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A Global Kuznets Curve?

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I. INTRODUCTION

This paper has two objectives. The first is to document developments in global inequality among national economies. The second is to analyze the factors that drive changes in global inequality. In particular, the paper focuses on investment in R&D and international knowledge spillovers as sources of these changes[1].

The motivation for this study is to provide an alternative perspective on the international economic convergence/divergence debate. Thus far the empirical literature has focused on 'catchup' rates. Essentially the idea is to determine whether there is a negative correlation between level of development (typically at some historical base year) and the average rate of growth[2]. If countries that are relatively more developed grow at a slower rate than that of relatively less developed countries, eventually the lesser developed countries can catchup to the level of development attained by the more developed economies. This is one way of testing for 'convergence' *per se*. But a potentially richer way of characterizing the international distribution of income is to look at summary measures of global inequality (such as the international Gini coefficient). The advantages are that these measures can more fully characterize the level and distribution of global income, and allow for the decomposition of changes in inequality to various informative sources. For instance, changes in inequality

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1. A Data Appendix is available from the authors upon request.
2. See, for example, BARRO (1991) and MANKIW et. al. (1992).

can be due to changes in relative income shares as well as to changes in 'ranking' among nations. Furthermore, it is possible to determine to what extent the global level of inequality can be attributed to within-group (or within-region) inequality or between-group (or between-region) inequality, and to the degree of 'stratification' of nations into separate well-defined groupings (such as a high-income group, moderate-income group, and so forth). The global economy would be viewed as having weak stratification if there is significant 'mobility' of nations between groups, with nations changing rank or catching up. Yet another advantage of using measures of global inequality is that they are robust to country heterogeneities. In contrast, existing studies which use 'catch-up' rates assume identical production functions and factor shares across countries.

Both the Solow model which emphasizes diminishing returns to capital and the Kuznets hypothesis which postulates an inverted U-relationship between the level of development and inequality, when applied in the open economy context, predict long run international economic convergence. However, the evidence largely points to divergence of per capita national incomes. This fact has led researchers, such as MANKIW et al. (1992) to control for other factors, such as differences in human capital investment across nations, which lead countries to converge to different steady-state levels of per capita national incomes. The finding in MANKIW et al. (1992) is that of conditional convergence (conditional on controlling for human capital).

This paper emphasizes another important factor to control for, namely differences in R&D investment across countries. The interesting aspect about R&D investment is that two effects can be identified: 'own-investment' effects and 'spillover' effects. On the one hand, productive domestic investments in R&D (by relatively higher income countries) can potentially widen the income and growth rate gap between countries, since the country undertaking the investment improves its own productivity growth. On the other hand, international knowledge spillovers associated with R&D can potentially narrow the gap between nations as spillovers improve foreign productivity growth. The question is which effect dominates. If at low levels of global development, the 'own investment' effects of R&D dominate the spillover effects and at high levels of global development, the reverse is true, this would reveal a 'Kuznets-type' curve operating at the global economy.

In this paper, each country is treated as an individual, so that the analog to a personal distribution of income can be determined for the global economy as a whole. In section II, data on global income distribution and R&D activities are discussed. Global Gini coefficients are computed for each year between 1960 and 1988, using two measures of income: GDP per capita and consumption per capita, the latter representing a measure of permanent income. This section finds that global inequality has worsened over time and that the international economy consists of stratified groups although the levels of stratification have fallen. This section also shows that R&D activities are heavily concentrated in certain countries and that the R&D gap between countries has widened during 1960-1988.

In section III, a global Kuznets curve is estimated for the period 1960-1988. While the raw data do not support the existence of a Kuznets curve for the world as a whole, once certain R&D variables are controlled for, an inverted-U relationship between global development and inequality emerges. It is found that divergences in R&D activities across countries worsen global inequality, while a higher level of international R&D (or an increase in the pool of world R&D knowledge) promotes global equality. The latter is argued to represent the effects of increased international R&D spillovers. Thus R&D spillovers do have a 'convergence' effect while national R&D differences contribute to international economic divergence. On balance, however, the paper finds that world R&D investments contribute to international economic convergence and reduce global inequality[3].

This paper extends research by LICHTENBERG (1992) who studies cross-country R&D and productivity, using the MANKIW et al. (1992) framework. LICHTENBERG considers the consequences of R&D spillovers but does not derive a measure of international R&D spillovers, as in this paper. The paper also extends research by RAM (1989) who estimates a global Kuznets curve using time-series data, but does not consider the role of growth-enhancing investments[4]. The focus of this paper – which treats the nation as the unit of analysis – differs somewhat from the present literature on the international distribution of income[5] which treats the individual (or household) as the unit of analysis, and compares the relative position of the individual *vis-à-vis* individuals at home and in the rest of the world. This paper also has some relevance for theoretical work by GALOR-TSIDDON (1993) who illustrate how positive

3. For a historical discussion of the role of international technology diffusion in international economic convergence, see ROSTOW (1980).
4. Estimates of national Kuznets curves (i.e., the relationship between domestic inequality and domestic development) are often obtained using cross-country data. CAMPANO-SALVATORE (1988) find evidence supporting the inverted-U hypothesis while other works on macroeconomics and inequality such as ALESINA-PEROTTI (1993) and PERSSON-TABELLINI (1991) find a monotonic relationship: namely a positive association between inequality and growth. ANAND-KANBUR (1993) and FIELDS-JACUBSON (1993) point out that underlying structural changes may shift the Kuznets curve over time and/or be at different positions for different countries. This points out the need to control for third variables, as pursued in this paper.
5. See for example BERRY et al. (1983); SUMMERS et al. (1984), and SPROUT-WEAVER (1992).

externalities from higher-income (and skilled) groups to the lower-income (less-skilled) groups can pull up the latters' incomes and thereby help promote greater equity. A similar kind of mechanism operates at the global level, where R&D spillovers from high-income nations help to pull up the rest of the world's incomes. Finally, theoretical work by GOODFRIEND-MCDERMOTT (1993) emphasizes that catching-up by followers to leaders is not a monotonic process, but involves at various phases convergence, divergence, and overtaking. The next section explores changes in global inequality that are due to shifts in international ranking.

II. TRENDS IN INEQUALITY AND R&D AMONG NATIONS

This section adopts the Gini methodology of LERMAN-YITZHAKI (1989, 1991, 1993) – henceforth referred to as LY[6]. The Gini coefficient is:

$$G = 2 \operatorname{cov}(s, f) \qquad (1)$$

where s is (y/μ), y income, μ mean income, and f the normalized rank of income. More specifically, suppose N countries are ranked from lowest to highest per capita real income. $f(y_i)$ then indicates the position country i (whose income is y_i) occupies in the international distribution of income. By dividing by the 'length' of the cumulative distribution, one can normalize f to lie between 0 and 1. For example, in a 3 person economy, the 'length' of the distribution is 3. f is estimated at the mid-interval of adjacent observations. The first person, for instance, occupies a position between 0 and 1, or 0.5; the second person between 1 and 2, or 1.5; and the third, between 2 and 3, or 2.5. Division by 3 therefore gives the first person a normalized rank of 1/6, the second 1/2, and the third 5/6. The sum of f is 1.5 and the mean 0.5.

Based on (1), LY derive two types of Gini decompositions. The first isolates the effects of changes in s, the relative shares of income, from changes in f, the relative ranking, on changes in inequality. The second decomposes the Gini index into a between-group Gini, within-Group Gini, and a term measuring the degree of sub-group stratification.

6. Interested readers are referred to those papers for proofs.

LY Decomposition 1.

Let b denote 'before' and a 'after'. The change in Gini is

$$\Delta G = 2*(cov(sa,fa) - cov(sb,fb)). \quad (2)$$

Adding and subtracting 2cov(sa,fb) to the RHS of (2) gives two terms:

$$\Delta G = 2*(cov(sa,fa)-cov(sa,fb)) + 2*(cov(sa,fb)-cov(sb,fb)) \quad (3)$$

The first term holds sa (relative shares) constant, and examines how changes in relative ranking contribute to ΔG. The second term holds fb (relative ranking) constant, and examines how changes in relative shares contribute to ΔG. LY define the first term as the 'reranking' effect and the second the 'gap-narrowing' (or 'gap-widening') effect. In this paper, the second term will be called the 'scale' effect. In other words, changes in inequality are due to a mixture of changes in countries' shares of the global income pie and of changes in their ranks in the global distribution of income.

Note however that (3) poses a type of index number problem. The decomposition is potentially sensitive to the choice of base rank and share. For instance, an alternative decomposition involves adding and subtracting 2*cov(sb,fa) to the RHS of (2). Hence in this section the average of the two modes of decomposing (2) is taken, namely:

$$\Delta G = cov\ (sa - sb,\ fa + fb) + cov\ (sa + sb,\ fa - fb) \quad (4)$$

The first term identifies the 'scale' effect and the second the 'rank' effect.

LY Decomposition 2.

Suppose the N countries are placed in M different groups. The Gini index can be decomposed as follows:

$$G = \Sigma\ \omega_i\ G_i + G_b - \Sigma\ \omega_i\ G_i(1 - \pi_i)\ Q_i,\ i = 1, ..., M \quad (5)$$

where G is the Gini coefficient for group i, ω_i the income share of group i, π_i the population share of group i, G_b the between-group Gini coefficient, and Q_i the stratification index of group i, where:

$$Q_i = \frac{cov_i\,(fi - fni, y)}{cov_i\,(fi, y)} \qquad (6)$$

In (6) fi refers to the normalized ranking of countries of group i within group i and fni the normalized ranking of countries of group i outside group i. The value of Q ranges between -1 and 1. If $Q_i = 1$, group i forms a perfect stratum. No overlapping arises between countries outside and inside the group in the overall international ranking of countries by income. If $Q_i = 0$, the group forms no strata. Each country is at the same percentile within its group as it is in the overall international distribution. If $Q_i < 0$, group i itself is not a homogeneous group in the world economy, but rather consists of different groups. If $Q_i = -1$, group i consists of two perfect strata representing the extremes of the overall international income distribution. In other words, the rest of the world's rankings lie between those two sub-groups of group i.

Figure 1

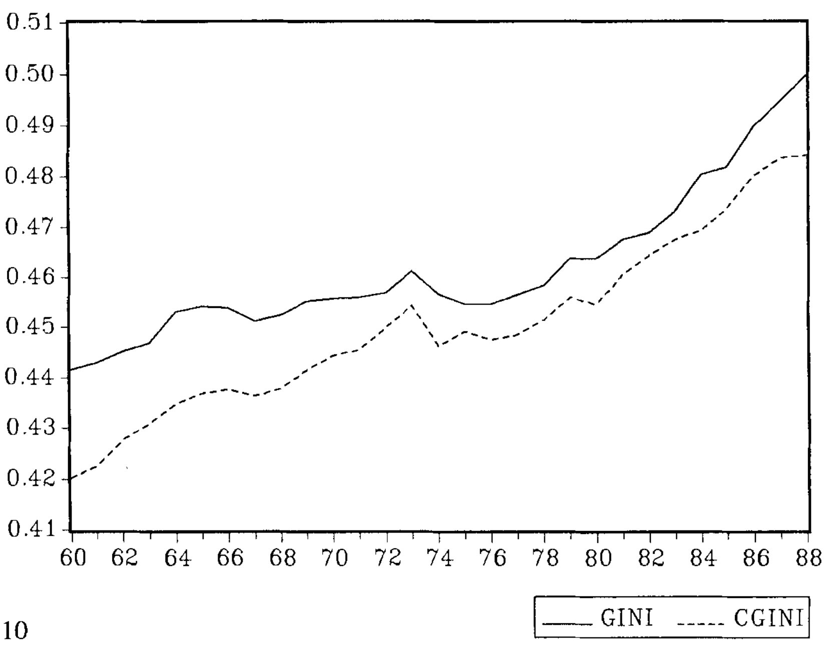


Table 1

International Ranking in Terms of Per Capita PPP GDP 91 Countries: Ascending Order

Rank 1960	Country	Y 1960	popn 1960	Y 1988	popn 1988	Rank 1988
1	Tanzania	272	10027	488	24739	4
2	Uganda	371	6563	398	17450	2
3	Zaire	379	15986	356	33615	1
4	Togo	411	1514	668	3362	8
5	Malawi	423	3530	543	8155	5
6	Botswana	474	481	2522	1210	40
7	Rwanda	538	2753	661	6657	7
8	Mali	541	4175	474	7989	3
9	Nepal	584	9403	820	17250	13
10	Niger	604	3234	602	6998	6
11	India	617	434835	786	813990	12
12	Banglades	621	52357	753	104530	11
13	Kenya	635	8049	902	23021	18
14	Cameroon	736	5332	1615	11213	29
15	Central A	806	1605	686	2794	9
16	Pakistan	820	45970	1567	105677	28
17	Sierra LE	871	2314	929	3950	20
18	Honduras	901	1934	1346	4837	25
19	Haiti	921	3857	877	6254	15
20	Korea, South	923	24756	5156	42593	61
21	Zimbabwe	937	3606	1265	9257	23
22	Liberia	967	1050	876	2340	14
23	Sudan	975	11165	883	23776	17
24	Thailand	985	26405	2879	54469	45
25	Ghana	1049	6827	877	14040	16
26	Benin	1075	2050	952	4454	21
27	Congo	1092	950	2073	2130	34
28	Senegal	1136	3498	1126	7154	22
29	Papua N.G	1136	1935	1696	3560	30
30	Bolivia	1142	3428	1362	6917	26
31	Zambia	1172	3141	715	7486	10

Rank 1960	Country	Y 1960	popn 1960	Y 1988	popn 1988	Rank 1988
32	Philippin	1183	27909	1947	59686	32
33	Paraguay	1200	1825	2376	4042	38
34	Dominican	1227	3325	2209	6859	35
35	El Salvador	1305	2578	1705	5056	31
36	Jordan	1328	1695	2356	3937	37
37	Mozambique	1368	7551	919	14967	19
38	Sri Lanka	1389	9889	1985	16590	33
39	Tunisia	1394	4221	2921	7796	46
40	Brazil	1404	72594	4432	141450	57
41	Ecuador	1461	4563	2727	10154	43
42	Malta	1516	329	6802	345	68
43	Panama	1533	1145	2941	2320	47
44	Portugal	1618	8943	5321	10162	63
45	Guyana	1630	538	1302	799	24
46	Guatemala	1667	3887	2228	8688	36
47	Turkey	1669	27508	3598	53772	50
48	Algeria	1676	10800	2726	23805	42
49	Nicaragua	1756	1578	1441	3620	27
50	Malaysia	1783	8197	4727	16921	59
51	Syria	1787	4561	4144	11667	54
52	Jamaica	1829	1622	2448	2360	39
53	Colombia	1874	15754	3568	30007	49
54	Greece	1889	8327	5857	10030	65
55	Iran	1985	20301	2607	52520	41
56	Cyprus	2039	573	7858	686	70
57	Mauritius	2113	660	4629	1048	58
58	Peru	2130	9936	2847	20681	44
59	Costa Rica	2160	1254	3800	2670	51
60	Hong Kong	2323	3051	13281	5674	86
61	Fiji	2354	394	3301	740	48
62	Singapore	2409	1647	12369	2650	82
63	Iraq	2589	6847	4211	17250	55
64	Spain	2701	30455	7406	38997	69

Rank 1960	Country	Y 1960	popn 1960	Y 1988	popn 1988	Rank 1988
65	Japan	2701	94104	12209	122433	80
66	Mexico	2870	38227	4996	83593	60
67	South Africa	2984	18039	4431	33938	56
68	Chile	3103	7695	4099	12760	53
69	Ireland	3214	2832	6239	3574	67
70	Argentina	3381	20618	4030	31506	52
71	Venezuela	3899	7303	6002	18420	66
72	Israel	3958	2114	9412	4444	71
73	Italy	4375	50200	11741	57470	76
74	Uruguay	4401	2538	5163	3004	62
75	Austria	4476	7048	11201	7563	73
76	Finland	4718	4430	12360	4944	81
77	Trinidad -Tobago	4754	776	5674	1241	64
78	Belgium	5207	9119	11495	9867	75
79	France	5344	45685	12190	55873	79
80	Iceland	5352	176	13204	249	85
81	Norway	5443	3581	14976	4205	88
82	Netherlands	5587	11487	11468	14760	74
83	Denmark	5900	4581	12089	5133	78
84	Germany	6038	55435	12604	61049	83
85	United Kingdom	6370	52557	11982	57019	77
86	Sweden	6483	7480	12991	8357	84
87	Australia	7204	10274	13321	16506	87
88	New Zealand	7222	2380	9864	3290	72
89	Canada	7758	17910	16272	26104	90
90	Switzerland	9313	5362	16155	6545	89
91	United States	9983	180673	18339	245871	91

Table 2

Gini Decomposition: Reranking Effects vs. Scale Effects

1960 – before (b)		
1988 – after (a)		
Using per capita PPP GDP as income measure		
1960 Gini	= 2*cov (sb, fb)	= 0.442
1988 Gini	= 2*cov (sa, fa)	= 0.499
Net Change		= 0.057
Due to:		
Reranking	= cov (sa+sb, fa-fb)	= 0.002 (3.5%)
Scaling	= cov (sa-sb, fa+fb)	= 0.055 (96.5%)
Total		= 0.057 (100%)
Using per capita PPP Consumption as income measure		
1960 Gini	= 2*cov (sb, fb)	= 0.42
1988 Gini	= 2*cov (sa, fa)	= 0.484
Net Change		= 0.064
Due to:		
Reranking	= cov (sa+sb, fa-fb)	= 0.004 (6.3%)
Scaling	= cov (sa-sb, fa+fb)	= 0.06 (93.7%)
Total		= 0.064 (100%)

Figure 1 displays the time-series evolution of two measures of the Gini coefficient, one based on PPP real GDP per capita and the other on PPP real consumption per capita[7] [8]. The Ginis are calculated for the 91 countries listed in *Table 1*. A reason for studying consumption is that for permanent-income consumers who consume their permanent income, consumption is a proxy for permanent income. *Figure 1* nonetheless shows that cyclical influences affected both measures of Gini, particularly in the early 1970s. Quite noticeable is the rise in global inequality during the period from 1960 to 1988. Note that consumption

7. Data are taken from Summers-Heston (1991). For 17 countries (Bangladesh, Botswana, Brazil, Congo, Fiji, Iran, Iraq, Jamaica, Liberia, Nepal, Nicaragua, Panama, Sierra Leone, Singapore, Sri Lanka, Uganda, and Venezuela) some figures were missing for some of the years 1986-1988, or for all of those three years. The growth rates reported in the World Bank's *World Tables* (1991) (less population growth rates) and figures from the UN *National Accounts Statistics* were used to fill in the gaps.
8. A reason for focusing on PPP exchange rates is that the official exchange rates are based on relative prices of internationally traded goods. This distorts the value of production of economies with a relatively large non-tradable goods sector.

inequality is less than income inequality. One explanation may be the idea that international trade permits consumption-risk smoothing. When production fluctuates asymmetrically across countries, countries can through trade and international lending/borrowing, smooth consumption so as to make the variance of cross-country consumption less than that of cross-country income.

Table 2 decomposes the change in inequality between 1988 (after) and 1960 (before) into its reranking and scale components. More than 90% of the changes in inequality is due to pure gap-widening. That is, the rich in 1960 got richer and the poor in 1960 got poorer. But at the same time, reranking effects did occur, so that some (but not very many) relatively poor in 1960 got relatively richer by 1988. In particular (see *Table 1*), countries such as Japan, S. Korea, Botswana, Thailand, Hong Kong, and Singapore have significantly increased their rankings, while Argentina, Mozambique, Nicaragua, among others have lost their relative standing. Several countries have also maintained a relatively steady place in the international income distribution: the U.S., Australia, Canada, Switzerland, Israel, India, Bangladesh, and Uganda.

Table 3 shows the second LY decomposition of the Gini (using only the GDP Gini measure). The 91 countries were put into 3 groups, based on their ranking in 1960. Group 1 is the bottom 3rd, Group 2 the middle 3rd, and Group 3 the top 3rd. Thus 1960 represents the initial case of perfect stratification. Over time, from 1960 to 1970, the world population share of Group 1 increased from 42% to 48%, while Group 2's increased from 16% to 18%. Meanwhile Group 1's population share fell from 42% to 34%. However, the income share of Group 1 fell from 10.4% to 7.9%, and would have fallen more significantly if S. Korea and Thailand were excluded from this group. Over the same period, Group 3's share of the world income grew from 67% to just over 68% the rest of the gains in income share going to Group 2. Note how the within-group inequality indexes of Groups 1 and 2 rise over time, while that of Group 3 declines until 1980 and then rises back to roughly the same level of within-group inequality prevailing in 1960. Relatively, the within-group inequality coefficients are small. Thus most of the world's inequality can be attributed to between-group inequality and stratification. Between-group inequality accounts for about 85% of overall inequality in 1960 (i.e., 0.369/0.442) and about 89% in 1988 (i.e., 0.447/0.499).

Table 3 also indicates a high degree of stratification of Groups 2 and 3 (although they have become less stratified over time). What is interesting is that by 1988, Group 1 no longer forms a strata (due to the exit from the 1960 rankings by a number of countries which have experienced a growth miracle or two during that period, such as S. Korea). By 1985, the stratification index falls to 0.36 and by 1988, it is negative, or close to zero. Overall, however, few countries have penetrated the upper income club (i.e., Group 3).

Table 3

International Stratification

	Group 1	Group 2	Group 3	
1960				
group popn share:	42%	16%	42%	
group income share:	10.4%	22.6%	67%	
stratifi index:	1	1	1	
within group Gini:	0.196	0.111	0.215	
between group Gini:				0.369
overall Gini:				0.442
1970				
group popn share:	44%	17%	39%	
group income share:	9.5%	22.7%	67.8%	
stratifi index:	0.946	0.953	0.995	
within group Gini:	0.239	0.17	0.194	
between group Gini:				0.389
overall Gini:				0.456
1980				
group popn share:	46%	18%	36%	
group income share:	8.1%	24.6%	67.3%	
stratifi index:	0.935	0.889	0.963	
within group Gini:	0.281	0.228	0.172	
between group Gini:				0.405
overall Gini:				0.464
1985				
group popn share:	47%	18%	35%	
group income share:	8.2%	24.5%	67.3%	
stratifi index:	0.36	0.82	0.89	
within group Gini:	0.32	0.27	0.208	
between group Gini:				0.423
overall Gini:				0.481
1988				
group popn share:	48%	18%	34%	
group income share:	7.9%	24%	68.1%	
stratifi index:	-0.09	0.73	0.88	
within group Gini:	0.35	0.31	0.21	
between group Gini:				0.447
overall Gini:				0.499

Notes:
Group 1 – bottom 31 countries in terms of 1960 ppp GDP per capita
Group 2 – middle 30 countries in terms of 1960 ppp GDP per capita
Group 3 – top 30 countries in terms of 1960 ppp GDP per capita

In summary, the rise in international inequality is due primarily to scale effects (that is, the rich getting richer and poor getting poorer), with very minor changes in international ranking between 1960 and 1988. Furthermore, according to the second Gini-decomposition, international inequality is mostly between-group inequality. There are, however, signs of declining international stratification.

Table 4

International Comparisons of R&D Spending, 1960-88

OECD	rdy %	R&D p.c.	% world R&D
USA	2.600	366.69	49.968
Switzerland	2.393	310.36	1.223
UK	2.239	196.64	6.956
W. Germany	2.238	209.40	8.032
Sweden	2.148	211.90	1.088
Japan	2.130	164.85	11.460
Netherlands	2.060	187.25	1.594
France	1.975	184.45	6.073
Belgium	1.475	127.45	0.784
Norway	1.294	125.65	0.315
Finland	1.236	102.21	0.306
Canada	1.176	143.32	2.034
Australia	1.175	124.24	1.063
Denmark	1.168	108.08	0.341
Austria	0.969	76.23	0.361
Italy	0.870	69.78	2.423
Ireland	0.793	41.37	0.083
New Zealand	0.765	68.29	0.127
Iceland	0.595	55.39	0.008
Turkey	0.494	13.60	0.342
Portugal	0.368	12.93	0.078
Spain	0.368	20.75	0.464
Greece	0.241	10.44	0.061

Sample Means	rdy %	R&D
overall	0.717	56.798
OECD	1.338	127.446
Non-OECD	0.321	11.661
overall Sample R&D Gini		0.7014
OECD share of World R&D		95.2%
OECD R&D Gini		0.3328
Non-OECD share of World R&D		4.8%
Non-OECD R&D Gini		0.4292

Notes:
rdy % – R&D as percentage of GDP
R&D p.c. – (real U.S.$) per 1000 population
% world R&D – R&D as percentage of World R&D

Non-OECD	rdy %	R&D p.c.	% world R&D
Israel	1.842	138.96	0.294
El Salvador	1.008	17.50	0.043
S. Korea	0.610	16.02	0.349
Jordan	0.545	11.69	0.019
Brazil	0.534	18.18	1.234
India	0.486	3.17	1.228
Chile	0.437	16.43	0.107
Argentina	0.437	18.29	0.301
Trinidad-Tobago	0.433	32.65	0.021
Mauritius	0.373	11.47	0.006
Singopore	0.350	22.91	0.032
Guatemala	0.337	7.43	0.028
Central African	0.322	2.47	0.003
Pakistan	0.285	3.35	0.152
Venezuela	0.281	16.39	0.131
Ecuador	0.280	6.77	0.030
Iran	0.245	7.51	0.160
Thailand	0.232	4.30	0.110

Non-OECD	rdy %	R&D p.c.	% world R&D
Peru	0.228	6.67	0.064
Sudan	0.223	2.28	0.024
Fiji	0.218	7.18	0.003
Malta	0.215	7.79	0.002
Nicaragua	0.210	4.75	0.007
Costa Rica	0.207	6.83	0.008
Rwanda	0.193	1.20	0.003
Sri Lanka	0.164	2.54	0.022
Mexico	0.159	7.35	0.281
Philippines	0.147	2.51	0.068
Colombia	0.131	3.71	0.054
Guyana	0.128	2.16	0.001
Iraq	0.093	3.71	0.026
Jamaica	0.061	1.55	0.002
Cyprus	0.053	2.48	0.001
Niger	0.037	0.27	0.001
Congo	0.036	0.62	0.001
Panama	0.024	0.70	0.001

The research question therefore is what factors are behind the rise in world inequality. One explanation lies in the pattern of international R&D investment. The next section explores the impact of R&D on the international distribution of income. Before analyzing the role of R&D, it is necessary to review some trends in national R&D activities. *Table 4* indicates the vast disparities in national R&D investments[9]. The countries are grouped into 2 regions: OECD and non-OECD. In each group, the countries are arranged in descending order of the ratio of gross R&D expenditures to GDP. For most OECD countries, R&D spending is at least 1% of GDP, though Turkey, Portugal, Spain, and Greece spend less than 0.5% of GDP on R&D. Among the non-OECD, Israel's R&D spending to GDP is similar to the Western European countries of the OECD. The vast majority of non-OECD countries devote less than 0.5% of their GDP to R&D investment.

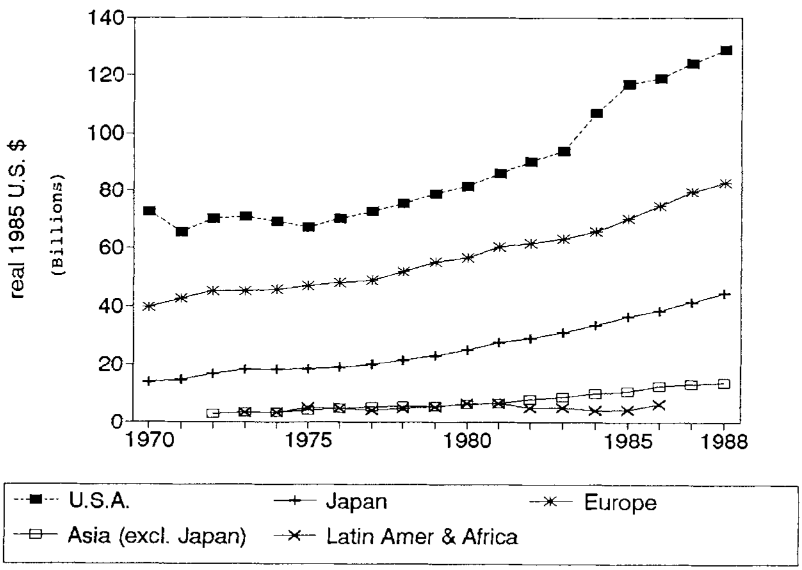
9. R&D data are taken from the UNESCO's *Statistical Yearbooks*, 1967-1993. Adequate observations on R&D spending could only be obtained for 59 of the 91 countries. See *Table 4* for the list of countries.

As a percentage of world R&D, the top five contributors are the U.S. (which accounts for nearly 50% of the world's R&D expenditures), Japan (11.46% of world R&D), Germany (8.032%), U.K. (6.956%), and France (6.073%). Among the non-OECD countries, El Salvador devotes a relatively high share of GDP to R&D (namely 1.008%), but its R&D accounts for only 0.043% of world R&D. Together the OECD accounts for 95.2% of world R&D.

According to the Gini coefficient for per capita R&D (which equals 0.701), greater disparities exist in terms of R&D than of income or consumption. Within groups, however, the disparities are less. The R&D Gini is 0.33 for the OECD and 0.429 for the non-OECD. Thus the overall disparities are largely between-group, with the allocation of world R&D activities and resources heavily concentrated in the G7 countries. It also appears that the disparities are not diminishing over time. *Figure 2* shows the U.S., Europe, and Japan steadily increasing their R&D expenditures, while the rest of the world commits to a slower rate of expansion in R&D expenditures.

Figure 2

Gross R&D Expenditures by Region



III. GLOBAL KUZNETS CURVE

The fact that global inequality has risen, while the world has reached a higher level of development (that is, a higher level of average global per capita real income), casts doubt on the existence of a global Kuznets inverted-U Curve. It also casts doubt on the prediction of international economic convergence since the dispersion of income per capita across countries does not dissipate as the global economy experiences increased development. *Figure 3* plots the global Gini against the log of the average global per capita income (in real PPP U.S. dollars), and the global consumption Gini against the log of the average global consumption per capita, for 1960-1988. The averages are for the 91 countries listed in *Table 1*, and the global Ginis are those displayed in *Figure 1*. If anything, the scatter plots show a U-relationship – rather than an inverted-U. This section therefore investigates how international R&D activities have affected the international distribution of income, and whether they have on net contributed to international economic convergence or divergence. As stated earlier, two effects can be ascribed to R&D investments. On the one hand, the own-investment effects of R&D help to raise the income level and rank of a country. On the other hand, to the extent that R&D generates productive spillovers to the rest of the world, national R&D investment can offset the own-investment effect on the country's income and rank. The ultimate impact on 'relative' income shares and ranking is ambiguous a priori.

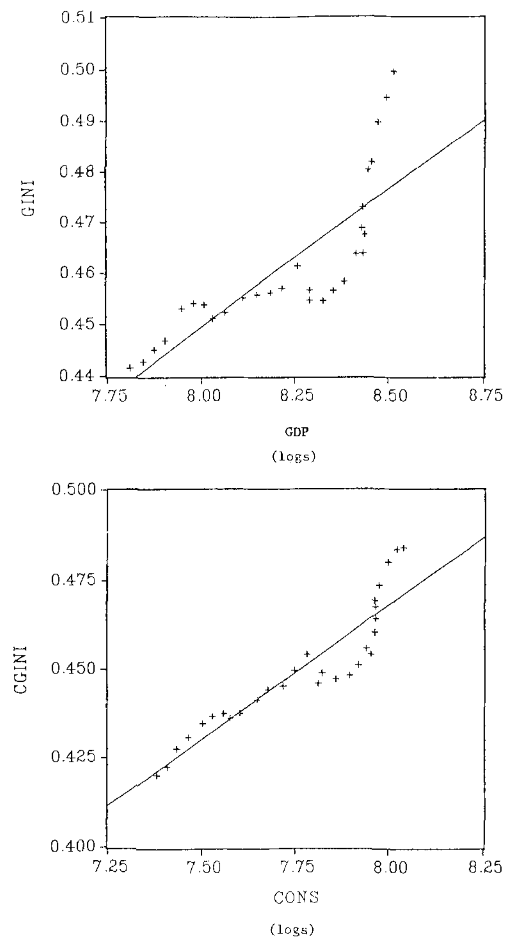
The Kuznets hypothesis is typically tested using the following estimation equation:

$$\text{Gini} = \beta_0 + \beta_1 y + \beta_2 y^2 + \text{error} \qquad (7)$$

where y is the log of real income per capita. In order for the inequality-income relationship to be an inverted-U (or concave downward), it must be the case that $\beta_1 > 0$ and $\beta_2 < 0$. However, as column I in *Table 5A* (which focuses on GDP per capita as the income measure) shows, the equation is concave upward. Note the DW statistic which indicates substantial first-order serial correlation, one possible cause of which is omitted variables.

In column II, both the time trend and quadratic time trend are included. In this case something about controlling for a linear and a quadratic time trend causes the relationship between inequality and income to conform with the Kuznets hypothesis (note that the equation is now concave downward in the Gini-y space). The DW statistic is also markedly higher, so that some improvements are made in the way of adding information.

Figure 3



Recall that R&D activities are heavily concentrated in a relatively few countries and that the dispersion of cross-country investments in R&D, if anything, has widened. Thus one conjecture is that the variance of R&D between countries has increased at a quadratic rate. On the other hand, the R&D expenditures of each country either have increased at a constant rate (thus following a linear trend) or have been constant over time, as *Figure 2* showed. In any case the sum of linear trends and constants is still linear. Thus the sum of world R&D expenditures increased at a linear rate.

Table 5A

Kuznets Curve, GDP-Gini

	Dependent Variable: GINI, Sample: 1960-1988		
	I.	II.	III.
c	8.52 (2.45)	-24.07 (2.86)	-2.94 (1.14)
y	-2.03 (0.599)	5.90 (0.677)	0.814 (0.293)
y^2	0.127 (0.037)	-0.354 (0.039)	-0.048 (0.018)
Time		-0.011 (0.00212)	
$Time^2$		0.000344 (0.0000424)	
sumrd			-0.042 (0.012)
varrd			0.011 (0.00153)
Adj R^2	0.749	0.980	0.982
DW	0.182	1.15	1.84
s.e.r.	0.007	0.0021	0.002

Notes: y is log GDP per capita, *sumrd* the sum of national R&D per 1000 global population (normalized) by dividing by the 1960 value of the sum), and *varrd* the variance of national R&D per capita (normalized by dividing by the 1960 value of the variance). GINI is the Gini coefficient of the international distribution of GDP per capita in PPP real 1985 U.S. dollars.
Standard errors are in parentheses.

Two R&D variables are therefore constructed. The first is the variance of national R&D per 1000 population. Here a nation's R&D per 1000 persons (or alternatively per 1000 workers) is the measure of input into the production process[10]. Division by population takes into account the fact that R&D expenditures are spread out across the population, and that agents are more productive in economies with a higher R&D per person[11]. The second variable is global

10. Data on workers are not fully available for all the 59 countries in the sample. Since the worker to population ratio is fairly steady for those countries for which data are available, the results should not differ too much if one uses number of workers instead. MANKIW et al. (1992) also use population to proxy for labor force.
11. For example, if a country's 'National Science Foundation' has a given R&D budget of $1 million, each scientist can be more productive if the budget were spread out among fewer scientists than among many. Conversely, a country with a given number of scientists will be better off if the R&D budget were larger.

R&D per 1000 population, obtained by summing national R&D (all in real 1985 U.S. dollars) and dividing by the total population of the R&D countries (and multiplying by 1000). This gives a measure of a global productive input[12] [13].

Thus replacing the quadratic trend term by the variance of national R&D per 1000 population and the linear trend term by the global sum of national R&D per 1000 global population, yields the results in Column III[14]. The variances and sums are normalized by dividing by their respective values in 1960, and are denoted by varrd and sumrd, respectively. The results support the above conjectures: a higher variance of R&D across countries contributes to world inequality, as the high R&D-countries experience relatively greater productivity gains than the rest who are low R&D-countries. This reflects the 'own-investment' effect of R&D. Next, the sum of national R&D (or the size of world R&D) contributes to lowering world inequality. A greater amount of world R&D enhances the possibility of countries enjoying R&D spillovers. The source of positive global externalities is expanded. This spillover effect of world R&D helps promote productivity

12. Note though that R&D spending here is a flow. Presumably the stock of R&D capital is the appropriate measure of a productive input. Rather than derive stocks from limited flow data, it is assumed that the flows are proportional to stocks, which is not unreasonable to assume across countries: countries with larger stocks of R&D capital undertake larger investments in R&D, as OECD data show. Furthermore, continual investments in R&D are needed to increase national output, particularly since the stock of R&D depreciates or becomes obsolescent over time. In a long run steady state, gross R&D expenditures would equal the fraction of R&D stock that depreciates. As long as the depreciation rate is constant across countries, R&D flows would indeed be proportional to R&D stocks.
13. Of course this latter variable does not take into account the fact that the R&D investments of different countries may be imperfect substitutes. However, for this time-series investigation, the size of world R&D is a reasonable measure of the pool of global knowledge available for productive use by individual countries. The 'effective' size of this pool, from the point of view of any one country, depends on how it weights the rest of the world's R&D. The simple summing up of all the countries R&D thus gives an upper bound as to the size of the global pool of R&D available to each and every country.
14. The R&D data for many of the non-OECD and for some OECD countries are not available for several periods in the 1960s, 1970s. Data on available trends in R&D to GDP ratios were used to interpolate or extrapolate the missing years of data. It turns out that the ratios of R&D to GDP have been fairly steady for the 59 countries in the sample, a factor which helps minimize the degree of mismeasurement. One reason for a relatively stable R&D to GDP ratio is that R&D investments incur higher adjustment costs so that stability in spending within a certain range is optimal. Another is that R&D investments are much riskier so that current expenditures are financed by current cash-flow (thereby matching the state of GDP in the aggregate), rather than by borrowing (to finance uncertain projects).

growth across a number of countries, thereby helping to pull up the incomes of the rest of the world (especially those of the low R&D-countries). Note also the absence of first-order serial correlation. This indicates that the omitted variables problem has largely been addressed by including the simultaneous convergence/divergence effects of national R&D.

To determine whether the 'own-investment' (i.e., divergence) effect or 'spillover' (i.e., convergence) effect dominates, consider what happens if the ith country increases its R&D expenditures per 1000 population by $1. Holding everything else constant, sumrd rises by p_i, the population share of country i. The coefficient of sumrd is -0.042, but this is the normalized coefficient. The unnormalized coefficient is obtained by dividing by the value of the sum of national R&D per capita in 1960, which is $25.6 (per 1000 population), giving the unnormalized coefficient value of -0.001641 (= -0.042/25.6). Thus a $1 increase in the ith country's R&D per 1000 population reduces the global Gini by $-0.001641 * p_i$.

Consider next the effect on the variance of national R&D per 1000 population. Taking the derivative of varrd with respect to the ith country's R&D per 1000 population gives:

$$\frac{d\,(\text{varrd})}{d\,(RD_i)} = \frac{2}{N}\,(RD_i - RD_M) \ , \qquad (8)$$

where $R\&D_M$ is the mean national R&D per 1000 population. Thus for small changes in national R&D, the variance (varrd) increases if the country undertaking the R&D investment has an R&D per 1000 population above the global average, and decreases if its R&D per 1000 population is below the global average. The normalized coefficient of varrd is 0.011 and unnormalized coefficient is 0.0000058 (since the 1960 value of the variance is $1903). The increase in the global Gini is thus 0.0000058 times the change in varrd.

For example if the U.S. increases its R&D per 1000 population by $1, sumrd increases by 0.11 since the U.S. population is 11% of the 59 countries'. This would cause the global Gini to change by -0.000185 (= -0.001641*0.11). The variance changes by 10.51 (since N=59, $R\&D_M$ = $366.69, and R&D = $56.8 – see *Table 4* which reports averages over 1960-1988). This would cause the Gini to increase by 0.000061 (=10.51*0.0000058). Hence the net impact of an increase in U.S. investment in R&D by $1 (for every 1000 U.S. population) would be to reduce the global Gini coefficient by 0.00012. An increase of $100 in R&D investment by the U.S. (for every 1000 U.S. population) would lower the Gini by 0.012 – for example, reduce a global Gini value of 0.5 to 0.488 [15]. In other words the convergence effect of U.S. R&D (through spillovers) would dominate the divergence effect of own U.S. national R&D, producing on net a locomotive effect of U.S. R&D.

Similar calculations for Canada (whose average R&D per 1000 population during 1960-88 is $143.32 and whose average share of population among the 59 R&D countries is 1.2%) show that a $1 increase in Canadian national R&D per 1000 population (in U.S. real dollars), would raise varrd by 2.93, and thereby raise the global Gini by 0.000017, and raise sumrd by 0.012, and thereby lower the global Gini by 0.0000197. Again the net effect is to encourage convergence or reduce world inequality. If India pursues the same amount of R&D investment at home, both varrd and sumrd would fall by 0.0000105 and 0.00051 respectively (as India's national R&D per 1000 population is below the global average)[16].

To summarize thus far, if the effects of national R&D on the international distribution of income are controlled for, it is possible to conclude that a conditional global Kuznets curve exists, conditional on taking into account a variable that grows linearly and one that grows quadratically over time. The characteristics of international R&D levels and distribution of activity over time appear to typify those variables. From the results, the 'turning points' of the conditional Kuznets curve can be determined. Using the column II results, the value of y at which the derivative of Gini with respect to y is zero (i.e., at which the maximum world inequality occurs) is 8.333 (= 5.9/(2*0.354)), or in natural units, $4160.26 U.S. real. Using the column III results, the critical y is 8.479 (= 0.814/(2*0.048)) or $4813.44. Since the global average GDP per capita has exceeded $5000 since 1990, it is likely that the world is experiencing conditional convergence.

The results are quite similar if real per capita PPP consumption is used as a measure of income. *Table 5B* reports the results. Again, in column I, there is no evidence supporting an unconditional global Kuznets curve – the relationship between CGini and consumption is concave upward. In column II, again, apparently a Kuznets curve exists if some variables growing at a linear and quadratic rate are controlled for. In column III, the candidate variables – sumrd and varrd – fulfill those roles.

15. The effect on the Gini is likely to be biased owing to the fact that the sumrd variable is unweighted (by measures of technological similarity). The direction of this bias is not clear. The coefficient of sumrd assumes that a $1 investment in U.S. R&D is widely available for all countries. For countries that put less than 100% weight on U.S. R&D, they experience a smaller output effect from U.S. R&D spillovers. On the other hand the sumrd variable would be smaller so that the coefficient of sumrd would be adjusted upward.

16. India's R&D per 1000 population has averaged $3.17 and her population share among the 59 R&D countries is 31%.

Table 5B

Kuznets Curve, Consumption Gini

	Dependent Variable: CGINI, Sample: 1960-1988		
	I.	II.	III.
C	4.63 (2.12)	-18.5 (4.05)	-5.07 (1.20)
CC	-1.16 (0.550)	4.85 (1.02)	1.41 (0.32)
CC^2	0.080 (0.035)	-0.310 (0.063)	-0.089 (0.022)
Time		-0.0057 (0.0027)	
$Time^2$		0.00021 (0.00005)	
sumrd			-0.019 (0.014)
varrd			0.007 (0.002)
Adj R^2	0.863	0.98	0.981
DW	0.279	1.53	1.88
s.e.r.	0.006	0.002	0.002

Notes: CC is log of per capita PPP Real Consumption. CGINI is the Gini coefficient of the international distribution of per capita PPP Consumption in Real U.S. dollars. See also Notes to *Table 5A*.

Calculations based on the coefficient estimates show that again the spillover effect of increases in national R&D investment dominate the own-investment effects – that is the convergence effects of R&D dominate the divergence effects. For example, the same $1 increase in U.S. R&D investment per 1000 population, changes varrd by 10.505, as before, and increases the consumption Gini by 0.0000387 (using the unnormalized value of the normalized coefficient of varrd which is 0.007, as indicated in column III, *Table 5B*). Sumrd increases again by 0.11 and this reduces the consumption Gini by 0.000082 (using the unnormalized value of sumrd's coefficient of -0.019). Thus on net, consumption inequality is reduced. The turning point of the conditional consumption Kuznets curve is cc* = 7.9213 (=1.41/(2*0.089)) or when the global average real consumption per capita is $2755.5, using the estimates from column III. Again the post 1988-era should be one where the global economy has reached the point of conditional convergence.

Finally, some remarks on dynamics are in order. The Gini coefficients are bounded between 0 and 1, but the quadratic trend variable is unbounded. Is this a problem for either estimation or conceptualization? First, even as 'varrd' and 'sumrd' increase over time, the Gini coefficient approaches unity extremely slowly and asymptotically. The Gini equals unity if one country has all the global income, and if this country is of measure zero – or if N (the number of countries) approaches infinity. Assuming N is constant, it is not feasible for one country to have all the income unless varrd explodes and spillover effects disappear entirely, which are not likely events. Secondly, the spillover effects of R&D do dominate the own-investment effects of national R&D. Thus as varrd and sumrd increase, the net effect is to push the Gini away from unity.

IV. CONCLUSION

This paper has reviewed changes in global inequality and has decomposed the changes into rank-scale effects and has decomposed the level of inequality into between-group inequality, within-group-inequality, and levels of stratification of groups. The raw evidence shows that global inequality has worsened over the period 1960-1988. The world in 1988 still consists of stratified groups, but the levels of group stratification have fallen, and a third group (namely the bottom group) has split apart, in that some members have moved up in the international ranking. The paper has also traced the changes in global inequality to differences in national R&D investment. Differences in R&D account significantly for the changes in global inequality. At the same time, the higher levels of world (aggregate) R&D have contributed to international economic convergence or to a narrowing of global inequality. The empirical results show that in the absence of international R&D spillovers, the international distribution of income would have been worse. On balance, the paper supports the existence of conditional convergence or of a conditional global Kuznets curve which predicts that increased development of the world economy is eventually associated with a reduction in inequality among nations. This hypothesis is confirmed with the existing data if R&D variables are controlled for. While the R&D variables explain why inequality has worsened according to the raw data, the empirical results also indicate that R&D investments worldwide have the net effect of reducing global inequality and raising the mean level of global per capita income.

Two extensions for this paper come to mind. The first is to distinguish between public and private R&D, since the two kinds of R&D are not perfect substitutes and have different economic functions. Secondly, a long-awaited research topic for the international growth literature is the examination of the role of international political relations. It is somewhat difficult for certain countries such as Iran, Iraq, Libya, or N. Korea, to catch-up to the advanced OECD nations when diplomatic relations between them and the OECD are either weak or non-existent. Knowledge spillovers presuppose the existence of some channels of communication or means of 'transport'. Furthermore, tensions between nations inhibit international economic development as nations cooperate less and divert productive resources for mutual defense or pre-emptive offense.

REFERENCES

ALESINA, A. and R. PEROTTI (1993): Income Distribution, Political Instability, and Investment, *National Bureau of Economic Research Working Paper* No. 4486.

ANAND, S. and S. KANBUR (1993): The Kuznets Process and the Inequality Development Relationship, *Journal of Development Economics*, Vol. 40, 25-52.

BARRO, R. (1991): Economic Growth in a Cross-Section of Countries, *Quarterly Journal of Economics*, Vol. 106, 407-444.

BERRY, A.; F. BOURGUIGNON and C. MORRISSON (1983): The Level of World Inequality: How Much Can One Say? *The Review of Income and Wealth*, Vol. 29, 217-241.

CAMPANO, F. and D. SALVATORE (1988): Economic Development, Income Inequality, and Kuznets' U-Shaped Hypothesis, *Journal of Policy Modeling*, Vol. 10, 265-280.

FIELDS, G. and G. JAKUBSON (1993): New Evidence on the Kuznets Curve, *Cornell University Working Paper*.

GALOR, O. and D. TSIDDON (1992): Income Distribution and Output Growth: The Kuznets Hypothesis Revisited, *Hebrew University Working Paper* No. 264.

GOODFRIEND, M. and J. MCDERMOTT (1992): A Theory of Convergence, Divergence, and Overtaking, *Federal Reserve Bank of Richmond mimeo*.

KUZNETS, S. (1955): Economic Growth and Income Inequality, *The American Economic Review*, Vol. 45, 128.

LERMAN, R. and S. YITZHAKI (1989): Improving the Accuracy of Estimates of Gini Coefficients, *Journal of Econometrics*, Vol. 42, 43-47.

LERMAN, R. and S. YITZHAKI (1991): Income Stratification and Income Inequality, *Review of Income and Wealth*, Vol. 37, 313-329.

LERMAN, R. and S. YITZHAKI (1993): Reranking and Gap-Narrowing Effects of Taxes and Transfers, forthcoming.

LICHTENBERG, F. (1992): R&D Investment and International Productivity Differences, *National Bureau of Economic Research Working Paper*, 41-61.

MANKIW, N.; D. ROMER and D. WEIL (1992): A Contribution to the Empirics of Economic Growth, *Quarterly Journal of Economics*, Vol. 107, 407-438.

PERSSON, T. and G. TABELLINI (1991): Is Inequality Harmful for Growth? Theory and Evidence, *National Bureau of Economic Research Working Paper*, 35-99.

RAM, R. (1989): Level of Development and Income Inequality: An Extension of Kuznets Hypothesis to the World Economy, *Kyklos*, Vol. 42, 73-88.

ROSTOW, W. (1980): *Why the Poor Get Richer and the Rich Slow Down.* Austin: Univ. of Texas Press.

SOLOW, R. M. (1956): A Contribution to the Theory of Economic Growth, *Quarterly Journal of Economics*, Vol. 70, 65-94.

SPROUT, R. and J. WEAVER (1992): International Distribution of Income: 1960-1987, *Kyklos*, Vol. 45, 237-258.

SUMMERS, R.; I. KRAVIS and A. HESTON (1984): Changes in the World Income Distribution, *Journal of Policy Modeling*, Vol. 6, 237-269.

SUMMERS, R. and A. HESTON (1991): The Penn World Table (Mark 5): An Expanded Set of International Comparisons, 1950-1988, *Quarterly Journal of Economics*, Vol. 106, 141.

SUMMARY

This paper studies the inequality of nations, treating the country as the unit of analysis. First, measures of inequality are computed for 1960 to 1988. The international distribution of income has become more unequal over time. Secondly, the contribution of R&D investments and spillovers to global inequality is studied. Cross-country differences in R&D significantly account for the changes in the global distribution of income. National R&D investments have both a divergence and a convergence effect. The divergence effect arises from a high R&D nation forging ahead of other nations. The convergence effect comes from international R&D spillovers enabling lesser developed nations to catch up. The empirical results indicate that on net, world R&D has a convergence effect. Controlling for R&D, the paper finds an inverted-U relationship between global inequality and global development.

ZUSAMMENFASSUNG

Diese Forschungsarbeit analysiert die internationale Einkommensverteilung zwischen armen und reichen Ländern, wobei ein Land als eine Einheit betrachtet wird. Zuerst werden Maßstäbe der unterschiedlichen Einkommensverteilung von 1960 bis 1988 berechnet. Die Konzentration der internationalen Einkommensverteilung hat im Laufe der Zeit zugenommen. Als nächstes wird der Beitrag von Forschungs- und Entwicklungsinvestitionen, sowie deren Überschwappen in andere Länder studiert. Der Unterschied von Forschungs- und Entwicklungsinvestitionen zwischen den Ländern hat maßgeblich zur Konzentration der internationalen Einkommensverteilung beigetragen. Nationale Forschungs- und Entwicklungsinvestitionen haben sowohl einen Divergenzeffekt als auch einen Konvergenzeffekt. Der Divergenzeffekt ergibt sich von einem unterschiedlichen Investitionsniveau zwischen den Ländern. Der Konvergenzeffekt ergibt sich aus internationalem Überschwappen von Forschungs- und Entwicklungsinvestitionen, die es einem weniger entwickelten Land ermöglicht, gegenüber einem weiter entwickelten Land aufzuholen. Die Analyse von Forschungs- und Entwicklungsinvestitionen ergibt, daß ein inverses U-Verhältnis zwischen globaler Einkommenskonzentration und globaler Entwicklung existiert.

RÉSUMÉ

Prenant les nations comme unité d'analyse, cet article étudie l'inégalité au niveau international. Dans un premier temps, une plus grande inégalité dans la distribution internationale des revenus est mise en évidence à partir d'indices calculés de 1960 à 1988. Ensuite, l'impact des investissements de recherche et développement (R&D) et de la diffusion des technologies sur l'inégalité entre nations est étudié. Les différences de R&D entre nations ont un impact statistiquement significatif pour l'évolution de l'inégalité des revenus. Un effet de convergence et un effet de divergence sont distingués. L'effet de divergence résulte de R&D élevées permettant à certains pays d'acquérir une avance technologique. L'effet de convergence résulte de la diffusion des acquis de R&D qui permet

aux pays moins développés de rattraper leur retard. Les résultats empiriques indiquent qu'au total, la R&D mondiale a un effet de convergence. Ainsi, lorsque la R&D est prise en compte, une relation 'U' inversée est observée entre l'inégalité et le développement au niveau international.