Dead Weight Losses from Immobile Capital

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Abstract

In a world with mobile capital, international investment should seek out the highest return. If true, we should see a tendency for the marginal product of capital to be the same in all countries. There are, of course, many reasons to think that this will not hold true. Political and institutional barriers to capital flows and risk premia may drive differences in returns. Insofar as these differences exist, they will cause a dead weight loss in world output. If the existing stock of capital in the world could be reallocated to equalize returns to capital, world output would be higher. This paper estimates the degree to which returns to capital vary across country using aggregate data on investment and output. These differences imply that the dead weight loss to output varies between 6% and 3% and has been falling over time.

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Introduction

Lucas (1990) asks the question "Why doesn't capital flow from rich to poor countries?" This question emerges as an obvious consequence of the textbook neoclassical growth model. Any model of cross country income differences which relies on differences in factor accumulation will result in cross country differences in the marginal product of capital. In particular, poor countries should have very high returns to capital. Lucas notes that these differences should be quite large. The question naturally arises, why is capital not flowing to the countries with the highest return?

One potential answer to this question has emerged in recent work emphasizing differences in productivity. Klenow and Rodriguez-Clare (1997), Hall and Jones (1999) and Easterly and Levine (2001) all emphasize that difference in productivity account for the majority of cross country income differences. Cross country income differences rooted in productivity differences do not necessarily imply large differences in return to capital.

This question is of potential importance because anything less than full equalization of cross country returns to capital has welfare consequences. If returns are higher in some countries than others, free flows of capital between nations could potentially raise world output.

Drawing on the recent work on productivity, this paper will empirically examine the differences in returns to capital between countries. I will then examine how much larger world output would be if capital truly flowed to the countries with the highest returns. In other words, I will calculate the dead weight loss created by the imperfect mobility of capital.

The results suggest that differences in returns to capital are not nearly as large as predicted by the neoclassical growth model. The size of the dead weight losses are on the order of 5% of world output and are falling over time.

1 Theory

Why doesn't capital flow from rich to poor countries? This section will describe why this question arises naturally from the textbook neoclassical growth model. Assume that all countries share the same Cobb-Douglas production function,

$$y_i = A_i k_i^{\alpha} \tag{1}$$

where y_i is output per capita, k_i is capital per worker, and A_i is a technological constant. If we assume that the share of capital is the same across countries, the ratio of output in any two countries can be expressed as

$$\frac{y_1}{y_2} = \frac{A_1}{A_2} \left(\frac{k_1}{k_2} \right)^{\alpha} \tag{2}$$

The marginal product of capital implied by equation 1 is

$$MPK_i = \alpha A_i k_i^{\alpha - 1} \tag{3}$$

If we assume that the share of capital is the same across countries, the ratio of the marginal product of capital in any two countries can be expressed as

$$\frac{MPK_1}{MPK_2} = \left(\frac{A_1}{A_2} \right) \left(\frac{k_2}{k_1} \right)^{(1-\alpha)} \tag{4}$$

Equation 4 shows clearly that the marginal product of capital will vary across countries due to differences in the technological constant and differences in the level of capital per worker.

The textbook Solow model and early empirical work on convergence such as Barro (1991) and Mankiw, Romer and Weil (1992) assume that all countries share the same technological constant (or that that the technological constant is randomly distributed).

All income differences are therefore attributable to differences in capital per worker.[1] This implies rather large disparities in capital per worker. If we assume that $A_1 = A_2$, we can express 4 in terms of output,

$$\frac{MPK_1}{MPK_2} = \left(\frac{y_2}{y_1}\right)^{(1-\alpha)/\alpha} \tag{5}$$

Recall that the parameter α represents capital's share of output. If we assume that $\alpha = 0.4$ [2] then the fraction $(1-\alpha)/\alpha = 1.5$. Given the earlier cited twenty fold difference in output per worker between India and the US, this implies that the marginal product of capital in India is roughly 64 times that of the US. If there is any degree of capital mobility in the world, this ratio is implausible.

Of course, the assumption of $\alpha = 0.40$ is a major factor driving this result. As Mankiw et al. (1992) point out, augmenting the Solow model with human capital (in the form of schooling) results in the total share for accumulable factors of nearly 2/3. With $\alpha = 2/3$ the fraction $(1-\alpha)/\alpha = 1/2$ and implies that the marginal product of capital in India is only 4 times that of the US. This ratio is still quite large.

The difficulty with this line of reasoning is that the Mankiw et al. (1992) results have not held up well to more intense scrutiny. The panel regressions of Caselli, Esquivel and Lefort (1996) show that the impact of schooling is potentially much lower than estimated by Mankiw et al. (1992). They find that the total return to accumulable factors is much closer to the 1/3 from the unaugmented model. This is largely a result of dropping the assumption that the technology parameter is the same in all countries. Using panel data allows for a different estimate of efficiency in each country. These estimates turn out to be significantly different from each other. Later work by Klenow and Rodriguez-Clare (1997) and Hall and Jones (1999) use growth accounting to arrive at similar results. Klenow and Rodriguez-Clare (1997) find that productivity differences can explain the majority of cross

[1]The definition of capital can easily be broadened to include human capital in the form of education as in Mankiw et al. (1992).

[2]Gollin (2002) finds that this is a reasonable estimate for capital share across many countries.

country income differences.

Equation 4 points out the direct connection between productivity and marginal product of capital. It is also important to note that the level of productivity is going to impact the level of capital per worker. To see the relationship between productivity and capital per worker, start with the Solow model with neutral technological progress:

$$y_{i,t} = A_{i,t}\ f(k_{i,t}) \tag{6}$$

$$\dot{k}_{i,t} = s_i A_{i,t} f(k_{i,t}) - (n_i + \delta) k_{i,t} \tag{7}$$

where $f(k_{i,t})$ is a neoclassical production function with decreasing returns to capital per worker, $A_{i,t}$ is an exogenous productivity parameter, $k_{i,t}$ is capital per worker, n_i is population growth, and δ is depreciation. We can state the requirements for a steady state where $\dot{k}_{i,t} = 0$.

$$(n_i + \delta)\ k^*_{i,t} = A_{i,t}\ f(k^*_{i,t})\ s_i \tag{8}$$

It can be shown that the steady state level of capital per worker, $k^*_{i,t}$ is an increasing function of the productivity level $A_{i,t}$. A shock to productivity will therefore produce an increase in the steady state level of capital per worker. On the other hand, the steady state level of the capital-output ratio,

$$\left(\frac{K}{Y}\right)^*_{i,t} = \frac{k^*_{i,t}}{A_{i,t}\ f(k^*_{i,t})} = \frac{s_i}{n_i + \delta} \tag{9}$$

is not a function of the productivity level. This fact will turn out to be useful because the marginal product of capital turns out to be a function of the capital output ratio,

2 The Marginal Product of Capital

The previous section explored the reasons that we might see vastly different levels of the marginal product of capital across countries. This section will turn to the data to examine the actual distribution of the marginal product of capital

Using time series for investment and the perpetual inventory method one can construct a time series for capital stocks. The following exercises utilize series constructed by Easterly and Levine (2001) using this method. Using these time series, it is possible to calculate a time series for the marginal return to capital in any given country. Assuming a Cobb-Douglas production function[3]

$$Y = A_i K_i^{\alpha} L_i^{1-\alpha} \tag{10}$$

the marginal product of capital can be expressed in terms of the aggregate capital stock and aggregate output.

$$MPK_i = \alpha A_i K_i^{\alpha-1} L_i^{1-\alpha} = \alpha \frac{Y_i}{K_t} \tag{11}$$

where α is capital's share of income, Y_i is aggregate output and K_i is the aggregate capital stock.

Note that this calculation can be accomplished without the need to make any assumptions about technology, human capital, or the labor force. All that is required is a time series for GDP and aggregate investment and the assumption that capital's share is equal in all countries. Appendix A contains the results of this calculation for 1985.

The most obvious result from this exercise is that variation in the return to capital is much lower than is implied by the textbook Solow model, even after augmentation by human capital. The ratio between MPK_{India} and MPK_{US}, for example is slightly above 2, (18% vs 9%). The list seems reasonable in a cursory examination. Countries with high relative MPK (greater than twice MPK_{US}) are almost uniformly poor and unstable,

[3]as usual this form is useful because it exhibits constant returns to scale and capital's share of income is constant

corresponding to the idea that differences in returns to capital represent risk premia.

Looking at the time dimension of the data reveals that the distribution of returns to capital is narrowing over time, and that this narrowing is evident for any subgroup of the data. Figures 1 and 2 shows the evolution of MPK for a constant set of countries between 1970 and 1989 grouped by region.

With the exception of the Middle East and North Africa (mena) and South Asia (sa) regions, the means of regional MPKs move monotonically toward the Western European/North American level (which is relatively constant). For mena, the increase in the mean in the 70's coincides with oil price shocks. By equation (4) it is clear that an increase in GDP caused by an increase in oil prices will increase the marginal product of capital. For sa, the sample is small, including only four countries: India, Pakistan, Sri Lanka, and Bangladesh.

Figures 3 and 4 shows the same group of countries grouped by income level. The results are quite similar to the regionally grouped graphs. The behavior of the upper middle group in the 70's can again be explained by the preponderance of oil producing nations in this group.

Figure 1: Mean of MPK by Region

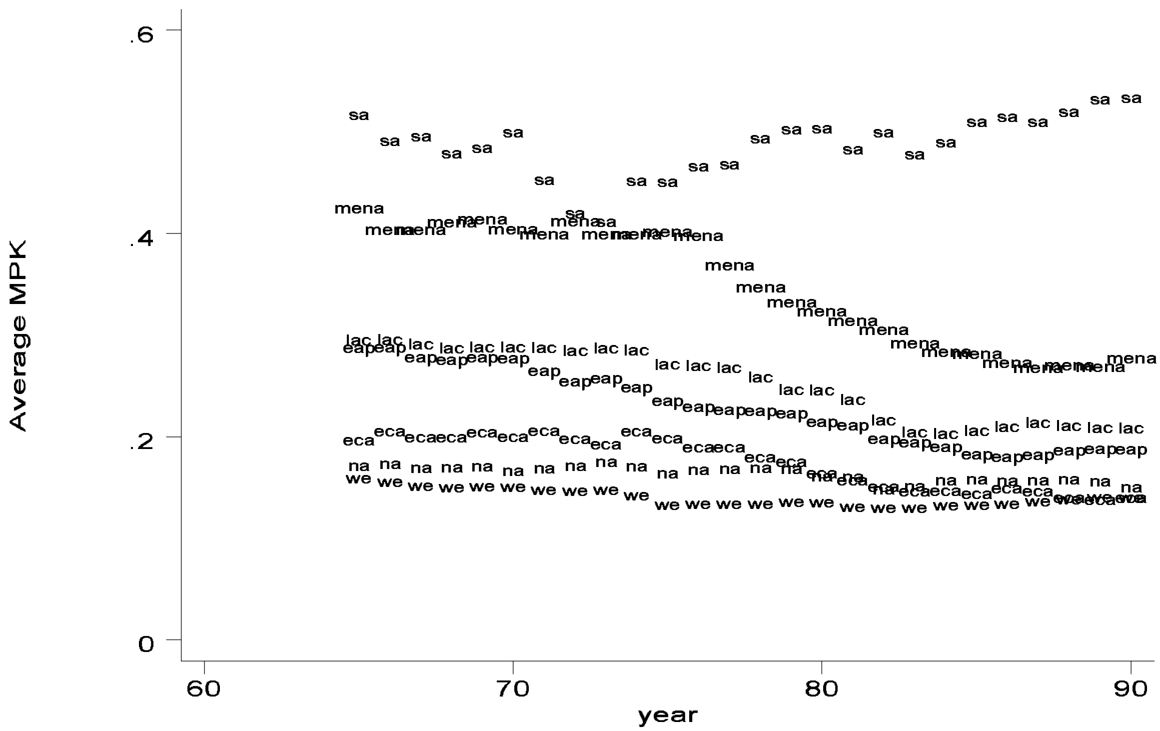


Figure 2: Standard Deviation of MPK by Region

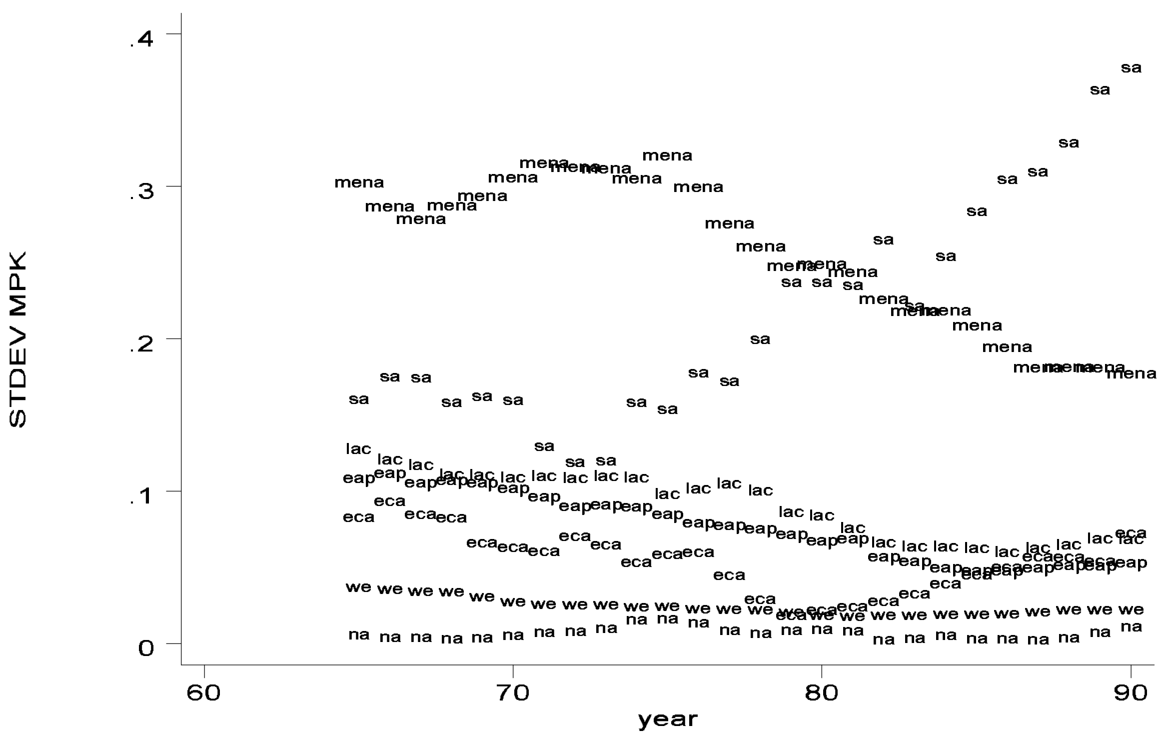


Figure 3: Mean of MPK by Income level

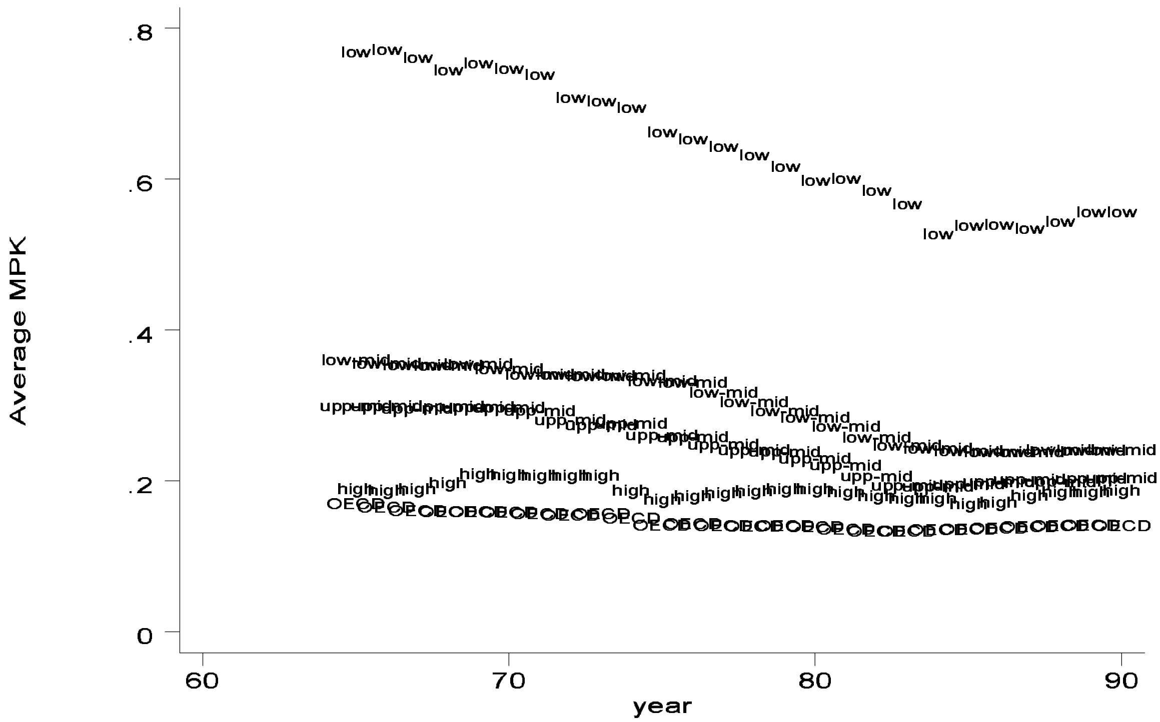
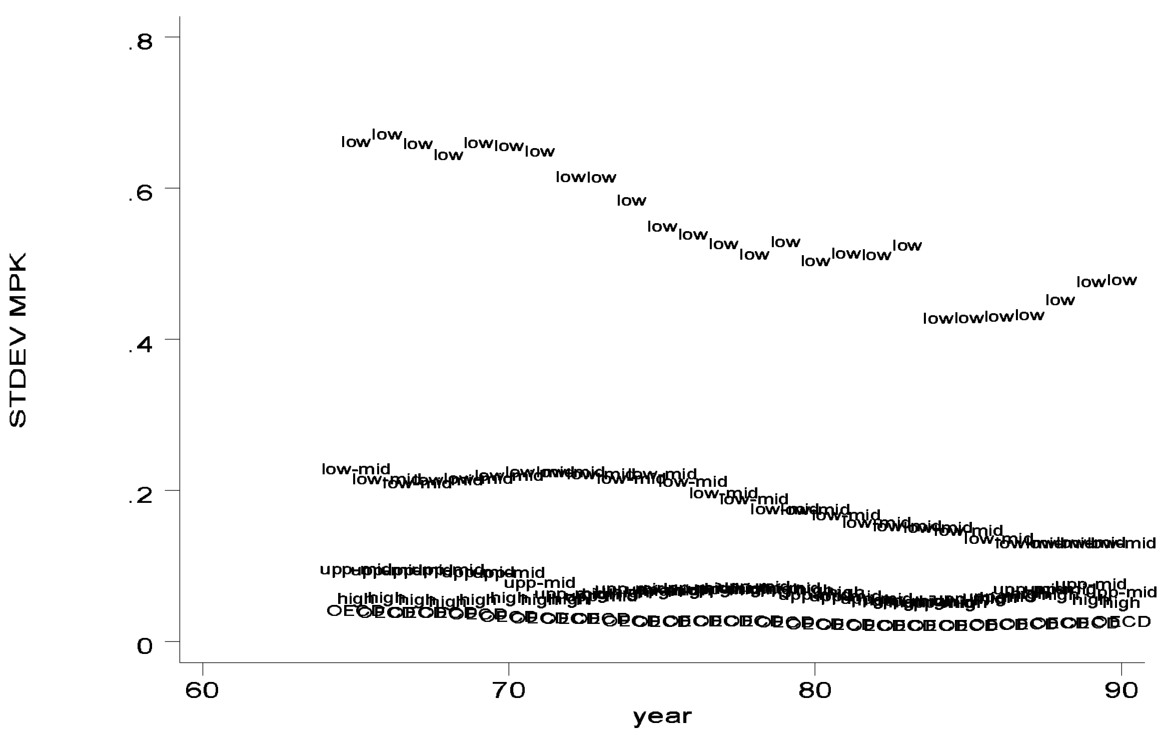


Figure 4: Standard Deviation of MPK by Income Level



3 Dead Weight Losses From Immobile Capital

The fact that returns to capital differ around the world has welfare consequences. Movements of capital from a country with low MPK to a country with high MPK will result in higher total output between the two countries. MPK differences therefore imply that there are dead weight losses caused by an inefficient world distribution of capital.

Using the data on MPK described in the previous section, a cross section of 119 countries with continuous data was selected. These countries represent 87% of world population. Assuming a Cobb-Douglas production function with human capital and labor augmenting technology, the production function can easily be expressed in terms of the marginal product of capital.

$$Y_{it} = A_{it} K_{it}^{\alpha} \tag{12}$$

$$Y_{it} = A_{it}^{1/(1-\alpha)} \left(\frac{K_{it}}{Y_{it}}\right)^{\frac{\alpha}{1-\alpha}} \tag{13}$$

$$Y_{it} = A_{it}^{1/(1-\alpha)} \left(\frac{\alpha}{MPK_{it}}\right)^{\frac{\alpha}{1-\alpha}} \tag{14}$$

In a hypothetical world economy with perfect capital mobility, all countries share the same $MPK_{it} = MPK_t$, in each year. Given some world level of MPK_t, output for each country at time t is given by

$$\hat{Y}_{it}(MPK_t) = \left(\frac{\alpha}{MPK_t}\right)^{\frac{\alpha}{1-\alpha}} A_{it}^{1/(1-\alpha)} = \left(\frac{MPK_{it}}{MPK_t}\right)^{\frac{\alpha}{1-\alpha}} Y_{it} \tag{15}$$

where $\hat{Y}_{it}$ describes the hypothetical output in country i at time t assuming a common world return to capital. Countries that have a high MPK would see output rise if capital were completely mobile while countries with a low MPK would see output fall. Similarly we can calculate the capital stock in each country if capital were perfectly mobile.

$$\hat{K}_{it}(MPK_t) = \alpha \frac{\hat{Y}_{it}(MPK_t)}{MPK_t} = \left(\frac{\alpha}{MPK_t}\right)^{\frac{\alpha}{1-\alpha}} \tag{16}$$

The only remaining problem is to determine the equilibrium level of world MPK, MPK_t^* for each year. This requires the assumption that the total capital stock in the hypothetical economy be equal to the total capital stock in the real economy for each year.

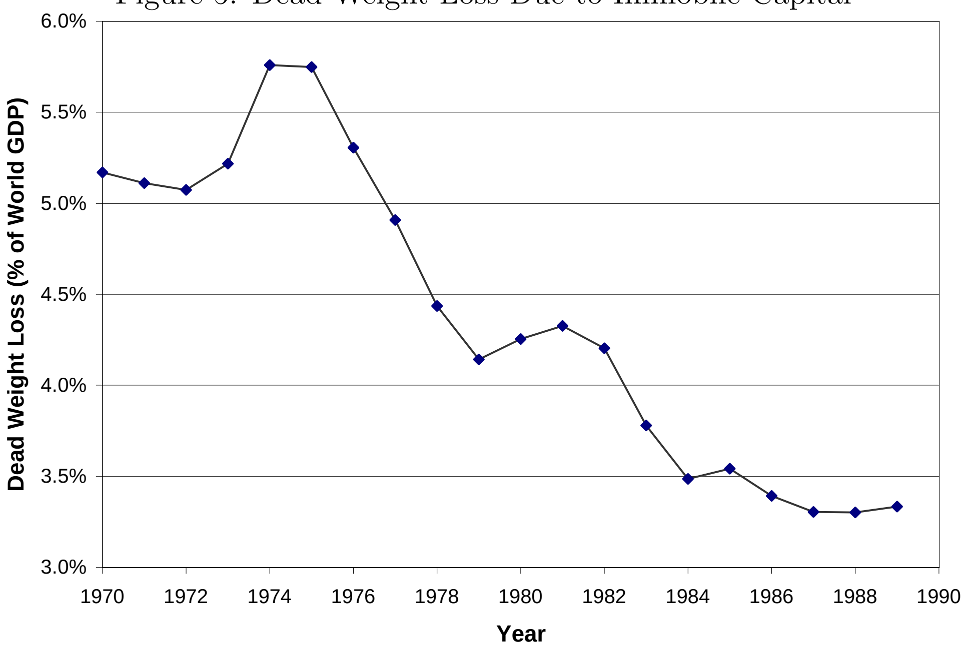
$$MPK_t^* = \left\{ MPK_t \;\middle|\; \sum_{i=1}^{n} \hat{K}_{it}(MPK_t) = \sum_{i=1}^{n} K_{it} \right\} \tag{17}$$

The dead weight loss to immobile capital is the difference between observed output and output in the hypothetical world with perfect capital mobility.

$$DWL_t = \sum_{i=1}^{n} \hat{Y}_{it}(MPK_t^*) - \sum_{i=1}^{n} Y_{it} \tag{18}$$

Figure 5 graphs the dead weight loss as a percentage of world output from 1970 to 1990. The value of the dead weight loss is surprisingly small, less than 3.5% of world GDP in

Figure 5: Dead Weight Loss Due to Immobile Capital



1989. In dollar terms the dead weight loss has remained close to $600 billion (measured in 1985 dollars) for the entire sample period, with increases in world income offset by decreases in the relative size of the dead weight loss. The jump at the beginning of the time series corresponds to the increase in MPK in the middle east discussed in the previous section.

This actually points to a distortion present in the data which will tend to bias the results. The same share of capital is assumed for all nations. If a nation has a capital share which is lower than the world average, their MPK will be overstated. For nations dependent on oil production, this may well be the case.

4 Distributional Dynamics in Returns to Capital

The previous section shows graphically that the overall distribution of returns to capital is narrowing over time and that this narrowing appears to hold for any subset over income or region. This section will look at the long run prospects for the distribution of returns to capital by examining the entire distribution in a dynamic framework.

The discussion closely follows Quah's Quah (1996) examination of the long run distribution of per capita income. He found that long run per capita income was moving toward a twin peaked distribution with some poor countries remaining in a low income, "poverty trap" state and rich countries remaining rich.

The evolution of the world distribution of MPK is modeled as a first order Markov process. Let λ_t represent a measure of the distribution of returns to capital at time t. The distribution evolves according to

$$\lambda_{t+1} = M * \lambda_t \tag{19}$$

where M is a stochastic kernel that maps the distribution at time t into the distribution at time $t + 1$.

The simplest way to construct a measure of the distribution, λ_t is to divide the distribution into discrete blocks. Following Quah, I divide MPK into five bins divided by MPK levels 0.08, 0.12, 0.20, and 0.36.

With a discrete λ_t, M is simply a transition probability matrix. Table 2 presents the transition probability matrix for MPK.

The top row represents the upper endpoint of each bin. Each row represents the proba-

	MPK_{t+1}					
MPK_t	0.08	0.12	0.20	0.36	∞	
0.08	0.95	0.05				(307)
0.12	0.04	0.91	0.04			(549)
0.20		0.06	0.92	0.02		(667)
0.36			0.06	0.91	0.02	(547)
∞				0.07	0.93	(330)
Ergodic	0.33	0.35	0.23	0.07	0.02	

Table 1: Transition Matrix for MPK, 1970-1989

bility of a country ending up in a particular MPK range at time $t+1$, given the MPK range at time t from the first column. The final column is a count of observations in each range. The Ergodic row represents the limiting distribution. If MPK follows a first order Markov process and the transition matrix is correctly estimated, in the long run the distribution will take on this form regardless of the starting distribution.

The relatively large values on the diagonals indicate that MPK is quite persistent from year to year. The ergodic distribution shows that MPK is converging to a median between 8% and 12%, roughly the range of values found in the OECD throughout the sample (MPK_{US} in 1989 is 9.4%). Less than 10% of countries in the limiting distribution have an MPK greater than 20%. Not surprisingly, an examination of the data shows that the number of high MPK countries ($MPK_i > 0.20$) has been falling rapidly, from 45% in 1970 to 27% in 1989.

5 Conclusion

This paper attempts to quantify the efficiency loss caused by capital immobility. The primary conclusion is that the efficiency loss, while significant, is not of primary importance in explaining world poverty.

These results point to the notion that economic forces are acting significantly to equalize returns to capital around the globe. This paper is agnostic as to the specific mechanism (or combination of mechanisms) that is acting to equalize MPK's around the globe. Three possibilities come to mind. The first is simply that capital is mobile and is flowing from low MPK nations to high MPK nations. The second possibility is described by the Heckscher-Ohlin model and states that the factor content of trade substitutes for actual factor flows and acts to equalize factor prices. The final possibility is that capital is immobile and we are seeing convergence in savings rates around the world.

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A Full list of MPK figures, 1985

wbcode	name	MPK
MDG	Madagascar	111.5%
SLE	Sierra Leone	96.1%
RWA	Rwanda	75.4%
MOZ	Mozambique	66.7%
UGA	Uganda	64.4%
EGY	Egypt,Arab Rep.	60.7%
TCD	Chad	56.5%
BGD	Bangladesh	53.1%
ETH	Ethiopia	45.6%
BDI	Burundi	43.4%
AGO	Angola	42.9%
NPL	Nepal	42.5%
ZAR	Congo,Dem. Rep.	40.0%
GMB	Gambia,The	39.2%
SEN	Senegal	38.6%
CMR	Cameroon	37.3%
MLI	Mali	36.1%
HTI	Haiti	34.4%
BFA	Burkina Faso	33.5%
BEN	Benin	30.8%
COG	Congo,Rep.	30.4%
GIN	Guinea	30.1%
PAK	Pakistan	29.1%
LKA	Sri Lanka	28.8%
GHA	Ghana	28.6%
MMR	Myanmar	27.7%
DJI	Djibouti	27.6%
MAR	Morocco	26.6%
LSO	Lesotho	25.0%
CAF	Central African Republic	23.8%
SAU	Saudi Arabia	23.2%
YEM	Yemen,Rep.	22.9%
SLV	El Salvador	22.6%
MWI	Malawi	22.5%
OMN	Oman	22.5%
TZA	Tanzania	22.2%
GTM	Guatemala	21.2%
MUS	Mauritius	21.2%
SOM	Somalia	20.7%
NER	Niger	20.4%
JOR	Jordan	19.5%
BWA	Botswana	19.4%
SYR	Syrian Arab Republic	18.8%
IDN	Indonesia	18.7%
TUN	Tunisia	18.5%
IND	India	18.2%
PRY	Paraguay	18.1%
CIV	Cote d'Ivoire	18.0%
THA	Thailand	17.9%
LBR	Liberia	17.3%

wbcode	Name	MPK
HKG	Hong Kong,China	17.2%
HND	Honduras	17.1%
SWZ	Swaziland	17.0%
TTO	Trinidad and Tobago	16.3%
SYC	Seychelles	16.3%
NIC	Nicaragua	16.0%
DOM	Dominican Republic	15.3%
IRQ	Iraq	15.2%
CHN	China	15.1%
SDN	Sudan	15.0%
TWN	Taiwan,China	15.0%
COL	Colombia	14.9%
NGA	Nigeria	14.9%
MEX	Mexico	14.8%
KOR	Korea,Rep.	14.7%
CRI	Costa Rica	14.7%
COM	Comoros	14.4%
BRB	Barbados	14.0%
IRN	Iran,Islamic Rep.	13.8%
TGO	Togo	13.7%
KEN	Kenya	13.5%
BRA	Brazil	13.5%
ZWE	Zimbabwe	13.0%
PHL	Philippines	12.6%
MYS	Malaysia	12.6%
REU	Reunion	12.6%
CPV	Cape Verde	12.4%
PAN	Panama	12.3%
DZA	Algeria	12.1%
TUR	Turkey	12.0%
MRT	Mauritania	11.9%
PNG	Papua New Guinea	11.8%
FJI	Fiji	11.6%
BOL	Bolivia	11.5%
ZAF	South Africa	11.3%
MLT	Malta	11.2%
ECU	Ecuador	11.2%
SUR	Suriname	10.5%
PRI	Puerto Rico	10.4%
ISR	Israel	10.4%
PER	Peru	10.3%
CHL	Chile	10.2%
CAN	Canada	10.0%
ARG	Argentina	10.0%
GBR	United Kingdom	9.9%
ROM	Romania	9.9%
SGP	Singapore	9.8%
VEN	Venezuela	9.6%
URY	Uruguay	9.5%
GAB	Gabon	9.5%

wbcode	Name	MPK
PRT	Portugal	9.4%
GRC	Greece	9.4%
USA	United States	9.3%
CYP	Cyprus	9.3%
GNB	Guinea-Bissau	8.8%
ISL	Iceland	8.7%
ESP	Spain	8.5%
JPN	Japan	8.3%
NLD	Netherlands	8.2%
AUS	Australia	7.9%
NZL	New Zealand	7.9%
AUT	Austria	7.9%
SWE	Sweden	7.8%
BEL	Belgium	7.7%
ITA	Italy	7.7%
DNK	Denmark	7.7%
FRA	France	7.6%
IRL	Ireland	7.5%
BHR	Bahrain	7.4%
NOR	Norway	7.2%
YUG	Yugoslavia,FR (Serbia/Mont)	7.1%
DEU	Germany	7.0%
CZE	Czech Republic	7.0%
JAM	Jamaica	6.9%
ZMB	Zambia	6.8%
CHE	Switzerland	6.6%
ZZZ	zzzU.S.S.R.	6.4%
FIN	Finland	6.2%
LUX	Luxembourg	5.7%
HUN	Hungary	5.7%
NAM	Namibia	5.6%
GUY	Guyana	5.2%
POL	Poland	4.6%
DFA	Germany,Fed. Rep. (former)	4.5%