimental to new innovations, and replaces them with more productive ones. Overall in longer term, it helps to overcome the fatal yet powerful law of diminishing returns, and put the country on a higher and more sustained growth trajectory.

Such competition could happen among domestic firms, but more likely foreign competition will help to expedite the process. This is another benefit of <u>economic</u> <u>openness</u> people often ignored...Shall I also remind you to have *the same readiness for change as the West Europeans before 1800s.*