ECONOMIC GROWTH

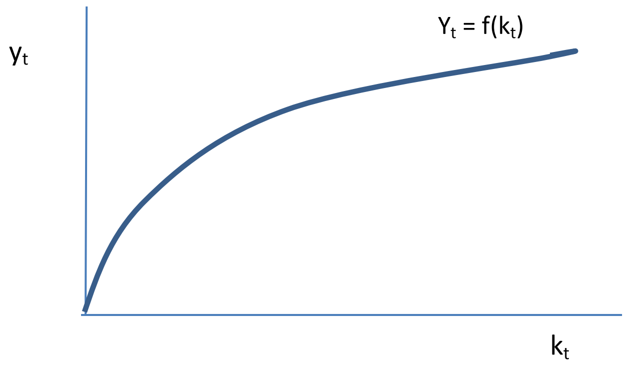
The Solow Growth Model

Define:
N_t = population at time t = employed workers at time t [everyone works]
n = growth rate of N
Y_t = output produced at time t
K_t = capital stock at time t
I_t = gross investment at time t
C_t= consumption at time t

Assume no Government (G) and no Foreign Sector :

Define per-worker variables:
$y_t = Y_t / N_t$ = output per worker at time t
$k_t = K_t / N_t$ = capital stock per worker at time t
$c_t= C_t / N_t$ = consumption per worker at time t

Define the per-worker production function:
$y_t = f(k_t)$



As k_t increases y_t increases (the curve is upward-sloping)
As k_t increases, the marginal increase in production per worker decreases and the curve becomes flatter as k_t increases. This is because with a fixed (at any one point in time) labour force, there are decreasing returns to expanding capital.

The economy reaches a steady state when output per worker (y), consumption per worker (c), and capital per worker (k) are constant (do not change over time)

Because K/N is constant in a steady state, then K must grow at the rate n (the rate of change of N):

$K_{t+1} = (1+n)K_t$

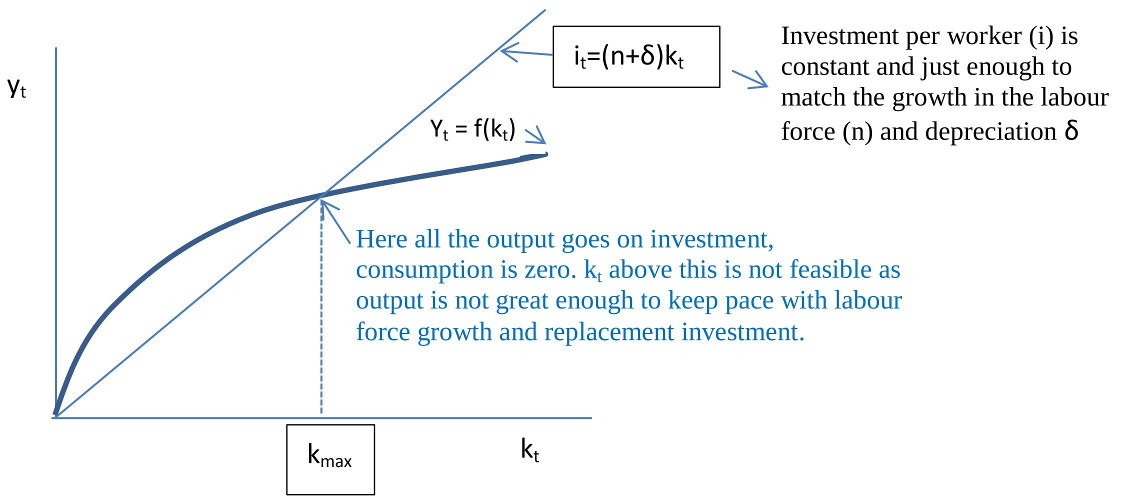
Recall that
$I_t = K_{t+1}-K_t + \delta Kt$

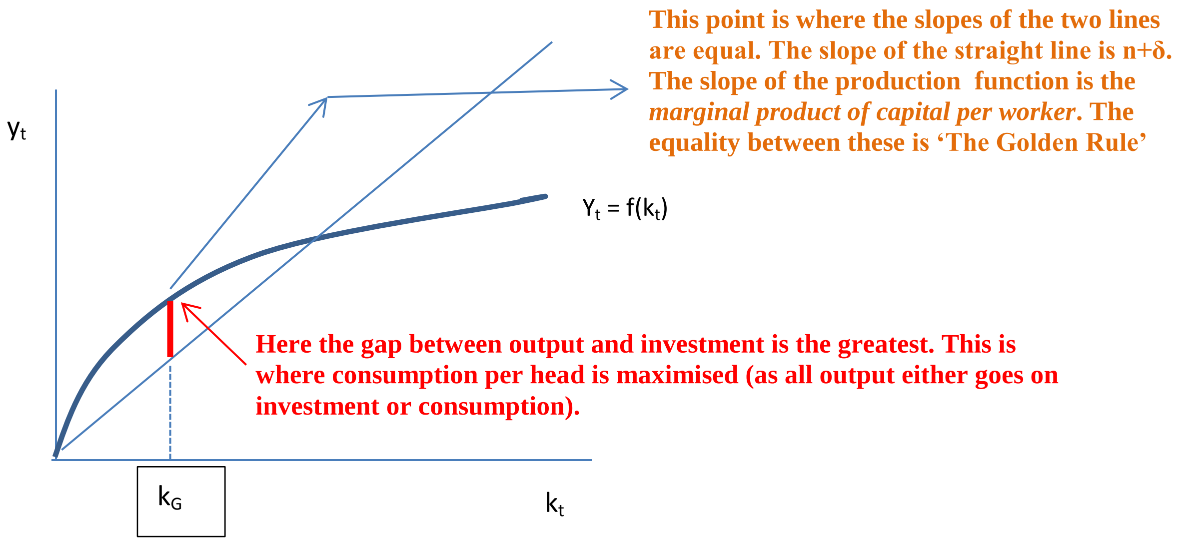
δ is the rate of depreciation of capital stock [replacement investment]. If δ=0.1 then we have to replace 10% of the capital every time period just to keep capital constant.

Then in the steady state it must be that

$I_t = (n+\delta)*K_t$ or (in per worker terms): $i_t = (n+\delta)*k_t$

Investment in accordance with this equation is just enough to keep capital per worker constant, taking into account the rate of growth of the population (and hence labour force) and the rate of capital depreciation.



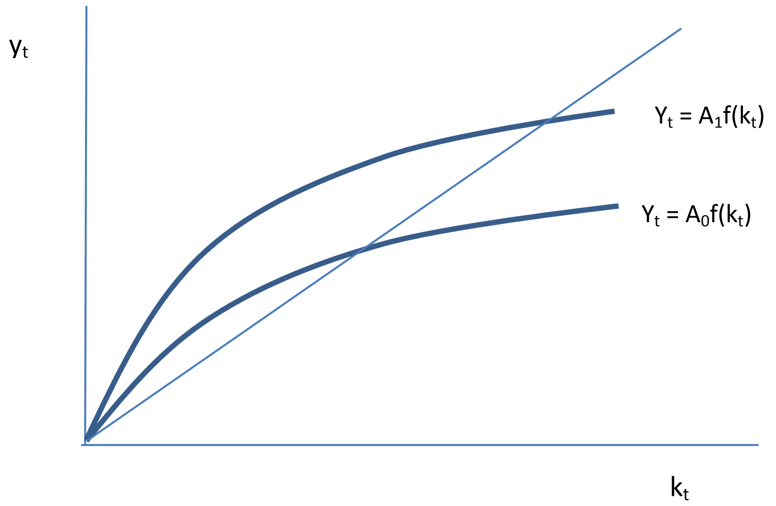


The Golden rule states that if we wish to maximise consumption, the marginal product of capital (per worker) should equal the rate of population growth + depreciation of capital. If we increase output beyond this then we get more output but all the extra output [and indeed more] goes into maintaining capital stock per worker constant. (Remember more capital, more depreciation). However less than this and we can increase output *and consumption.*

Endogenous Growth

The Solow model as we have shown it suggests that once we have reached the steady state there is no more growth per worker (the economy may only grow because of n, population growth). We can easily modify this by introducing the level of productivity (A) into the model:

$y_t = Af(k_t)$



$A_1 > A_0$ and hence this has shifted the production function outwards, this will increase potential output and consumption at the Golden rule. Note too it *may* increase the optimal level of capital per worker, but this depends upon what happens to the production function.

In an empirical study over 50 years ago, Solow compared growth rates across countries and across time, documented how much growth could be traced to growth of inputs of labour and capital via a standard production function, and attributed the unexplained part of economic growth to unmeasured technical progress. This unexplained element has been called 'the **Solow residual'.** In a sense it measures our ignorance about economic growth, and economists have spent the last 50 years trying to explain more and more of it. In reality there is not that much mystery. It is linked to quality of labour force, whether the country has a coast line (facilitates exports), quality of governance, extent of corruption, the rule of law. It is also linked to 'knowledge'.

The Solow model implies that the only source of long-run growth is productivity. It assumes that this is ***exogenous*** (determined outside the model, and taken to its logical conclusion outside government control) productivity growth that leads to long-run growth of output per worker. The ***endogenous*** growth model tries to explain productivity from 'within the model'. We look at the AK model. The initial work was done by Paul Romer.

For simplicity, assume that the number of workers is now constant (n=0). This means that changes in labour no longer have an impact on output and we can rewrite the production function as:

$Y = AK$

The impact of labour is included in A. This production function has constant marginal productivity of capital. There is no diminishing marginal productivity of capital. This is because of R&D and human capital (i.e. knowledge, skills, training). As economies accumulate K they become richer and invest more in human capital and in R&D (increasing A). If in a country human capital or R&D raise, then productivity raises. In this version of the endogenous growth rate model, the saving rate affects long-run growth. Higher saving stimulates K, that increases Y, that increases investment in human capital and R&D and that increases A. This endogenously increases productivity and hence spur growth. Government policy to stimulate saving is important here. Also they can:

- Stimulate human capital (education, health, training)
- Stimulate R&D

I find the AK model too simplistic and 'convenient', just why does technology make the coefficient on K=1? Why not:

$Y = AK^{0.9}$

If this is the case there are diminishing returns to capital and eventually growth comes to an end. What is valuable however is the insight that technical progress – which has always been in the production function - is now seen as ***endogeneous***. Taking this forward, it can be linked to R&D. R&D generates new inventions.

But inventions by themselves are not innovations, that needs the intervention of 'the entrepreneur' – someone who brings the invention to the market. Hence innovation – and hence technical progress – can also be linked to governance, corruption and intellectual property rights (IPRs). Entrepreneurs find it difficult to prosper in a corrupt economy, where corruption is at best a tax on innovation and profits and at worse can be a death sentence for the entrepreneur. IPRs – e.g. patents – ensure that the entrepreneur – or the inventor – get the rewards from their work. When a new drug is patented, then only that firm can produce that drug for so many years.

But technical progress in a country also depends upon the research done in other countries. Innovations made in California, spread to the rest of the USA and also to other countries (note it may arrive in London faster than Danville Kentucky. Hence growth may respond to the ability of a country to absorb foreign innovations. This will depend upon the skills of the workforce, factors which impact on the entrepreneur (corruption, rule of law, tax regimes), trade and foreign direct investment (FDI) which brings the country into contact with outside ideas.

Another version of the endogenous growth captures some of this. Define production of goods as:

$Y_t = F(K_t, A_t L_{Yt})$

A_t is the state of technical progress or knowledge. L_{Yt} the labour force working on the production of output. Not all of the labour force are engaged in this way, a fraction s_R are engaged in 'producing knowledge':

$L_{At} = s_R L$

Where L is the total labour force. A impacts on the efficiency of L_{Yt} . We could think of another model where it impacts on K instead/as well, but not in this lecture. Capital accumulation is defined similarly as before:

$K_{t+1} = (1 - \delta) K_t + sY_t$

δ is again depreciation and s the savings rate. Assume knowledge advances in the following manner:

$A_{t+1} - A_t = \rho A^{\varphi}_t L^{\lambda}_{At}$

λ can be regarded as the marginal product of labour in producing knowledge. ρ is a scale factor and φ is a variable reflecting the limits to the growth of knowledge. Rearranging we get:

$(A_{t+1} - A_t)/ A_t = \rho A^{\varphi-1}_t L^{\lambda}_{At} = \rho_t L^{\lambda}_{At}/(A^{1-\varphi}) = g_A$

g_A is the rate of technological progress and depends upon the parameters ρ, s_R, L ($L_{At}=s_R L$) and λ. In equilibrium these are constant (no population growth in this model, we could add it) and hence g is constant. There are three possibilities:

$\varphi<1$ In this case as A increases so does $A^{1-\varphi}$ and g_A declines
$\varphi=1$ In this case $g_A = \rho_t L^{\lambda}_{At}$ and there is no reason for g_A to either increase or decrease in the long run, the growth of knowledge is constant
$\varphi>1$ and $-(1-\varphi) = \varphi-1 = \pi>0$ In this case $g_A = \rho_t L^{\lambda}_{At} A^{\pi}$ as A increases so g_A increases also. In this case there are increasing returns to knowledge generation, the more we know, the faster we learn, which arguably describes the state of affairs at the beginning of the 21st century. [Note in this we have used: $\rho_t L^{\lambda}_{At}/(A^{1-\varphi}) = \rho_t L^{\lambda}_{At} A^{-(1-\varphi)} = \rho_t L^{\lambda}_{At} A^{(\varphi-1)}$].

The important point is that countries can influence growth, it is no longer determined by factors outside their control. The key parameter is φ in the knowledge production function. The key variable is the proportion of labour (and in more sophisticated models capital) which is allocated to knowledge generation. There is a trade off, the more labour that is allocated to knowledge, the less will be in production industries and the lower will be output and consumption today. But the greater will be the growth of knowledge and hence production, output and living standards in future years. Defining workers who work in the knowledge industries is a little difficult, but certainly the university sector is one where knowledge generation is significant. But all of this is done in an abstraction where there is just a single country. recognising the existence of other countries complicates the situation in two ways. Firstly, because knowledge is developed in country A it does not mean it will be exploited by firms living in country A. Research is becoming global and often benefits multinational firms from countries other than country A. Secondly, there is the possibility that countries can benefit from knowledge developed in other countries. In this case the key factors are (i) how quickly do they gain access to new knowledge and (ii) at what cost (direct costs e.g. paying for licenses and indirect ones, in learning about the knowledge and adopting it to local conditions). It is also apparent from the knowledge production function;

$A_{t+1} - A_t = \rho A^{\varphi}_t L^{\lambda}_{At} = \rho A^{\varphi}_t (s_A L)^{\lambda}$

where L is the total labour force and s_A the proportion of that labour force in knowledge production, that larger countries with a bigger labour force (L) will see more rapid growth in knowledge. Again this is reasonable as they have more resources to devote to knowledge generation. To a considerable extent the knowledge generating countries are the large ones.

We will return to endogenous growth in a mathematical appendix, but for now consider convergence.

Convergence

The Solow growth model implies that each country has the same steady state and, whatever the level of capital per worker with which an economy begins, the model implies that it will eventually converge to this steady state. Poor countries with a low inheritance of capital grow extra rapidly until they reach the steady-state growth rate of output and capital; rich countries just maintain their high level of capital per worker at its steady-state level k^*.

This explanation for convergence relies purely on the effect of capital accumulation. A second explanation for convergence or ‘catch-up’ operates through a different channel, technical progress. Technical progress no longer falls out of the sky at a fixed rate (as in the Solow model). Suppose instead we have to invest real resources (universities, research labs, R&D) in trying to make technical improvements. It is rich countries that have the human and physical capital to undertake these activities, and it is in rich countries that technical progress is made. However, once discovered, new ideas are (potentially at least) soon disseminated to other countries.

Since poorer countries do not have to use their own resources to make technical breakthroughs, they can devote their scarce investment resources to other uses, such as building machines. By 'slipstreaming' the richer countries, they can temporarily grow faster. But if innovation always occurs first in the rich countries, the USA, Germany, Japan, and if it takes time for this to be diffused to other countries. Then the rich will always have a permanent advantage over others. This suggests that there are limits to convergence, we can expect to see permanent differences between countries.

Does convergence occur?

The table below shows World Bank estimates of per capita income in 1970 and 2010 and the growth rate. East Asian economies such as China [not shown in the data] and South Korea grew very quickly during the last 40 years. India is also now growing strongly. Yet convergence cannot be a powerful force in the world or the very poorest countries would all be growing very rapidly. In reality, many poor countries stay poor and sometimes even decline in absolute terms.

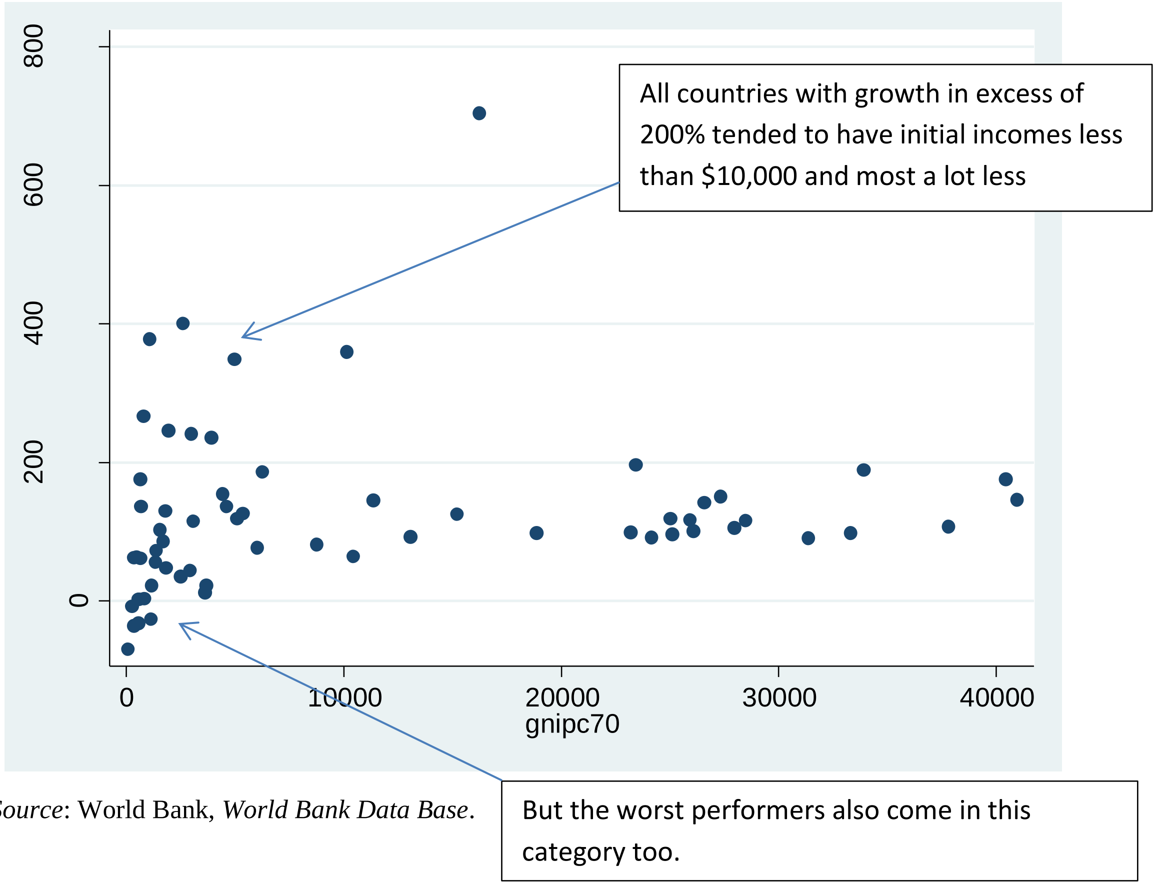
We could analyse this formally by regressing growth in GDP per capita (g_t) over a period say 30 years (e.g. 1980-2010) on GDP per capita at the beginning of this 30 year period (Y_{1980}):

$$g_t = \alpha + \beta Y_{1980}$$

This regression is done for a range of countries if analysing convergence across countries, or regions if analysing convergence within countries). For convergence $\beta<0$, i.e. richer countries grow more slowly and vice versa. Do the regression is β significantly negative? We will not be doing that, but explore the issue diagrammatically.

The figure below plots the final column, the growth of per capita income between 2010 relative to 1970, on the vertical axis, and on the X axis plots 1970 per capita income (in terms of Gross National Income, similar to GDP). The figures shows that some countries have taken advantage of catch up. The fastest growing countries tend to be the poorest, but it also shows that many other poor countries perform very poorly. What is it that means that some of the poorest countries do so badly? Why the difference between success and failure? On that there is a lot of literature.

Growth in GNI per capita constant US$ 1970-2010 compared to GNI in 1970



Source: World Bank, *World Bank Data Base*.

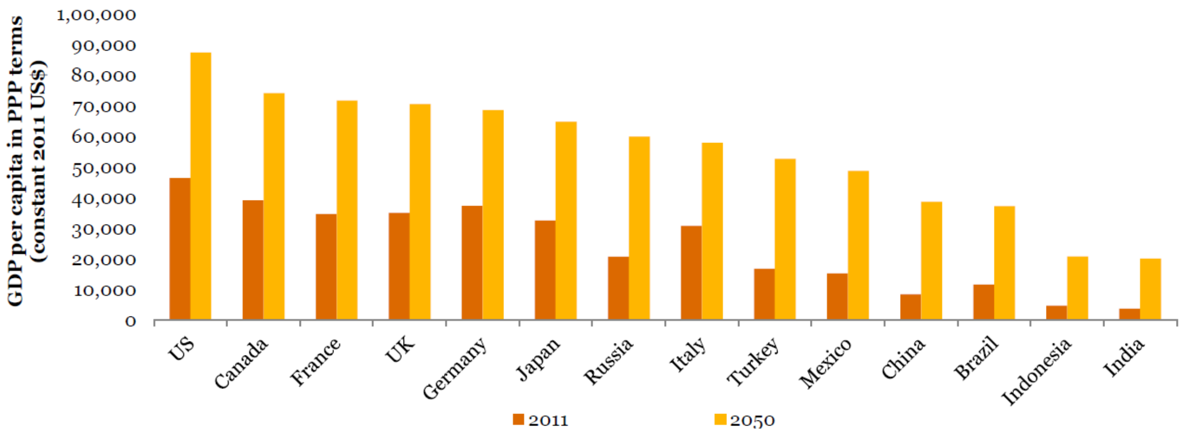
	country	gnipc70	gni~2010	growth
8.	Argentina	10442.7	6362.38	64.1318
11.	Australia	24154.3	12584.2	91.94096
12.	Austria	26580.6	11002.4	141.5891
19.	Belgium	25027.7	11456	118.4676
24.	Bolivia	1173.63	963.501	21.80944
27.	Brazil	4627.96	1959.94	136.1278
33.	Cameroon	645.389	400.744	61.04767
34.	Canada	25103.1	12787.7	96.30671
40.	Chile	6253.42	2185.15	186.1784
42.	Colombia	3077.79	1436.46	114.2623
44.	Congo, Dem. Rep.	98.84	330.619	-70.10456
45.	Congo, Rep.	819.261	799.607	2.457971
46.	Costa Rica	5092.11	2332.87	118.2765
47.	Cote d'Ivoire	562.707	827.893	-32.03142
49.	Cuba	4429.86	1741.77	154.3309
53.	Denmark	31383.3	16451.8	90.75943
56.	Dominican Republic	3921.3	1167.22	235.952
57.	Ecuador	1694.69	910.944	86.03671
58.	Egypt, Arab Rep.	1939.6	560.355	246.1375
59.	El Salvador	2492.33	1847.16	34.92793
66.	Finland	27349.5	10920	150.4537
67.	France	23192.7	11655	98.99399
69.	Gabon	3614.95	3235.35	11.73296
72.	Germany	25930.3	11965.7	116.7048
74.	Greece	13076.8	6780.76	92.85146
78.	Guatemala	1808.47	1224.78	47.6571
83.	Honduras	1343.95	862.337	55.84944
85.	Hungary	5362.77	2379.23	125.3992
86.	Iceland	27968.8	13604.1	105.5906
87.	India	786.624	214.979	265.9075
88.	Indonesia	1088.83	227.968	377.6271
91.	Ireland	23420.8	7912.16	196.0098
94.	Italy	18855.6	9542.66	97.59258
96.	Japan	40957.2	16623.5	146.382
99.	Kenya	468.109	286.924	63.14729
102.	Korea, Rep.	16242	2019.17	704.3906
109.	Lesotho	645.862	234.443	175.4879
114.	Luxembourg	33898.5	11743.3	188.6629
119.	Malaysia	4981.4	1111.52	348.1592
122.	Malta	10157.8	2211.32	359.3559
124.	Mauritania	594.179	582.893	1.936312
126.	Mexico	6043.65	3425.52	76.43012
132.	Morocco	1800.11	783.59	129.7259
137.	Netherlands	26084.7	13011.8	100.4698
140.	Nicaragua	1138.16	1548.65	-26.50602
144.	Norway	40436.2	14683.2	175.3906
146.	Pakistan	688.09	291.155	136.3314
150.	Paraguay	1546.64	763.919	102.4614
151.	Peru	2930.99	2039.66	43.69992
152.	Philippines	1386.84	804.184	72.45334
154.	Portugal	11351.3	4622.99	145.5412
159.	Rwanda	349.746	215.706	62.13983
164.	Senegal	554.558	543.742	1.989265
174.	South Africa	3672.6	2994.44	22.64732
176.	Spain	15219.8	6759.58	125.1586
185.	Sweden	33323.9	16834.5	97.94983
190.	Thailand	2604.22	520.44	400.3882
192.	Togo	264.266	288.351	-8.352837
195.	Tunisia	2987	874.26	241.6599
203.	United Kingdom	28481.6	13197.7	115.8066
204.	United States	37808.2	18219.3	107.5173
205.	Uruguay	8779.56	4839.6	81.41089
213.	Zambia	361.447	564.048	-35.91908

With this understanding, what should we expect for the next 40 years, long after the consequences of the financial crash have worked themselves out [Hopefully]? Global consultancy PricewaterhouseCoopers make projections for the future. They estimate population growth, the evolution of skills and human capital, investment in physical capital, and rates of technical progress and its dissemination across countries. From this information, they make estimates of future growth in GDP.

http://www.pwc.com/en_GX/gx/world-2050/assets/pwc-world-in-2050-report-january-2013.pdf

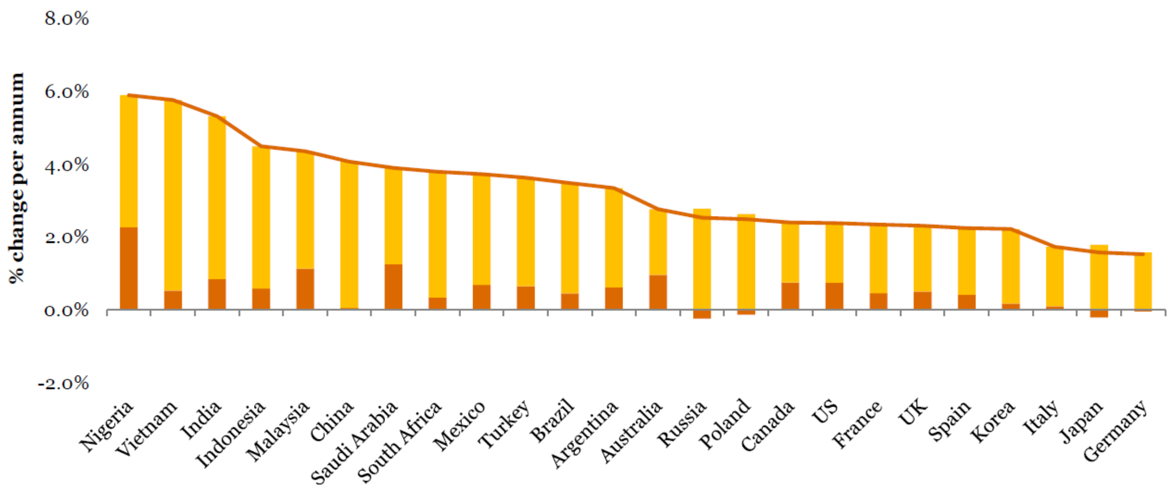
The chart below shows GDP capita. All countries are set to become more prosperous with the developing countries gaining most.

Chart 8: GDP per capita levels in PPP terms for the G7 and E7 economies



When we look at GDP rather than GDP per capita we see the high growth countries are all in the developing world.

Chart 1: Breakdown of components of average real growth in GDP at PPP (2011 – 2050)

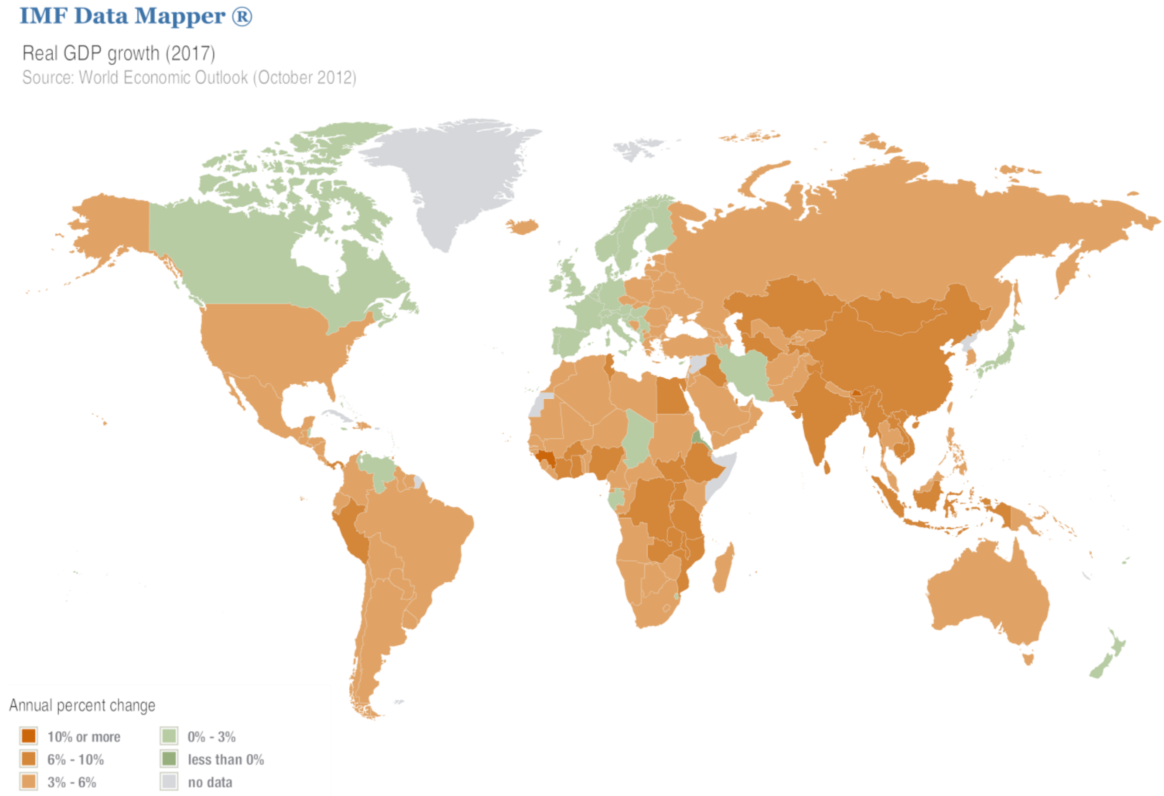


The table below shows that by 2030 China will have overtaken the US in terms of the size of its economy, and by 2050 India will be close behind. Then we have a group of second rank countries. In 2011 6 countries were from the west (including Japan) with four in the EU. By 2050 the west will only have 4 members in the top 10 and the EU (just) two.

Table 2: Actual and projected top 20 economies ranked based on GDP in PPP terms

	2011		2030		2050	
PPP rank	**Country**	**GDP at PPP (2011 US$bn)**	**Country**	**Projected GDP at PPP (2011 US$bn)**	**Country**	**Projected GDP at PPP (2011 US$bn)**
1	US	15,094	**China**	30,634	**China**	53,856
2	**China**	11,347	US	23,376	US	37,998
3	India	4,531	India	13,716	India	34,704
4	Japan	4,381	Japan	5,842	**Brazil**	8,825
5	Germany	3,221	**Russia**	5,308	Japan	8,065
6	**Russia**	3,031	**Brazil**	4,685	**Russia**	8,013
7	**Brazil**	2,305	Germany	4,118	**Mexico**	7,409
8	France	2,303	**Mexico**	3,662	**Indonesia**	6,346
9	**UK**	2,287	**UK**	3,499	Germany	5,822
10	Italy	1,979	France	3,427	France	5,714
11	**Mexico**	1,761	**Indonesia**	2,912	**UK**	5,598

The poorer countries have more rapid GDP growth not merely because they have opportunities for productivity catch-up but also because they often have more rapid population growth. Whether this will continue until 2050, as assumed in the table, is hard to assess at this juncture. The middle-income countries (Malaysia through to Poland) are expected to have fewer opportunities for rapid productivity growth, and in the case of Eastern Europe and Russia, may actually experience falling populations. This helps their per capita growth – capital widening is less of a burden – but not their aggregate GDP growth. ***Of course forecasting the future is difficult, subject to massive uncertainties. Climate change, unexpected increases in raw material prices, new technological advances, new diseases, could all impact on this scenario. It also assumes the countries remain as they are now. They may not. They may break up. They may forge unions.***

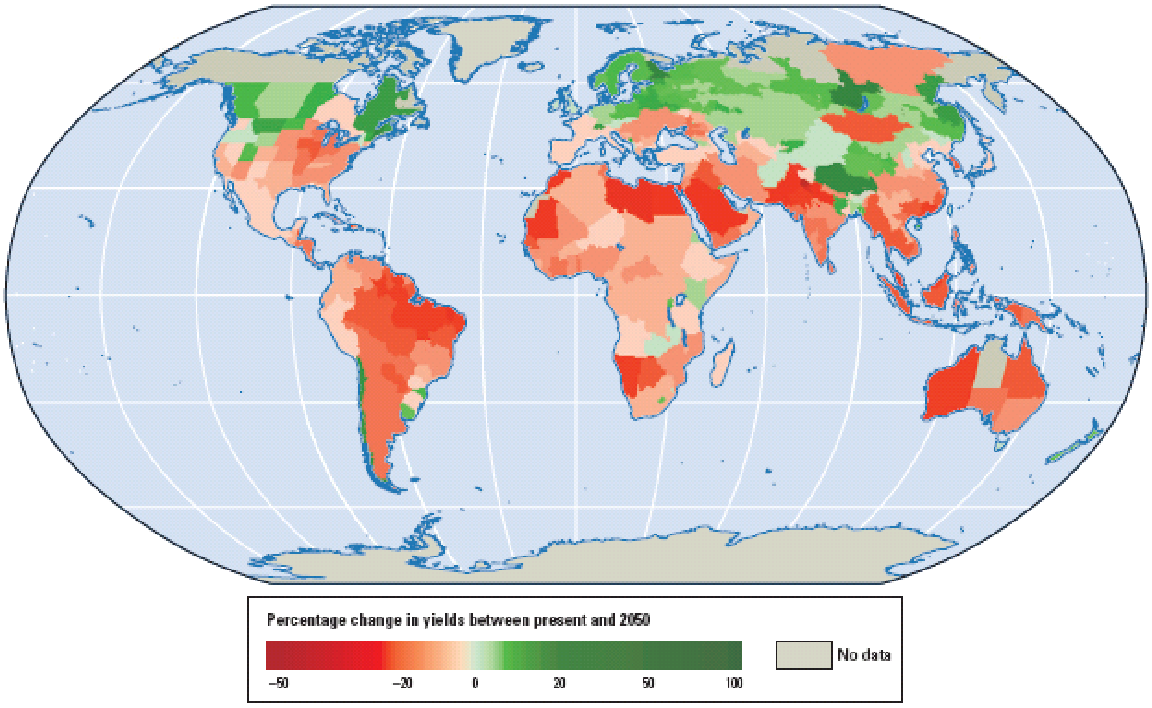


http://www.imf.org/external/datamapper/index.php

Post Script I A 'Slight' problem

Climate change is a real problem. It has many aspects. Most, but not all countries, will lose. Coastal areas will disappear. Many major cities are on coastal areas and are at risk. Below is one aspect of this taken from the World Development Report 2010 "Development and Climate Change".

Map 3.3 Climate change will depress agricultural yields in most countries by 2050 given current agricultural practices and crop varieties



Source: Müller and others 2009.

Note: The figure shows the projected percentage change in yields of 11 major crops (wheat, rice, maize, millet, field pea, sugar beet, sweet potato, soybean, groundnut, sunflower, and rapeseed) from 2046 to 2055, compared with 1996–2005. The values are the mean of three emission scenarios across five global climate models, assuming no CO_2 fertilization (see note 54). Large negative yield impacts are projected in many areas that are highly dependent on agriculture.

We now turn to an in depth study of why some countries have succeeded and others have not. Once more this is also to alert you to the large amount of material which you can access.

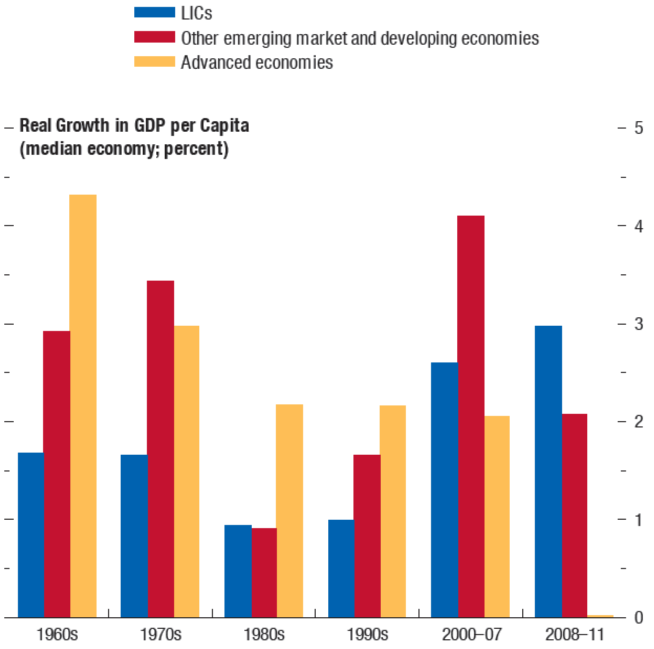
http://www.imf.org/external/pubs/ft/weo/2013/01/pdf/text.pdf

Chapter 4 above helps shed light on just why some countries have been successful and others not. All the diagrams which follow are taken from this chapter. This has relevance for regional economics. Convergence studies have not just been limited to convergence between countries, but also convergence between regions within countries. In addition that factors which facilitate some countries to ‘catch up’ or done well can also help poorer regions do better.

The diagram below shows that since the 1990s LICs (low income countries) have been performing increasingly well, a performance not really affected by the economic crisis. Why is this?

Figure 4.1. Economic Performance of Low-Income Countries and Others

Low-income countries (LICs) have seen a major improvement in their economic performance since the 1990s. Growth in output per capita for the median LIC has increased since the 1990s. It is now higher than median growth in other economy groups.



Sources: IMF, World Economic Outlook database (October 2012); Penn World Table 7.1; World Bank, World Development Indicators database; and IMF staff calculations.
Note: Economy groups and indicators are defined in Appendix 4.1. Real GDP per capita is in purchasing-power-parity terms. The 2008–11 median of real GDP per capita growth of advanced economies is near zero (0.02 percentage point).

The table below lists some economic take offs since 1990. ***A 'growth take-off' is identified as an upswing in LIC output per capita that lasts at least five years, with average annual growth in real output per capita during the upswing of at least 3.5 percent.*** Together, these criteria identify 29 growth take-offs during 1990–2011 (Table 4.1) and 41 episodes in earlier decades (Table 4.2).

Panel 2 shows the total number and share of LICs that either took off or sustained an ongoing take-off. It suggests that there were two waves of take-offs, one from the mid-1960s to the early 1970s and one beginning in the 1990s. The frequency of growth take-offs declined after 2008, in part because of lack of up to date data, but also because of a drop in the share of LICs that had sustained their take-offs. Nevertheless, despite the Great Recession, one-third of LICs still sustained their take-offs as of 2011 compared with an average of 20 percent during the 1980s.

Table 4.1. Takeoffs in Low-Income Countries, 1990–2011

Economic Structure	Country	Start	End[1]	Duration (years)[2]	Average Annual Real GDP per Capita Growth (percent)[3]
Predominantly Agricultural	Sudan	1994		18	4.62
	Rwanda	1995		17	6.93
	Kyrgyz Republic	1996	2008	13	3.65
	Liberia	1996	2002	7	17.54
	Nigeria[4]	1996	2008	13	4.70
	Lao P.D.R.[4]	1999		13	6.10
	Sierra Leone	2000		12	5.87
	Ethiopia	2004		8	7.09
	Liberia	2006		6	4.12
Predominantly Manufacturing	Sri Lanka	1992	2000	9	4.39
	Yemen[4]	1992	1998	7	5.12
	Cambodia	1996		16	5.63
	Bangladesh	1997		15	3.93
	Tajikistan	1997	2007	11	6.20
	Indonesia[4]	2000		12	3.76
	Moldova	2000	2008	9	6.00
	Sri Lanka	2002		10	4.88
Predominantly Nonrenewable Resource and Forestry	Azerbaijan	1997	2010	14	11.97
	Chad	1997	2005	9	6.55
	Zambia	2000	2008	9	4.70
	Angola	2002	2009	8	10.72
	Georgia	2002		10	6.28
	Ghana	2002		10	4.59
	Mongolia	2002	2008	7	6.22
	Uzbekistan	2002		10	6.04
Other (no specialized economic structure)	Mozambique	1996		16	5.78
	Tanzania	1997		15	4.10
	Afghanistan	2002	2007	6	13.15
	Malawi	2002		10	4.32

Source: IMF staff calculations.

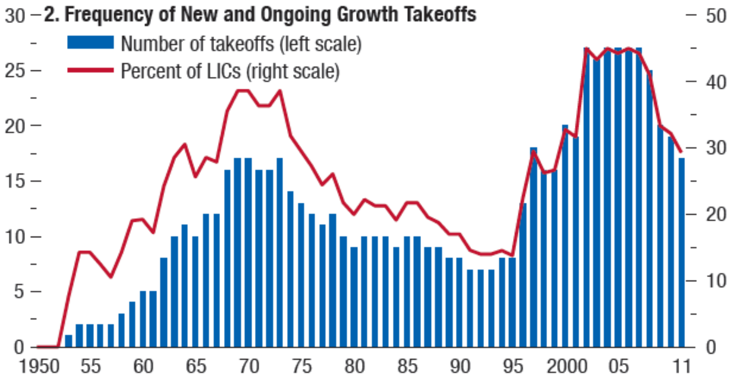
Note: The table lists emerging market and developing economies that started with real output per capita (purchasing-power-parity-adjusted constant 2005 U.S. dollars) below the time-varying threshold at the beginning of the episode and grew at an average rate of 3.5 percent or higher for at least five years at any time since 1990. See Appendix 4.1 for details on how the economic structure classifications are derived. Countries in red were experiencing or recovering from a serious external or internal conflict at the start of their takeoffs. See Appendix 4.1 for the definition of conflict and the source of the conflict data.

[1]Ongoing takeoffs as of 2011 are left blank.

[2]Ongoing takeoffs as of 2011 use duration as of 2011.

[3]Ongoing takeoffs as of 2011 use average growth as of 2011.

[4]Countries are also validly classified as predominantly nonrenewable resource and forestry producers.



Global conditions helped spur LIC takeoffs, but there was obviously more at play. Figure 4.3 documents the behavior of global growth, the U.S. real interest rate (as a proxy for global interest rates), and terms-oftrade growth underlying LIC takeoffs before and after the 1990s. Each global indicator is presented in three snapshots:

- its average level during the five years before takeoff,
- five years after takeoff,
- and during years six to ten after takeoff.

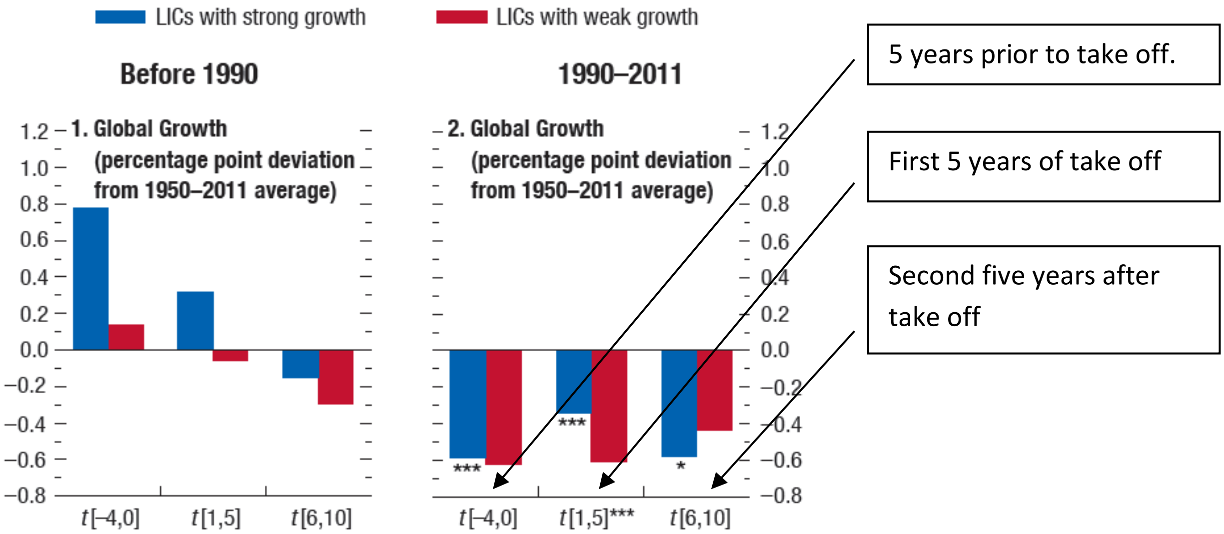
Compared with pre-1990 takeoffs, recent takeoffs started under weaker global growth and higher global interest rates. However, global growth and interest rate conditions tended to improve after takeoff for the current generation, whereas they deteriorated for the previous generation.

Comment seems a bit ad hoc and what does it mean anyhow? Are they saying that prior to 1990 take off was dependent on a favourable global economic climate but afterwards less so? But why? In part an answer follows below JH.

Figure 4.3. The Global Environment behind Low-Income Countries' Growth Takeoffs

(Median economy; t = 1 in the first year of a strong or weak growth episode)

Global growth and interest rate conditions tended to improve after takeoff for the current generation, whereas they deteriorated for the previous generation. Terms-of-trade growth tended to improve during takeoffs for both generations.



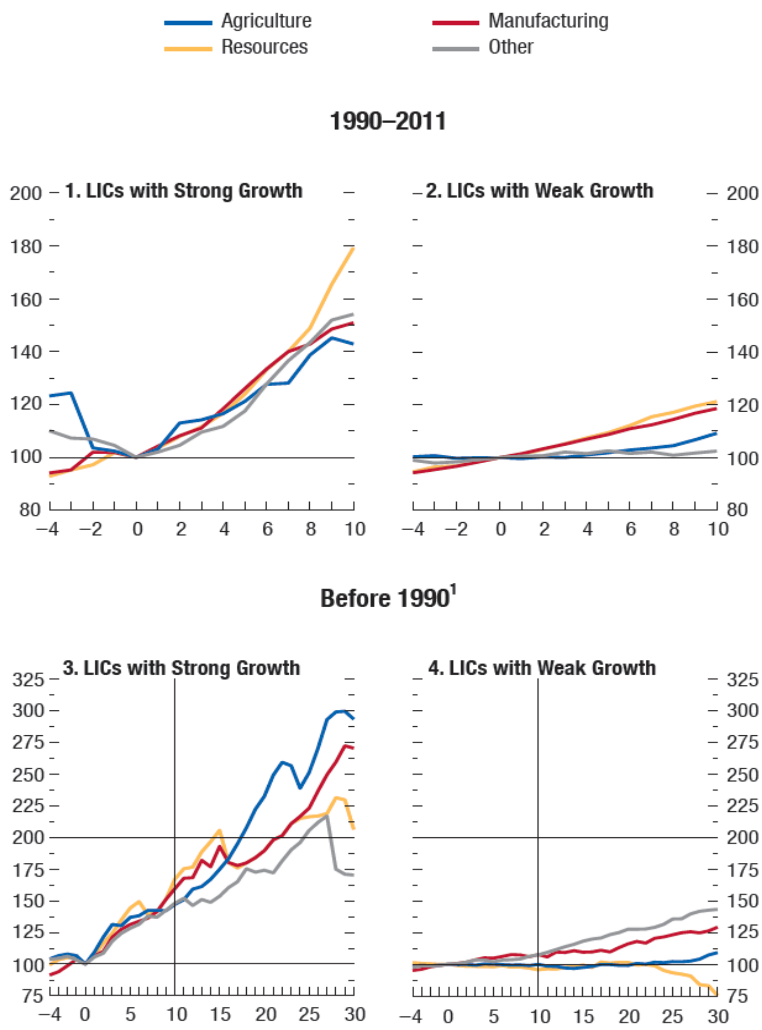
Sources: Haver Analytics; IMF, World Economic Outlook database (October 2012); Penn World Table 7.1; World Bank, World Development Indicators database (2012); and IMF staff calculations.

Note: LICs = low-income countries. Economy groups and indicators are defined in Appendix 4.1. LICs exclude countries experiencing or recovering from a serious external or internal conflict at the start of their takeoffs. See the text for definitions of strong and weak growth episodes (takeoffs are strong growth episodes). See Appendix 4.1 for the definition of conflict and the source of the conflict data. *, **, and *** denote statistically significant difference in distributions (based on the Kolmogorov-Smirnov test) at the 10 percent, 5 percent, and 1 percent levels, respectively. Significance tests on the *x*-axis are for the difference in the distributions between the groups of strong and weak growth. Significance tests on the blue bars are for the difference in the distributions across 1990–2011 and before 1990 (not shown for red bars). A constant composition sample underlies each of the panels to ensure comparability within the group of strong and weak growth episodes across time for that panel.

Figure 4.5. Economic Structure and Real Output per Capita after Takeoff in Low-Income Countries

(Median economy; normalized to 100 at t = 0, the year before the start of a strong or weak growth episode; years on x-axis)

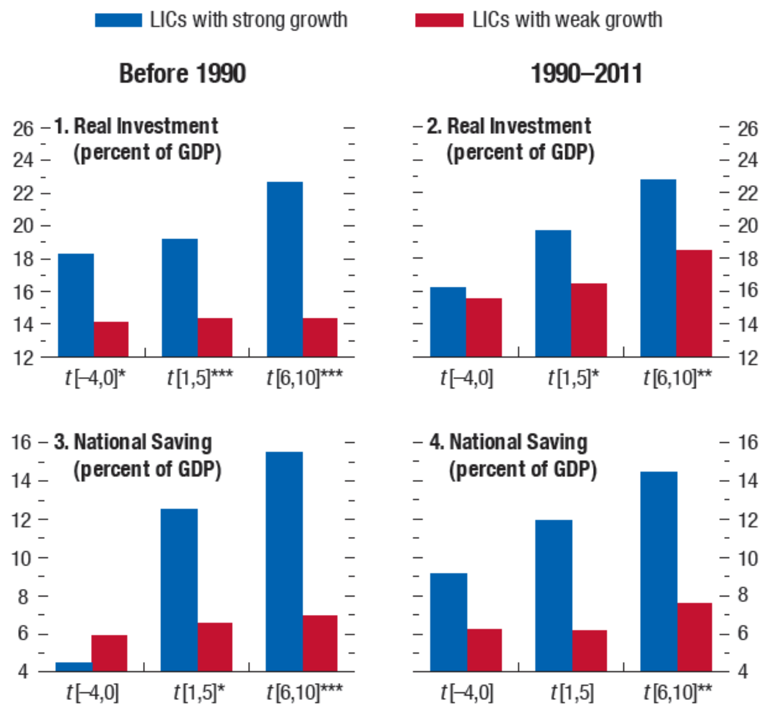
Among the current generation of dynamic low-income countries (LICs) resource-rich LICs have typically grown faster than others. For the previous generation, although resource-rich economies were also among the strongest performers during the first 10 years after takeoff, they were eventually overtaken by other LICs. Among the weak performers, resource-rich LICs experienced the slowest growth.



Source: IMF staff calculations.
Note: Economy groups and indicators are defined in Appendix 4.1. LICs exclude countries experiencing or recovering from a serious external or internal conflict at the start of their takeoffs. See the text for definitions of strong and weak growth episodes (takeoffs are strong growth episodes). See Appendix 4.1 for the definition of conflict and the source of the conflict data.
[1] The vertical line indicates the 10-year horizon.

Note how resource rich countries fared badly before the 1990s, an example of 'the resource curse', where resource rich countries do badly for a variety of reasons, some linked to exchange rate effects and some corruption. But since 1990 the 'resource curse' problem has, if not solved, at least reduced.

The Figures above emphasise just how much of the growth in successful LICs is down to resources. One wonders to what extent this is due to the rising price of raw materials and richer countries concerns about securing their supply lines. Arguably growth not based on resources, but manufacturing and services (other)is on a stronger footing.



Although both the current and previous generation of takeoffs coincided with strong investment growth, they differed significantly in how the saving-investment gaps were financed. Takeoffs in both generations were correlated with higher levels of investment and national saving rates compared with LICs that could not launch a growth takeoff (Figure 4.6, panels 1–4). **However, a larger share of the current account deficits was financed by Foreign direct investment (FDI) flows for the current generation of takeoffs compared with the previous generation** *[see diagram in publication]***.** FDI flows also rose sharply after takeoff for the current generation of dynamic LICs compared with both the LICs with weak growth and the previous generation of dynamic LICs (Figure 4.6, panels 7 and 8).

But will the LICs ultimately benefit from this In many cases the multinationals are associated with extraction of natural resources, mineral reserves and the like. The record of multinationals in putting benefits into the country is problematic. They are also often associated with corruption. John Hudson

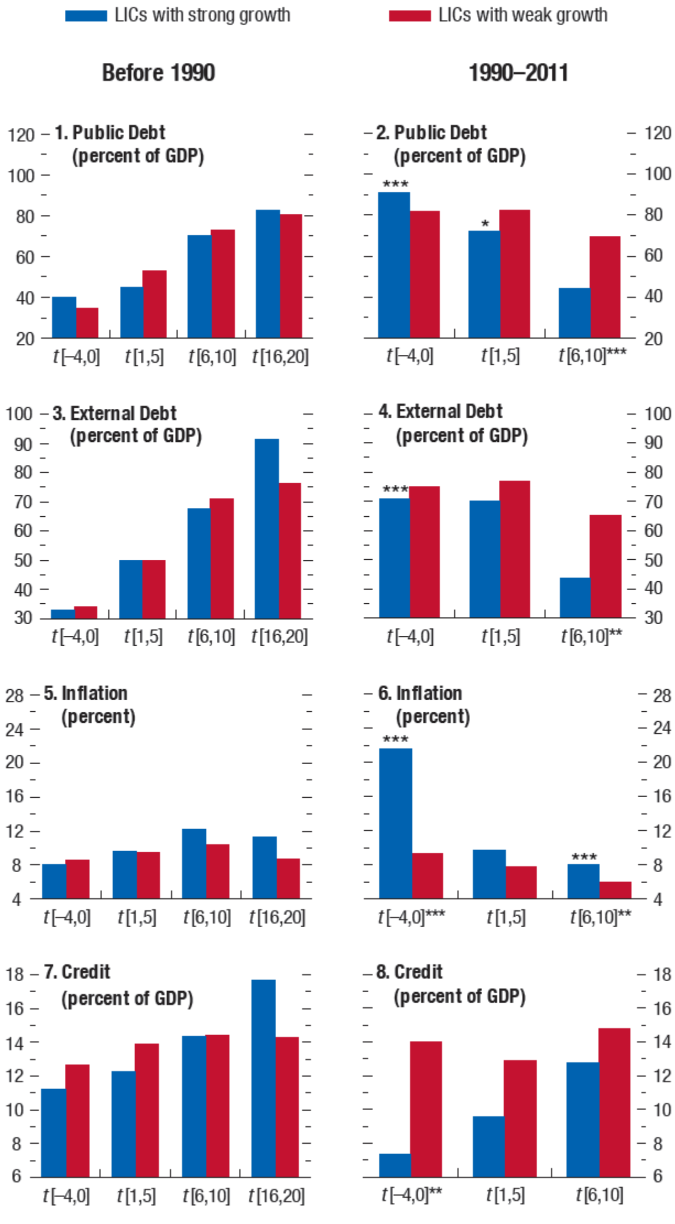
More reliance on FDI and greater macroeconomic policy discipline have fostered similarly strong growth but lower inflation after takeoff relative to dynamic LICs in the previous generation (Figure 4.7, panels 5 and 6). For the latter, public and external debt stood at 40 and 33 percent of GDP, respectively, before takeoff, but more than doubled within 10 to 20 years after takeoff, and inflation tended to increase as well.

Competitiveness and export growth are important for LIC takeoffs. Both today and in the previous generation, LICs with takeoffs experienced stronger export growth than LICs with weaker growth (Figure 4.8, panels 1 and 2, not shown here - in document). Today's LIC takeoffs tended to have more geographically diversified exports, which may be one reason they were able to sustain strong export growth—along with the fast growth in EMDEs such as China and India—despite anemic growth in advanced economies (Figure 4.8, panels 3 and 4). However, greater trade exposure to other EMDEs also implies greater exposure to risks to growth in the latter and the related risks to commodity prices.

Figure 4.7. Macroeconomic Conditions in Low-Income Countries

(Median economy; t = 1 in the first year of a strong or weak growth episode)

Recent takeoffs were characterized by sharp reductions in public and external debt levels and inflation. In contrast, previous-generation takeoffs were characterized by generally worsening macroeconomic conditions.



Sources: Abbas and others (2010); IMF, International Financial Statistics database; IMF, World Economic Outlook database (October 2012); Lane and Milesi-Ferretti (2007) updated to 2011; World Bank, World Development Indicators database (2012); and IMF staff calculations.

Note: LICs = low-income countries. Economy groups and indicators are defined in Appendix 4.1. LICs exclude countries experiencing or recovering from a serious external or internal conflict at the start of their takeoffs. See the text for definitions of strong and weak growth episodes (takeoffs are strong growth episodes). See Appendix 4.1 for the definition of conflict and the source of the conflict data. *, **, and *** denote statistically significant difference in distributions (based on the Kolmogorov-Smirnov test) at the 10 percent, 5 percent, and 1 percent levels, respectively. Significance tests on the *x*-axis are for the difference in the distributions between the groups of strong and weak growth. Significance tests on the blue bars are for the difference in the distributions across 1990–2011 and before 1990 (not shown for red bars). A constant composition sample underlies each of the panels to ensure comparability within the group of strong and weak growth episodes across time for that panel.

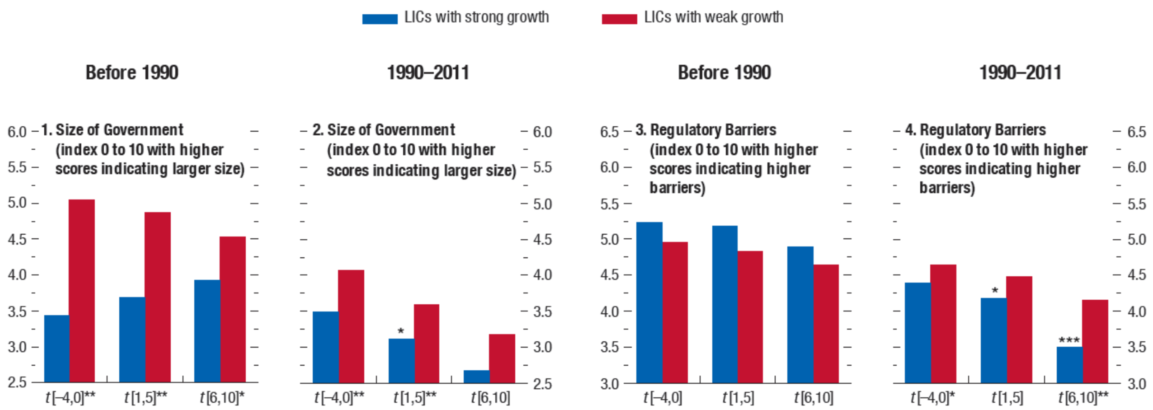
So the fortunes of many LICs appear to be tied in with the growth of the Emerging Market and Developing Economies (EMDEs) which may explain the changes exhibited in Figure 4.3 noted earlier. But again having your fortunes tied to so small a group of countries may, as the report says, be risky. John Hudson

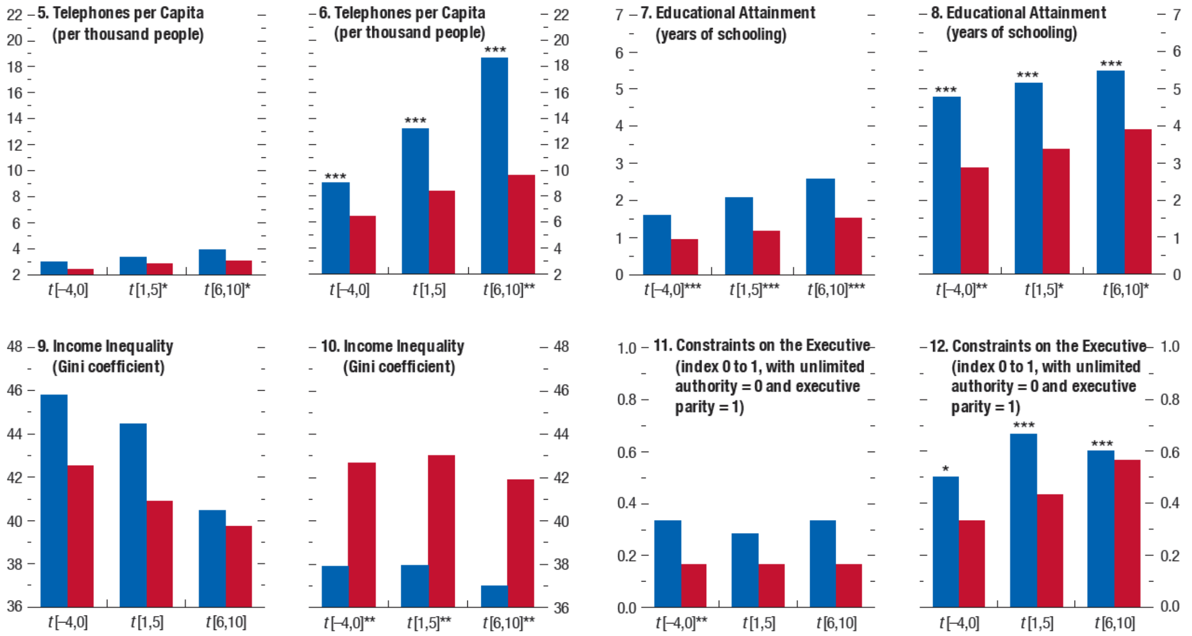
LIC takeoffs tend to be complemented by improvements in the business climate and with productivity growth, but the record for the recent generation of takeoffs is much stronger than for the previous generation. Dynamic LICs in both generations tend to have smaller governments, lower regulatory barriers (proxied by the level of regulation in business, labor, and credit markets), better infrastructure, and higher human capital levels (proxied by the number of years of schooling) than LICs with weaker growth (Figure 4.9, panels 1–8). For recent takeoffs, the size of government and the level of regulatory barriers continued to decline after takeoff, and infrastructure and education continued to improve, whereas with the exception of education, these conditions remained the same or deteriorated for the previous generation.

Figure 4.9. Structural Reforms, Infrastructure, and Political Conditions in Low-Income Countries

(Median economy; t = 1 in the first year of a strong or weak growth episode)

Today's dynamic low-income countries (LICs) tend to have smaller governments, lower regulatory barriers, and better infrastructure than their weaker counterparts from the current generation and dynamic LICs of previous generations. In addition, growth takeoffs tended to occur in economies with higher human capital levels and, for the current generation, more equal income distributions. The current generation of LICs also tends to have better checks and balances on the executive branch of the government.





Sources: Banks and Wilson (2012); Barro and Lee (2010); Gwartney, Lawson, and Hall (2012); Political Regime Characteristics and Transitions database (2011); Solt (2009); World Bank, World Development Indicators database (2012); and IMF staff calculations.
Note: Economy groups and indicators are defined in Appendix 4.1. LICs exclude countries experiencing or recovering from a serious external or internal conflict at the start of their takeoffs. See the text for definitions of strong and weak growth episodes (takeoffs are strong growth episodes). See Appendix 4.1 for the definition of conflict and the source of the conflict data. *, **, and *** denote statistically significant difference in distributions (based on the Kolmogorov-Smirnov test) at the 10 percent, 5 percent, and 1 percent levels, respectively. Significance tests on the *x*-axis are for the difference in the distributions between the groups of strong and weak growth. Significance tests on the blue bars are for the difference in the distributions across 1990–2011 and before 1990 (not shown for red bars). A constant composition sample underlies each of the panels to ensure comparability within the group of strong and weak growth episodes across time for that panel.

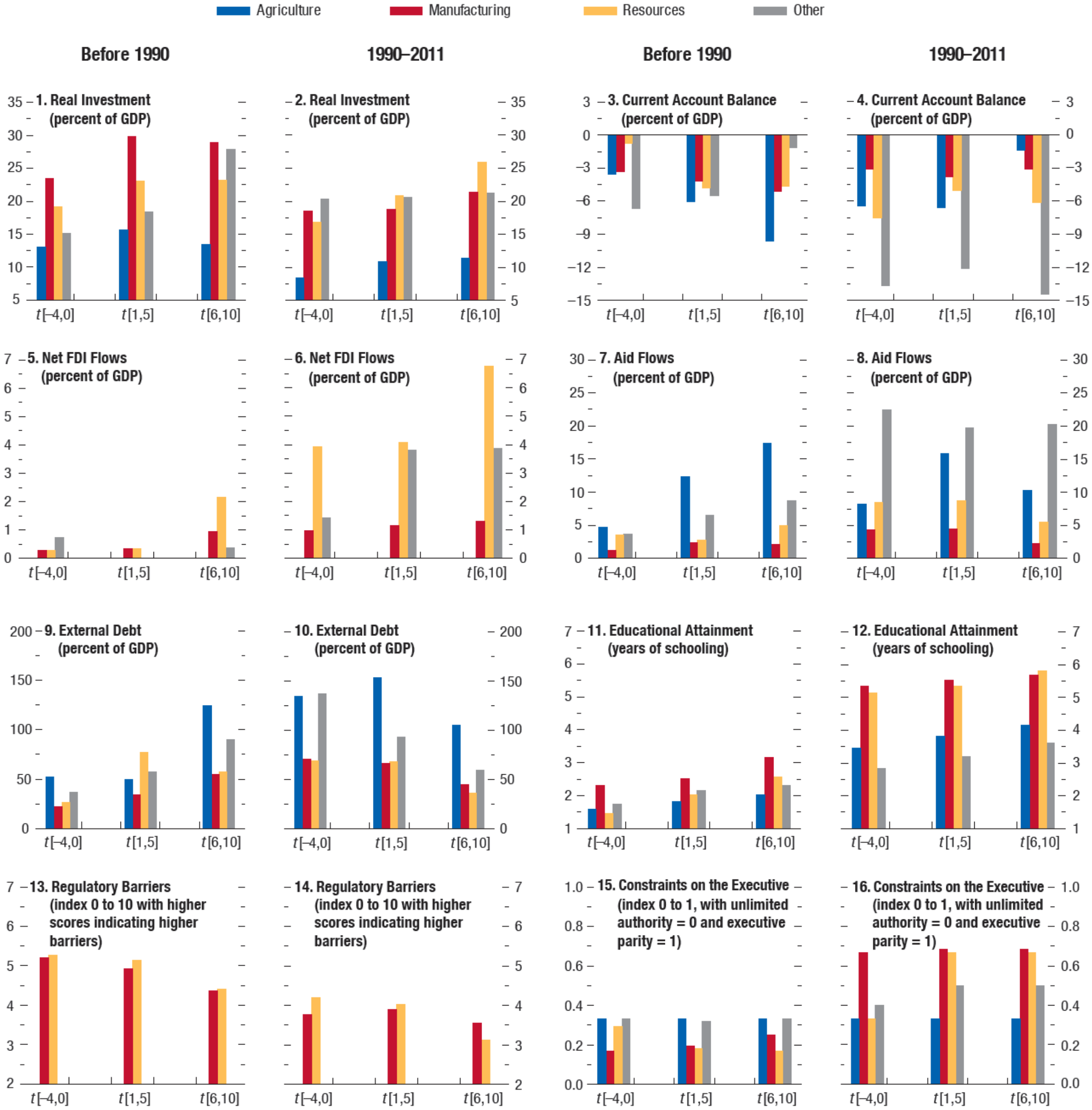
Turning to the role of social and political institutions in underpinning growth takeoffs, the findings suggest that today's dynamic LICs performed better on these institutional measures compared with both LICs with weak growth and dynamic LICs before the 1990s.

The recent literature emphasises the central role of economic and political institutions in determining why some economies are able to escape poverty and sustain strong growth, whereas others are not. They analyse the evolution of economic and political inclusiveness, as proxied by the degree of income inequality and the degree of control over the executive, respectively (Figure 4.9, panels 9–12). Recent takeoffs display less income inequality, whereas income inequality was typically high in the previous generation of takeoffs. Political institutions are also stronger in the current generation of takeoffs—possibly reflecting the end of conflicts or greater democratization in many dynamic LICs in recent years.

All this is good and may reflect the input of aid donors in pushing for more efficient institutions and a reduction in corruption. John Hudson

Figure 4.10. Investment and Financing across the Spectrum of Today's Dynamic Low-Income Countries
(Median economy; t = 1 in the first year of a strong growth episode)

Investment rates were relatively high for both generations of dynamic low-income countries (LICs). However, external financing of this investment differed across groups. In the current generation, resource-oriented economies benefited most from foreign direct investment (FDI), while agriculture- and other-oriented economies benefited most from aid. Partly because of shifts in external financing, external debt eventually fell for all groups of today's dynamic LICs. Moreover, today's manufacturing- and resource-oriented economies helped to fuel their growth by reducing regulatory barriers while strengthening political institutions. At the same time, educational attainment improved for all groups.



Sources: Barro and Lee (2010); Gwartney, Lawson, and Hall (2012); IMF, Balance of Payments Statistics database; IMF, International Financial Statistics database; IMF, World Economic Outlook database (October 2012); Lane and Milesi-Ferretti (2007) updated to 2011; Penn World Table 7.1; Political Regime Characteristics and Transitions database (2011); World Bank, World Development Indicators database; and IMF staff calculations.
Note: Economy groups and indicators are defined in Appendix 4.1. LICs exclude countries experiencing or recovering from a serious external or internal conflict at the start of their takeoffs. See the text for the definition of weak growth episodes (takeoffs). See Appendix 4.1 for the definition of conflict and the source of the conflict data. A constant composition sample underlies each of the panels to ensure comparability within the group of strong and weak growth episodes across time for that panel. Bars are plotted only if there are at least three takeoffs.

Although the nature of takeoffs is broadly similar for dynamic LICs regardless of their economic structure, a few differences emerge in patterns of investment and its financing (Figure 4.10). For resource-rich dynamic LICs, investment rates increased sharply around the time of takeoff for both generations (Figure 4.10, panels 1 and 2). Although saving rates rose as well, they fell short of investment rates. This deficit was somewhat larger for the current generation, but it was more than fully offset by net FDI inflows (Figure 4.10, panels 5 and 6).

The current generation also received a sizably higher share of foreign aid (Figure 4.10, panels 7 and 8). Thus, these LICs were able to resist building up external debt after takeoff (Figure 4.10, panels 9 and 10). Resource-rich dynamic LICs from the current generation also outperformed their resource-rich peers of the previous generation in terms of stronger human capital levels, lower regulatory barriers, and stronger political institutions (Figure 4.10, panels 11–16). Such reforms, if sustained, will [the report says 'will', but as an economist one knows nothing is guaranteed, and I would replace this with 'should'] help these LICs engineer more broad-based growth over time.

But correlation is not causality, none of this definitively tells us anything about the causes of successful LIC takeoffs. For that we need regression analysis. Never confuse, as many do, correlation with causation.

*The regression below examines what causes a takeoff to start. Anything with a positive coefficient suggests that factor facilitates takeoff. But it needs to be significant. Something with *** means we are 99% certain it is having an impact and is not due to chance. Something with * means we are 90% certain. Focus on the penultimate column – don't worry about the last column. Focus too on the coefficients not the terms below in (.). OK high World GDP growth facilitates take-off, it is easier to take off when the world is doing well. High initial GDP per capita has the opposite effect – its sign is negative (-7.095). Richer counties are less likely to see take-off. Why? (Linked to convergence, the poor have more potential to grow). But given this, big economies per se are more likely to see take off (the GDP variable). Hence size matters. A competitive exchange rate also helps. Take off is also likely in a country with high educational attainment (human capital). Finally it is facilitated by low public debt (the sign is negative -0.014) and high investment.*

But what was left out of the regression and why? Why nothing for corruption? The rule of law? Why nothing reflecting the extent to which a country has mineral reserves? Still the results are interesting. In terms of policy the lessons are focus on education as a means to generate growth and ensure that the exchange rate is competitive. Obviously a region of a country cannot change its exchange rate, nor can the countries of the Eurozone, but it can emphasise education. And I still think quality of governance is important. John Hudson

Table 4.4. Explaining Growth Takeoffs in Dynamic Developing Economies

	Full Sample		Before 1990		1990–2011	
Explanatory Variable	Logit Coef.	Aver. Marg. Eff.	Logit Coef.	Aver. Marg. Eff.	Logit Coef.	Aver. Marg. Eff.
Global Conditions						
Contemporaneous World Real GDP Growth	0.800**	2.250**	0.859**	2.450**	1.866***	4.200***
	(0.323)	(1.060)	(0.420)	(1.210)	(0.567)	(1.480)
Contemporaneous U.S. Three-Month Treasury Bill Real Rate	0.032	0.091	0.110	0.313	0.433	0.973
	(0.220)	(0.621)	(0.381)	(1.110)	(0.330)	(0.764)
Contemporaneous Terms-of-Trade Growth	0.008	0.024	0.031	0.088	0.002	0.005
	(0.018)	(0.052)	(0.019)	(0.063)	(0.028)	(0.062)
Income per Capita and Size						
Initial Log Real GDP per Capita	–2.439***	–6.880***	**–1.543**	–4.400	**–7.095*****	–16.000***
	(0.724)	(2.160)	(1.361)	(3.900)	(2.073)	(4.820)
Initial Log Real GDP Level	0.538*	1.520*	**0.363**	1.030	**1.707*****	3.840***
	(0.290)	(0.903)	(0.566)	(1.630)	(0.417)	(1.160)
Openness and Integration						
Initial Real Exchange Rate vs. U.S. Deviation	–0.013*	–0.038*	**0.005**	0.015	**–0.069*****	–0.154***
	(0.007)	(0.020)	(0.010)	(0.029)	(0.015)	(0.040)
Change in Real Exchange Rate vs. U.S.	–0.021*	–0.058*	**–0.004**	–0.010	**–0.087*****	–0.195***
	(0.011)	(0.032)	(0.017)	(0.050)	(0.025)	(0.063)
Initial Trade Openness	0.001	0.003	–0.005	–0.015	0.036	0.080
	(0.013)	(0.035)	(0.022)	(0.063)	(0.042)	(0.092)
Initial Exports to EMDEs[1] Divided by GDP	0.027	0.075	**–0.298****	–0.851*	**0.012**	0.026
	(0.016)	(0.046)	(0.137)	(0.435)	(0.058)	(0.131)
Structural Conditions						
Initial Indicator for Constraint on Executive	0.063	0.176	1.470	4.190	–2.472	–5.560
	(0.820)	(2.310)	(1.663)	(5.030)	(1.833)	(4.560)
Initial Life Expectancy	0.012	0.033	0.059	0.170	0.044	0.099
	(0.046)	(0.129)	(0.071)	(0.188)	(0.065)	(0.147)
Initial Educational Attainment	0.301*	0.848*	**0.048**	0.137	**0.903****	2.030*
	(0.163)	(0.484)	(0.270)	(0.773)	(0.422)	(1.060)
Initial Real Investment Divided by GDP	0.066	0.186	0.160***	0.456***	0.010	0.023
	(0.041)	(0.123)	(0.045)	(0.126)	(0.132)	(0.299)
Macroeconomic Conditions						
Change in Real Investment Divided by GDP	0.149***	0.420***	0.234***	0.668***	0.177***	0.397***
	(0.045)	(0.148)	(0.082)	(0.245)	(0.053)	(0.125)
Change in Inflation	–0.002	–0.006	–0.004	–0.012	0.019	0.043
	(0.006)	(0.018)	(0.071)	(0.202)	(0.013)	(0.029)
Change in Public Debt Divided by GDP	–0.003	–0.009	–0.019	–0.055	–0.014***	–0.031**
	(0.004)	(0.012)	(0.030)	(0.088)	(0.005)	(0.012)

Source: IMF staff calculations.

Note: The dependent variable is a dummy variable for the start of a new growth takeoff. Indicators (variables) are defined in Appendix 4.1. Heteroscedasticity and autocorrelation within country robust standard errors are in parentheses under the logistic (logit) regression coefficient estimates. *, **, and *** denote significance at the 10 percent, 5 percent, and 1 percent levels, respectively. Statistically significantly different coefficient estimates across the subsamples before 1990 and for 1990–2011 are shown in bold (at the 10 percent level or lower). The average marginal effects by variable on the chances of a new growth takeoff are shown in the column next to the corresponding sample's logit coefficients. The marginal effect shows the average impact of a one-unit change in the explanatory variable on the probability of a growth takeoff (scaled to range from zero to 100).

[1]EMDEs = emerging market and developing economies.

[2]AUC = area under the receiver operating characteristic curve.

MATHEMATICAL APPENDIX Endogenous growth model.

This is slightly more complex than before and illustrates the use of Phase diagrams.

$Y_t = [(1-s_k)K_t]^{\alpha}[A_t(1-s_L)L_t]^{1-\alpha}$ [A1]

$(1-s_k)$ the share of capital devoted to production industries (s_k devoted to knowledge production) $(1-s_k)K_t$ amount of capital devoted to production industries.

$A_t(1-s_L)L_t$ A_t impacts on the efficiency of labour and this is linked to knowledge. This is how knowledge affects production.

$(1-s_L)$ the share of labour devoted to production industries (s_L devoted to knowledge production) $(1-s_L)L_t$ amount of labour devoted to production industries.

It's a ***Cobb Douglas production function*** with constant returns to scale, the two superscripts (1-α and α) sum to one.

$\dot{A}_t = B[s_kK_t]^{\beta} [s_LL_t]^{\gamma}A_t^{\theta}$ [A2]

The growth or rate of change of knowledge (that is what the dot in $\dot{A}_t$ denotes) depends upon B (not that important, just a scale factor) the amount of capital devoted to knowledge production s_kK_t, the marginal productivity of capital in knowledge production β, s_LL_t the amount of labour devoted to knowledge production, γ its marginal productivity in this respect, and existing knowledge with a marginal product θ. Its also a Cobb Douglas type function but the superscripts no longer have to sum to one.

$\dot{K}_t = sY_t$ [A3]

The change in capital stock, net investment, where s is the savings rate, all savings get channelled into investment and there is no depreciation (hence also gross investment).

$\dot{L}_t = n$ [A4]

N is the rate of growth of the labour force (also the population).

There are two endogenous variables whose dynamic properties determine the properties of the model.

$\dot{K}_t = sY_t = s[(1-s_k)K_t]^{\alpha}[A_t(1-s_L)L_t]^{1-\alpha}$ *(from A1)*

$= s[(1-s_k)^{\alpha}(1-s_L)^{1-\alpha}K_t^{\alpha}A_t^{1-\alpha}L_t^{1-\alpha}$

$g_k = \dot{K}_t/K_t = s[(1-s_k)^{\alpha}(1-s_L)^{1-\alpha}K_t^{\alpha-1}A_t^{1-\alpha}L_t^{1-\alpha}$

$= s[(1-s_k)^{\alpha}(1-s_L)^{1-\alpha} [A_tL_t/K_t]^{1-\alpha}$

$= c_k[A_tL_t/K_t]^{1-\alpha}$

Where $c_k = s[(1-s_k)^{\alpha}(1-s_L)^{1-\alpha}$

Note for what follows, when x depends upon time, differentiating the natural log of x with respect to t gives us the proportionate growth rate of x over time. Take logs:

$Ln(g_k) = \ln(c_k) + (1-\alpha)[\ln(A_t) + \ln(L_t) - \ln(K_t)]$

Differentiate with respect to time and we get the proportionate growth rate of g_k:

$\dot{g}_k/g_k = (1-\alpha)\,[\partial\ln(A_t)/\partial t + \partial\ln(L_t)/\partial t - \partial\ln(K_t)/\partial t]$

Note equation changed from video

$= (1-\alpha)\,[g_{At} + n - g_{kt}]$ [A5]

Turning to A_t, dividing [A2] by A we get

$g_A = \dot{A}_t/A_t = B[s_kK_t]^{\beta}\,[s_LL_t]^{\gamma}A_t^{\theta-1} = Bs_k^{\beta}s_L^{\gamma}\,K_t^{\beta}\,L_t^{\gamma}A_t^{\theta-1} = c_A\,K_t^{\beta}\,L_t^{\gamma}A_t^{\theta-1}$

where $Bs_k^{\beta}s_L^{\gamma} = c_A$

Takings logs

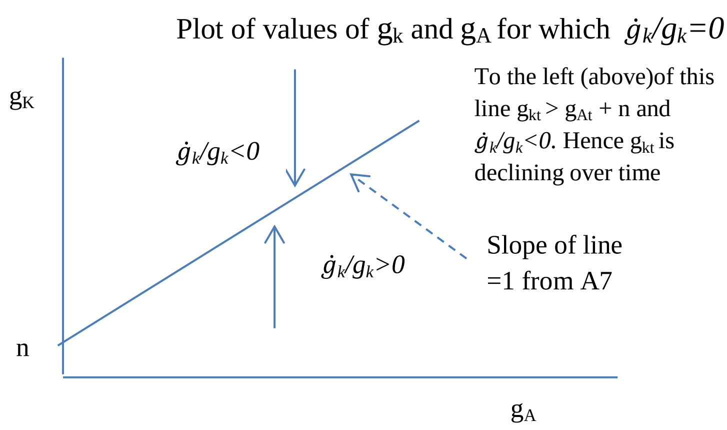
$\ln(g_A) = \ln(\dot{A}_t/A_t) = \ln(c_A) + \beta\ln(K_t) + \gamma\ln(Lt) + (\theta-1)\ln(At)$

Differentiate with respect to time and we get the proportionate growth rate of g_A:

$\dot{g}_{At}/g_{At} = \beta g_{kt} + \gamma n + (\theta-1)g_{At}$ [A6]

We can use A5 and A6 to form a *phase diagram*. From A5, rearrange and set =0:

Figure A1



From A5, rearrange and set =0:

$\dot{g}_k/g_k$ = (1-α) [g_{At} + n –g_{kt}] =0 [A7]

g_{kt} =g_{At} + n [A7A]

when g_{kt} =g_{At} + n; $\dot{g}_k/g_k$ =0, if $g_{kt} > g_{At}$ + n then $\dot{g}_k/g_k<0$ and vice versa (from A7]. This is shown in the diagram

Now turn to [A6], , rearrange and set =0:

$\dot{g}_{At}/g_{At}$ = βg_{kt} +γn + (θ-1)g_{At} =0 [A8]

g_{At} = (βg_{kt} +γn)/(1-θ) [A9]

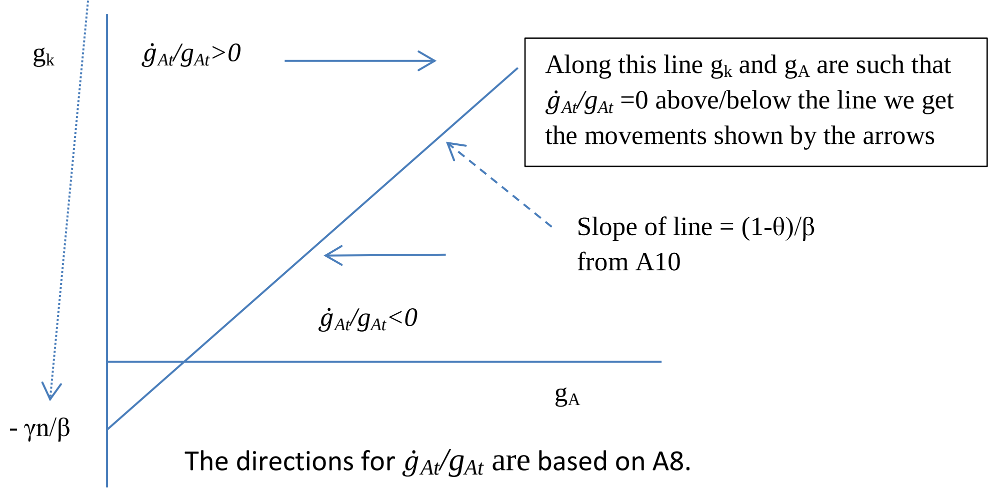
when g_{At} = (βg_{kt} +γn)/(1-θ); $\dot{g}_{At}/g_{At}$ =0, if g_{At} > (βg_{kt} +γn)/(1-θ) then $\dot{g}_{At}/g_{At}$ <0 and vice versa (from A9]. We can rearrange A9 to give:

βg_{Kt}/(1-θ) = g_{At} –(γn/(1-θ)) [A9]

g_{Kt} = ((1-θ)/β)g_{At} –γn/β [A10]

Now we have an equation similar to A7A with g_{Kt} on the left hand side. We can plot this line.

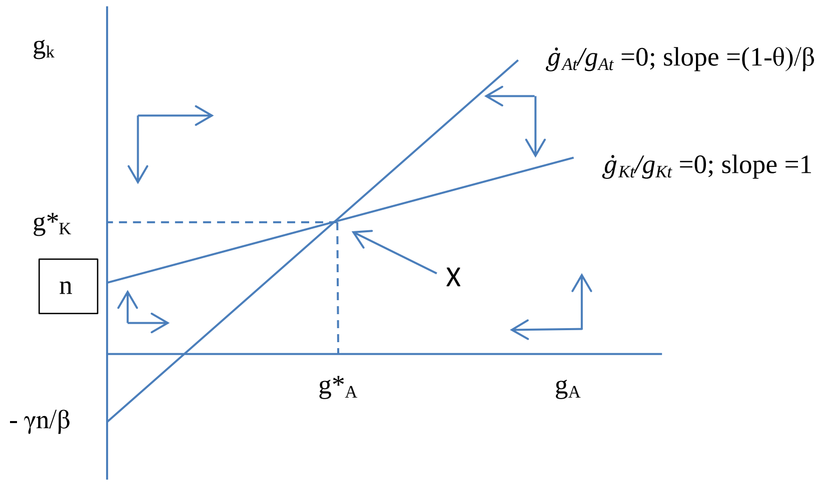
Figure A2: Diagram for the dynamics of the growth of knowledge (in the case when θ<1)



Phase Diagram for the dynamics of the growth of knowledge and capital when (1-θ)/β>1.

In this case the slope of $\dot{g}_{At}/g_{At}$ > the slope of $\dot{g}_{Kt}/g_{Kt}$. Being as $\dot{g}_{At}/g_{At}$ starts below $\dot{g}_{Kt}/g_{Kt}$ (look at the interecepts in the two diagrams). Note the slope of $\dot{g}_{At}/g_{At}$ *is* (1-θ)/β from Figure A2 and the slope of $\dot{g}_{Kt}/g_{Kt}$ is 1 from Figure A1.

Figure A3



g^*_A and g^*_K form a stable equilibrium. At this point the growth of capital and knowledge is constant. They are an **equilibrium** because they lie at the intersection of the line where g_K is unchanging ($\dot{g}_{Kt}/g_{Kt}$ =0) and the line where g_A is unchanging. It is a **stable equilibrium** because wherever we are in the diagram, the dynamics take us to this equilibrium, as at X when we move up and to the left.

But in other cases we do not get this equilibrium. Let us look at one example where (1-θ)/β<1. In this case the curves do not cross there is no equilibrium. This may be the result of θ being large or β being large. Both relate to the knowledge production function in A2. They suggest knowledge growth is high. And the growth rates of A and K increase continually, with the economy witnessing *ever-increasing growth.*