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THE POVERTY OF NATIONS: A QUANTITATIVE EXPLORATION

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ABSTRACT

We document regularities in the distribution of relative incomes and patterns of investment in countries and over time. We develop a quantitative version of the neoclassical growth model with a broad measure of capital in which investment decisions are affected by distortions. These distortions follow a stochastic process which is common to all countries. Our model generates a panel of outcomes which we compare to the data. In both the model and the data, there is greater mobility in relative incomes in the middle of the income distribution than at the extremes. The 10 fastest growing countries and the 10 slowest growing countries in the model have growth rates and investment-output ratios similar to those in the data. In both the model and the data, the "miracle" countries have nonmonotonic investment-output ratios over time. The main quantitative discrepancy between the model and the data is that there is more persistence in growth rates of relative incomes in the model than in the data.

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1. Introduction

In this paper we develop a quantitative model to account for the following seven regularities in the distribution of income and the patterns of investment across countries: (1) there is a large disparity in per worker gross domestic product; (2) the dispersion of relative output per worker has increased; (3) countries in the middle of the world income distribution show more mobility than countries at the extremes; (4) growth rates in relative income show little persistence; (5) there have been both development miracles and disasters; (6) investment rates of the miracle countries are not monotonic over time; and (7) countries with high output per worker have high capital-output ratios.

The model is a neoclassical growth model in which distortions to capital accumulation follow a stochastic process. We model these distortions as affecting returns to capital. These distortions follow a stochastic process which is common to all countries. We examine the extent to which our model can account for the regularities in the data. At a qualitative level our model displays features similar to the seven regularities, and at a quantitative level the model is roughly consistent with all of the regularities.

The spirit of the paper is to see how far we need to deviate from the standard growth model in order to account for the seven regularities. This paper shares the spirit of the work by Barro and Sala-i-Martin (1995); Christiano (1989); Mankiw, Romer, and Weil (1992); and Parente and Prescott (1994), all of whom try to account for at least some of the regularities by using variants of the neoclassical model. In the neoclassical tradition we assume that technology is common to all countries so that variations in relative incomes can arise only from variations in capital-output ratios. We confirm Mankiw, Romer, and Weil's (1992) finding that measured capital-output ratios account for about 70 percent of the variability in output per worker across countries, and the data provide strong evidence for a production function with a capital share of 2/3. Capital-output ratios are systematically lower in poor countries because investment-output ratios are systematically lower.

This observation leads us to consider models in which distortions affect investment decisions and to model the distortions as taxes on the returns to capital. We think of these distortions as extending well beyond capital taxes levied by governments and as capturing the disincentives to investment arising from corruption, inefficient bureaucracies, and resistance to technology adoption. These obstacles to development have been emphasized by many authors (see, for example, de Soto 1989).

The papers in the neoclassical tradition that deal with development issues all try to account for the dynamic patterns in the data by using the deterministic transition paths of their models. Our reading of the transition patterns leads us to think that this approach will not be very successful. Part of our data analysis involves constructing a 25-year transition matrix documenting the patterns of 125 countries' relative incomes. From these data we see that some poor countries become rich while others remain poor, and some rich countries become poor while others remain rich. In short, there is a lot of mobility in both directions in the data. (See Easterly et al. 1993.) We also find that there is very little persistence in growth rates in the data. Specifically, we plot growth rates in relative incomes in the second half of the sample against growth rates in the first half and find that there is no pattern. These mobility and persistence findings lead us to discard deterministic models and turn to models with stochastic distortions.

The main innovation of the paper is development of a simple model where an underlying shock process common to all countries generates a panel of outcomes which can then be compared to the data in a systematic way. In the model there is a good regime and a bad regime for the distortions. In the good regime, distortions decline until they reach their lowest value, while in the bad regime they rise until they reach their highest value. The probability of switching between regimes follows an exogenous stochastic process. The probability of a switch is a function of the number of periods since the last switch. We choose parameters so that the probability of switching back to the previous regime is high right after a switch and then declines monotonically over time.

A motivation for the switching process is that countries with bad policies often try reforms, but many of these reforms fail quickly, and then the countries may return to the old bad policies. The longer a reform lasts, however, the more likely it will be successful. Symmetrically, countries which start down the path to bad policies often recover and return to good ones. The longer a bad policy lasts, however, the more likely it will be permanent.

We choose parameters for preferences and technology as in the real business literature. We choose the range of distortions to generate a range of disparity in output per worker similar to that in the data. We let the switching probabilities have a simple linear form. We choose initial conditions so that the initial relative incomes in our model coincide with the relative incomes in the data in 1960.

Our model generates patterns of mobility in relative incomes similar to those in the data. For example, both the model and the data show more mobility in the middle of the income distribution than at the extremes. The 10 fastest-growing countries (the *miracles*) and the 10 slowest-growing countries (the *disasters*) in the model have growth rates and investment-output ratios similar to those in the data. In both the model and the data, the miracle countries have nonmonotonic investment-output ratios over time. It is worth noting that, in models with standard preferences and technology, the investment-output ratio is monotonic along a deterministic transition to a steady state. (See Christiano 1989 and King and Rebelo 1993 for models with Stone-Geary preferences in which this ratio is not monotonic along a deterministic transition.) In our model, following a switch from a bad regime to a good regime, investment-output ratios rise over time as investors gain confidence in the permanence of the switch. Eventually, the usual transition dynamics dominate and the ratio falls. We find three discrepancies between the model simulations and the data. The main quantitative discrepancy between the model and the data is that growth rates in relative incomes are more persistent in the model than in the data. Furthermore, the disparity in incomes increases less in the model than in the data. Finally, for very poor countries, average investment-output ratios in the model are smaller than those in the data.

In our view the central facts about development are the disparity in the wealth of nations, the great mobility in relative incomes, and the lack of persistence in growth rates. Our reading of the development literature is that none of the models in this literature is consistent with these facts. We have already argued that deterministic neoclassical growth models are not useful for understanding the regularities in development. We also argue that convex models without diminishing returns (see, for example, Jones and Manuelli 1990 and Rebelo 1991) and nonconvex models (Grossman and Helpman 1991 and Rivera-Batiz and Romer 1991) which address disparity of incomes across countries cannot reproduce the relationship in the data between the capital-output ratio and output per worker across countries. Furthermore, in both of these types of models persistent changes in the level of distortions typically induce persistent changes in growth rates. We believe that careful measures of the level of distortions will show that changes in their levels are typically persistent. In this sense these models are likely to be inconsistent with the observed lack of persistence in growth rates.

Section 2 contains the data analysis, Section 3 lays out the economy, Section 4 discusses calibration and measurement issues, Section 5 presents the findings, and Section 6 concludes.

2. Data Analysis

Our data are from the Penn World Table, version 5.6. (See Summers and Heston 1991 for a complete description.) These data are a panel of various measures of annual aggregate output and its components from 1960 onward for almost all countries. We use the data for the years 1960 through 1985 in our analysis. Our sample consists of the 125 countries for which investment and output-per-worker data are available for every year from 1960 to 1985. Our measure of the relative wealth of a nation is *relative gross domestic product per worker,* which is defined as GDP per worker divided by the (geometric) average of gross domestic product per worker. We refer to this measure as *relative output* or *relative income.* Our main findings are as follows:

1. There is great disparity in output per worker throughout the sample period.
2. The dispersion of relative output per worker has increased somewhat from 1960 to 1985.
3. Countries in the middle of the world distribution of income show more mobility in relative positions than countries at either extreme.
4. Growth rates in relative income show little persistence.
5. There have been development miracles and disasters. The miracle countries have much higher investment-output ratios than the world average, while the disaster countries have much lower investment-output ratios than the world average.
6. Investment-output ratios of the development miracle countries are not monotonic over time.
7. Countries with high per worker outputs in 1985 have high capital-output ratios in 1985.

Many of these findings are well known in the development literature (see DeLong 1988, Easterly et al. 1993, Maddison 1991, Parente and Prescott 1993, and Quah 1993, for example). The nonmonotonicity of savings rates for Japan is the focus of a detailed investigation in Christiano (1989). While we have focused on relative incomes, we should note that absolute incomes have increased. The geometric average of output per worker grew at an annually compounded rate of 2.3 percent from 1960 to 1985, so that it was 1.8 times as high in 1985 as in 1960.

One measure of the disparity in output per worker is the ratio of the incomes of the richest countries relative to the poorest countries. We calculate the ratio of the geometric average of the richest 6 countries' incomes relative to the geometric average of the poorest 6 countries and graph this ratio in Figure 1. (Since there are 125 countries in our sample, this is the ratio of the top 5 percent to the bottom 5 percent in our sample.) This ratio is 33.2 in 1960 and 31.7 in 1985, and it reaches its high of 38.3 in 1970 and its low in 1985. We examine three aspects of the dispersion of income. We think of the ratio of the incomes of the richest 5 percent to the poorest 5 percent as capturing the range of the distribution. The range shows little change. The second aspect of the dispersion is the standard deviation of the logarithm of relative incomes, graphed in Figure 2. The standard deviation is 0.97 in 1960, and it is 1.06 in 1985. From Figure 2, this standard deviation is largest in 1980 at 1.07, and smallest in 1960. Note that a 10 percent change in the standard deviation of relative incomes is fairly big. The ratio of incomes of a country one standard deviation above the mean to a country one standard deviation below the mean in 1960 is about 7, while this same ratio in 1970 is about 8.5.

The histogram of the distribution of relative income provides the third aspect of income dispersion. To construct this histogram we place countries into one of six equally spaced bins based on their relative incomes. The first bin consists of all countries with output per worker between 1/8 and 1/4 of world output per worker. The second bin consists of countries with outputs per worker between 1/4 and 1/2 of world output per worker, and so on. With one exception, there are no countries with outputs per worker less than 1/8 or more than 8 times the world average. (The exception is Ethiopia, which reaches a minimum relative income level of 0.11 in 1979.) Figure 3A displays the histogram for 1960 and Figure 3B shows the histogram for 1985. The histogram shows that mass has moved from the middle to the extremes. In this sense the dispersion has increased.

An important feature of these data is that individual countries changed their positions in the distribution, sometimes dramatically. One way of summarizing the mobility of individual countries is to construct a mobility matrix (displayed in Table 1A; see also Quah 1993). The rows of this matrix correspond to relative positions in 1960, and the columns correspond to relative positions in 1985. Each cell gives the fraction of all countries that started at the relative position given by the row and ended up at the relative position given by the column. For example, the entry (0.09) in row 1, column 2 shows that 9 percent of those countries with incomes between 1/8 and 1/4 of the world average in 1960 had incomes between 1/4 and 1/2 of the world average in 1985. On the left side of the box we give the histogram values for each bin in 1960, while on the bottom we give the histogram values for each bin in 1985. As can be seen, the diagonal elements are largest at the extremes of the distribution. Mobility is, in this sense, highest in the middle of the distribution.

One interpretation of this mobility matrix is as a Markov chain on relative incomes. Under this interpretation, countries at the extremes of the distribution have a very low probability of changing their relative position. A country in the middle of the distribution is much more likely to change its relative position. For example, the probability that a country with a relative income between 1/2 and 1 of the world average changes its position is 0.59, while countries with incomes between 4 and 8 of the world average change their positions with a probability of 0.20. In Table 1B we give the actual number of countries in each cell. The numbers in parentheses on the left side of the matrix give the number of observations in each bin in 1960, while those below give the number of observations in each bin in 1985.

In Figure 4 we plot the growth rates of relative income from 1972–85 against growth rates of relative income from 1960–72. Clearly, there is no systematic relation between these growth rates. The correlation between these rates is 0.25. (See Easterly et al. 1993 for a detailed investigation of the persistence of growth rates.)

It is well known that some countries grew at very rapid rates over this time period, while many others experienced declines in output per worker. In Table 2A we report on statistics for the 10 countries with the highest growth rates in relative incomes. These countries are the miracles. On average their relative incomes grew at 3.4 percent. Since world output per worker grew at 2.2 percent, the miracles' growth rates of output per worker averaged 5.6 percent. This table also shows that the miracles' investment-output ratios averaged 21.2 percent, which is 7.1 percent higher than the world average investment-output ratio. In 1960, these countries were not substantially richer or poorer than the world average. Table 2A shows that their average incomes in 1960 were 68 percent of the world average. Table 2B displays the same statistics for the 10 countries with the lowest growth rates in relative incomes. These countries are the disasters. The disasters' average growth rates in relative income were -3.1 percent; their growth rates of output per worker averaged -0.9 percent. The disasters' investment-output ratios were 8.7 percent lower than the world average. These countries were also predominantly in the middle of the income distribution in 1960. Remarkably, the average of their incomes in 1960 was also 68 percent of the world average. In this sense it is difficult to distinguish prospective miracles and disasters based on information in 1960.

Next, we examine the behavior of the investment-output ratio for the 10 miracle countries and the 10 disaster countries. In Figure 5 we display the investment-output ratios of the 10 miracles, and in Figure 6 we display the corresponding series for the 10 disasters. These figures show that investment-output ratios are substantially higher on average in the miracles than in the disasters. The figures also show the nonmonotonicity of investment. The most striking feature of the disaster countries is that 7 out of the 10 have very low investment-output ratios. Similar patterns also hold for other countries in our sample. In Table 3 we display average investment-output ratios for each cell of our mobility matrix on relative incomes. For example, 25.6 is the average investment-output ratio for countries that started in the highest relative income bin and ended there. The striking feature of this matrix is that for each starting bin the relatively more successful countries, in terms of relative income, have higher investment-output ratios.

We now turn to the relationship between output per worker and the capital-output ratio. This aspect of our data analysis is motivated by the implications of standard neoclassical theory. Consider a Cobb-Douglas production function, (2.1) $Y = K^{\alpha}(AL)^{1-\alpha}$.

This function can be written as

(2.2) $$\frac{Y}{L} = A\left(\frac{K}{Y}\right)^{\alpha/1-\alpha}.$$

Let y = log Y/L denote the output per worker in country i, and let k = log K/Y denote the capital-output ratio in country i. Under the assumption that the technology parameter A is the same in all countries, (2.2) can be written as

(2.3) $$y_i - \bar{y} = \frac{\alpha}{1-\alpha} k_i - \frac{\alpha}{1-\alpha} \bar{k}$$

where $\bar{y}$ is the average of y_i and $\bar{k}$ is the average of k_i. Standard neoclassical theory thus leads us to expect that higher capital-output ratios should be associated with higher levels of output per worker. To see how well the theory works, we must construct estimates of the capital stock in each country. We use the standard perpetual inventory method, which uses data on investment, an initial capital stock, and a depreciation rate to estimate capital stocks. This method uses the law of motion for capital accumulation given by

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

where K denotes the capital stock at date t, I_t denotes investment, and δ is the depreciation rate. For our investment series we use real investment in 1985 international prices from the Penn World Table.

For our benchmark calculation we choose a depreciation rate of 6 percent. We choose the initial capital stock so that the capital-output ratio in 1960 equals the capital-output ratio in 1985. Note that this way of estimating the final capital stock is a very good approximation if the economy is roughly on a balanced growth path. Alternative ways of choosing the initial capital stock yield similar estimates of the final capital stock. For example, for one alternative we set the initial capital-output ratio equal to $I/Y/(n+g+\delta)$, where I/Y is the average investment-output ratio from 1960 to

1965, n is the average rate of growth of the workforce over the same period, g is the common world rate of technical change (2.3 percent per year), and the depreciation rate $\delta = 0.06$. This way of choosing the initial capital stock would be exactly correct if each country had been on a balanced growth path before 1965. In Figure 7 we plot the capital-output ratios constructed with the two alternative procedures. The two procedures clearly yield similar estimates.

For our sample, the correlation between the log of the constructed capital-output ratio and the log of the output per worker is 0.70. In Figures 8, 9, and 10 we plot the left-hand side of (2.3) against the right-hand side of this equation for $\alpha = 1/3$, 2/3, and 0.9 respectively. Inspection of these figures reveals that for $\alpha = 2/3$ these observations cluster around the 45 degree line. For $\alpha =$ 1/3 or 0.9, the observations tend to be quite far from the 45 degree line. Since physical capital shares of 2/3 are extremely high, these findings suggest that we should interpret the capital stock in this model as including other types of capital, such as human capital and business capital.

King and Levine (1994) use a similar procedure for estimating the capital stock and obtain capital-output ratios similar to ours. Mankiw, Romer, and Weil (1992) arrive at conclusions similar to ours using a different methodology. They regress the log of GDP per working-age person in 1985 on I/Y and $(n+g+\delta)$, where I/Y is the average investment rate, n is the growth rate of the country's population, g is the common rate of technical change, and δ is the depreciation rate. They obtain a high R^2, and their preferred estimate of α is 2/3. The reason that our preferred estimates of α are the same as those of Mankiw, Romer, and Weil is that their right-hand side variable is exactly the capital-output ratio along a balanced growth path, and this variable is a good estimate of the capital-output ratio as long as the economy is not too far from such a path.

Other authors have used different methods to obtain a measure for the capital share. Barro and Sala-i-Martin (1995) and others regress growth rates of output per worker on a variety of variables, including the level of initial income. They use linearized transition dynamics to interpret the coefficient on initial income to obtain a measure of capital share. Their preferred estimate for capital share is 0.75. Parente and Prescott (1994) account for postwar Japanese economic performance using a model with both physical capital and business capital. Their preferred estimate for the share of income accruing to broadly measured capital is 0.71.

Several authors, including Young (1994), have discussed the large changes in participation rates among some of the East Asian tigers. In Figures 11 and 12 we plot the participation rates of the miracles and the disasters. Clearly, there is a large upward trend in Hong Kong, Korea, and Singapore, as noted by Young. However, several of the other miracles, such as Botswana, Jordan, and Lesotho, have clear downward trends. Indeed, as Figure 13 shows, in terms of the (geometric) means there is virtually no difference between the participation rates of the miracles and the disasters.

3. The Economy

Consider the following economy. There is a single final good which is produced using labor, and there are two capital goods called physical and human capital. The resource constraint defined over economy-wide aggregates is

(3.1) $\tilde{C}_t + \tilde{X}_{kt} + \tilde{X}_{ht} \leq F(\tilde{K}_t, \tilde{H}_t, A_t L_t).$

Here F is a constant returns to scale production function. $\tilde{C}_t$ is consumption, $\tilde{X}_{kt}$ is investment in physical capital, $\tilde{X}_{ht}$ is investment in human capital, $\tilde{K}_t$ is physical capital, $\tilde{H}_t$ is human capital, L_t is the exogenously given labor force, and A_t is a labor-augmenting technology parameter. The laws of motion for physical and human capital are given by

(3.2) $\tilde{K}_{t+1} = \tilde{X}_{kt} + (1-\delta_k)\tilde{K}_t$

(3.3) $\tilde{H}_{t+1} = \tilde{X}_{ht} + (1-\delta_h)\tilde{H}_t$

where δ_k and δ_h are the depreciation rates for physical and human capital. The technology parameter grows according to

$$(3.4) \quad A_{t+1} = (1+g)A_t$$

with A_0 given. The labor force evolves according to

$$(3.5) \quad L_{t+1} = (1+n)L_t.$$

Competitive firms rent both types of capital and labor to maximize profits given by

$$(3.6) \quad \max F(\tilde{K}_t,\tilde{H}_t,A_tL_t) - w_tA_tL_t - r_{kt}\tilde{K}_t - r_{ht}\tilde{H}_t$$

where w_t, r_{kt}, and r_{ht} denote the rental rates on the three types of inputs.

In our quantitative analysis we will assume that F is Cobb-Douglas so that $F(\tilde{K},\tilde{H},AL) = \tilde{K}^{\alpha_k}\tilde{H}^{\alpha_h}(AL)^{1-\alpha_k-\alpha_h}$. One interpretation of our aggregate production function is that there are two inputs: physical capital and a composite labor input $G(\tilde{H},AL)$, where $F(\tilde{K},\tilde{H},AL) = F(\tilde{K},G(\tilde{H},AL))$. The firm rents physical capital and this composite labor input. Here consumers make decisions about producing the composite labor input from human capital and their time. The preferences of the representative, infinitely lived household are given by the expected utility function

$$(3.7) \quad E_0\sum_{t=0}^{\infty} \tilde{\beta}L_tU(\tilde{c}_t)$$

where $\tilde{c}_t$ denotes per person consumption. The endowment of labor per person is normalized to 1.

We use a standard utility function $U(\tilde{c},\ell) = \tilde{c}^{1-\sigma}/(1-\sigma)$. The budget constraint of the representative household is given by

$$(3.8) \quad \tilde{c}_t + (\tilde{x}_{kt}+\tilde{x}_{ht}) \leq w_tA_t + (1-\theta_t)[r_{kt}\tilde{k}_t+r_{ht}\tilde{h}_t] + \tilde{T}_t.$$

The analogues of (3.2) and (3.3) also hold. Here θ_t is the common distortion affecting the returns from both types of capital, and $\tilde{T}_t$ is lump-sum taxes or transfers. We discuss the assumptions of common distortions below.

It is convenient to normalize our variables so that they are in units per effective worker. For the aggregates, we divide by A_tL_t; so, for example, $K_t = \tilde{K}_t/A_tL_t$. The representative household variables are already in per person terms, so we divide them only by A_t. Thus, for example, $k_t = \tilde{k}_t/A_t$. The transformed discount factor is given by $\beta = \tilde{\beta}(1+n)(1+g)^{(1-\sigma)}$.

The only uncertainty in this economy is about distortions. There are two regimes for distortions: a good regime and a bad regime. We let $R \in \{G,B\}$ denote good and bad regimes. The regime of the economy switches according to an exogenous stochastic process. The probability of a regime switch is a function of the number of periods since the last switch. Let $\pi_{GB}(\tau)$ denote the probability of switching from the good regime to the bad regime, given that the good regime has lasted τ periods. Let $\pi_{BG}(\tau)$ denote the corresponding probability of a switch from a bad to a good regime.

The distortions can take on one of I values, with $\theta(1) < \theta(2) < \ldots < \theta(I)$. If the economy is in a good regime in the current period, and if $\theta(i)$ was the distortion level in the previous period, then the current distortion level is $\theta(i-1)$, unless the economy was already at the lowest distortion level $\theta(1)$, in which case it stays there. Likewise, if the economy is in a bad regime in the current period, then the distortion level increases by one step relative to its previous period level, unless the distortion was already at its maximum level.

We now develop a recursive competitive equilibrium. Let $S = (i,R,\tau,K,H)$ denote the aggregate state of the economy and $s = (k,h)$ denote the state of a representative household. The household's problem is to choose nonnegative values for c, x_k, x_h, k', and h' to solve

(3.9) $\quad v(s,S) = \max U(c) + \beta E[v(s',S')|S]$

subject to

$$c + x_k + x_h = w(S) + (1 - \theta(i))[r_k(S)k + r_h(S)h + T(S)]$$

$$(1+g)(1+n)k' = x_k + (1-\delta_k)k$$

$$(1+g)(1+n)h' = x_h + (1-\delta_h)h$$

where, if R = G,

$$(3.10)\quad E[v(s',S')\,|\,S] = \pi_{GB}(\tau)v(s',\, i+1,\, B,\, 1,\, K'(S),\, H'(S)) + (1 - \pi_{GB}(\tau))v(s',\, i-1,\, G,\, \tau+1,\, K'(S),\, H'(S))$$

where it is understood that $\theta(I+1) = \theta(I)$ and $\theta(0) = \theta(1)$. The first term on the right side of (3.10) is the probability of switching from G to B times the value in the new regime B, given that the number of periods in this regime is now 1. The associated distortion rate is $\theta(i+1)$. The second term is the probability of not switching times the value in old regime G, given that the number of periods since the last switch is τ. The associated distortion rate is $\theta(i-1)$. An analogous equation holds for R = B. In (3.9), w(S), $r_k(S)$, and $r_h(S)$ denote the rental-rate functions for the three inputs. The aggregate capital stocks evolve according to the aggregate allocation functions

$$(3.11)\quad K' = K'(S) \text{ and } H' = H'(S)$$

and the lump-sum transfers according to the transfer function T(S). The household's problem yields allocations for its choice variables as functions of (s,S). For example, the allocation function for consumption is given by c(s,S).

A *recursive competitive equilibrium* is a value function for the household, household allocation functions, aggregate allocation functions, rental-rate functions, and a transfer function which satisfy the following conditions: (i) the value function and the household allocation functions solve (3.9), (ii) the rental-rate functions satisfy

$$w(S) = F_L(K,H,1)$$

$$r_k(S) = F_K(K,H,1)$$

$$r_h(S) = F_H(K,H,1)$$

and (iii) the household and aggregate allocations satisfy the market-clearing conditions

$$k'(S,S) = K'(S)$$

$$h'(S,S) = H'(S)$$

$$c(S,S) + x_k(S,S) + x_h(S,S) = F(K,H,1).$$

To gain some intuition for the properties of this model, consider the steady state of a deterministic economy with a distortion level θ. In the steady state the consumer's first-order conditions imply

$$(3.12)\quad 1 = \beta[(1-\theta)\alpha_k Y/K + (1-\delta)]$$

$$(3.13)\quad 1 = \beta[(1-\theta)\alpha_h Y/H + (1-\delta)].$$

Consider two economies which have distortions θ and θ' respectively. Let $y(\theta)$ and $y(\theta')$ denote output per worker in the two economies. Using the form of the production function we obtain

$$(3.14)\quad \frac{y(\theta)}{y(\theta')} = \left[\frac{1-\theta}{1-\theta'}\right]^{(\alpha_k+\alpha_h)/(1-\alpha_k-\alpha_h)}.$$

It is clear from (3.14) that what matters for determining two countries' relative incomes is the ratio of the retention rates $(1-\theta)/(1-\theta')$. For concreteness, suppose $\theta = 0$ and $\alpha_k = \alpha_h = 1/3$. If the retention rate $1 - \theta'$ in the distorted economy is 1/4, then the income of the undistorted economy is $16(=4^2)$ times that of the distorted economy. It should be clear from (3.14) that the larger the total capital share $\alpha_k + \alpha_h$, the greater the magnification of distortions on relative income. For example, if $\alpha_k + \alpha_h = 3/4$, then the relative retention rate of 1/4 gives relative incomes of $64(=4^3)$.

4. Calibration and Measurement Issues

In this section we calibrate the parameters of preferences, technology, and policy. We list the value of these parameters in Table 4. The preference parameters β and σ are standard in the real business-cycle literature (see, for example, Chari, Christiano, and Kehoe 1994 or McGrattan 1994). We set the technology parameters α_k, δ_k, g, and n as in the real business-cycle literature, and we set $\delta_h = \delta_k$.

We use an argument in Mankiw, Romer, and Weil (1992) to calibrate α_h. In the model, for a person with no given human capital, the total compensation for N units of labor services is wN. The compensation for N units of labor services and H units of human capital services is $wN + r_hH$. Profit maximization implies the wage premium

$$\text{(4.1)} \qquad \frac{wN + r_hH}{wN} = \frac{(1-\alpha_k-\alpha_h)Y + \alpha_hY}{(1-\alpha_k-\alpha_h)Y} = \frac{(1-\alpha_k)}{(1-\alpha_k-\alpha_h)}.$$

Mankiw, Romer, and Weil measure the wage premium in the United States. They assume the minimum wage is the wage paid to a person with zero human capital. They report that in the United States the ratio of the wage paid to the average worker to the minimum wage is approximately 2. Using this as a measure of the wage premium in (4.1) and assuming that $\alpha_k = 1/3$ gives $\alpha_h = 1/3$.

We turn next to the policy parameters. We normalize the minimum level of distortion $\theta(1)$ to zero. We choose the maximum level of distortion $\theta(I)$ so that in the stationary distribution the ratio of the richest 5 percent to the poorest 5 percent is about 30. This gives $\theta(I) = 0.86$, and thus the retention rate for the least distorted economy relative to the most distorted economy is approximately 7. Notice that if the most distorted economy and the least distorted economy were in deterministic steady states, (3.14) would imply relative incomes of $49(=7^2)$. The reason this ratio is smaller in the stochastic economy than in the deterministic economy is that in the stochastic economy there is a positive probability of a regime switch. This tends to bring the capital stocks in the two extremes closer together. We choose the number of distortion levels $I = 20$, and we choose $\theta(2)$, ..., $\theta(19)$ so that the consecutive relative retention rates $(1 - \theta(i))/(1 - \theta(i+1))$ are constant. (See Figure 14 for the values of the distortions.) We choose the switching probabilities so that $\pi_{BG}(\tau) = \pi_{GB}(\tau)$, $\pi_{BG}(1) = 0.6$, and $\pi_{BG}(20) = 0.0021$. These probabilities linearly decrease with τ up through $\tau = 20$ and are equal to 0.0021 for $\tau > 20$.

We turn next to some measurement issues. We assume that the human capital accumulation described in our model occurs in the workplace. The national income accounts do not include human capital investment of this kind in measures of investment. We now describe the procedure used to make the results of our model and the data comparable. Consider the following description of technology in our model. For measurement issues, our model is best interpreted as a two-sector model. (Of course, with identical production functions this model aggregates to the one-sector model used in the theory. We find the two-sector interpretation to be a simple device to clarify measurement issues.) The goods production sector's technology is given by

$$c_t + x_{kt} = F(K_{1t}, H_{1t}, L_{1t})$$

and the human capital sector's technology is

$$x_{ht} = F(K_{2t}, H_{2t}, L_{2t})$$

where K_{it}, H_{it}, L_{it}, $i = 1, 2$ are the amounts of the three inputs used in the two sectors. The aggregate capital stocks are given by $K_t = K_{1t} + K_{2t}$ and $H_t = H_{1t} + H_{2t}$. Under our interpretation, x_{ht} is unmeasured investment in the workplace. Thus if we denote variables in the theory by superscript T and those in the data by superscript D, we have that the measure of output in the data is related to the measure of output in the theory by $Y^D_t = Y^T_t - x^T_{ht}$. Of course, since physical capital is measured in the data, $x^T_{kt} = x^D_{kt} = x_{kt}$. Thus the physical investment-output ratio in the theory that corresponds to our measured ratios in the data is given by

$$\frac{x_{kt}}{Y_t^T} = x_{ht}^T.$$

5. Findings

In this section we report our findings for the model. All the statistics we compute come from realizations of 125 countries, with initial conditions set to mimic the 1960 income distribution and the initial policies set in accordance with our model. We find that the model does a fairly good job on many of the statistics. The main problem is that the income distribution does not spread out as much in the model as in the data.

We begin by describing the initial states. In order to simulate the model we first choose initial states (i,R,τ,k) for 125 countries. Our model implies a stationary joint distribution over (i,R,τ,ry), where ry denotes relative income and is given by the difference between the log of income and its mean. We divide the marginal distribution of relative income into 6 bins that are analogous to the bins we used for the data analysis. We sample from these bins so that the number of draws from each bin is equal to the number of countries in that bin in the 1960 data. Each such draw has an associated state (i,R,τ,k) and represents the initial condition for a particular country. Given these initial conditions, we then simulate all 125 countries for 26 periods and calculate various statistics. We repeat this procedure 100 times. In what follows we focus on both statistics from a single simulation and on averages across the 100 simulations.

In Figure 15 we graph the relative incomes of the richest 5 percent to the poorest 5 percent from a single simulation. The disparities are about the same order of magnitude as in the data. Given that we calibrated the extreme values of the distortions to match this disparity in the data, this is not too surprising. The average disparity across simulations is 33.7 (with the standard deviation of 0.45). More interesting is the standard deviation of the log of relative incomes. In Figure 16 we graph this statistic for a single simulation. The standard deviation increases from 0.97 to 1.04: a spreading out of 0.07. The ratio of incomes in the 26th period of a country that is one standard deviation above the mean to a country one standard deviation below the mean is 8.0, which is a little less than the ratio of 8.3 we found in the data in 1985.

In Figures 17A and 17B we plot the means of the histograms from the simulations. The period 1 histogram matches the one from the data in 1960 by construction. Notice that the period 26 histogram shares some features with the 1985 histogram. For example, in both the model and the data the sum of the masses in the two highest bins is 0.31. The sum of the masses in the two lowest bins is 0.32 in the model and 0.29 in the data. The main difference is that in the model there is less spreading out than in the data. In particular, in the model the mass in the lowest bin is the same in the beginning and ending histograms, while in the data the mass in this bin rises from 1960 to 1985.

In Table 5 we report the means across simulations of the 25-period mobility matrix. The numbers in parentheses denote standard deviations across simulations. This matrix shares some features with the analogous matrix in the data. Consider the diagonal elements which measure the fraction of countries that stay in their original relative positions. With the exception of countries in the lowest bin, these numbers are close to the analogous numbers in the data. Note that both the data and the model show more mobility in the middle than in the extremes. The main problem is that not enough countries move into the very poor category. To see this, note that in the data 10 out of 125 countries move from relative incomes greater than 1/4 to incomes less than 1/4, while in the model, on average, fewer than 4 countries do so. This problem contributes to our finding that there is less spreading out in relative incomes in the model than in the data.

Using data from a single simulation in Figure 18, we plot the growth rates of relative incomes in the last 13 periods against the growth rates in the first 13 periods. The correlation of these growth rates is 0.67, while the analogous correlation in the data is 0.25. Comparing Figure 18 with Figure 4, we see that there is more persistence in growth rates in the model than in the data.

Consider next the miracles and disasters. Following the same criterion as we did in the data, we dub the 10 fastest growers *miracles* and the 10 slowest growers *disasters*. Tables 6 and 7 report some summary statistics. Basically the miracles and the disasters in the data look similar to those in the model. The main difference is that in the model the disasters are, on average, initially richer than the miracles, while in the data the disasters and the miracles are equally wealthy. As in the data, the miracles and disasters are not the richest or the poorest in the initial period. In Figures 19 and 20 we display the investment-output ratios for the 10 miracles and the 10 disasters from one simulation. As in the data, the miracle countries have nonmonotonic investment-output ratios. It is worth pointing out that in a deterministic version of our model, starting from a capital stock below the steady state, the investment-output ratio falls monotonically over time. In our stochastic model, investment-output ratios for the miracles rise gradually until the probability of a switch to the bad regime is sufficiently small. Eventually, the deterministic dynamics take over and the investment rate falls.

In Table 8 we display the mean across simulations of the average investment-output ratios for each cell of our mobility matrix. The standard deviations across simulations are reported in parentheses. This matrix, like its analogue in the data, has the feature that for a given starting bin, relatively successful countries have higher investment-output ratios. The main difference is that the very poor countries have higher investment-output ratios in the data than in the model.

So far we have considered a world in which each country is a closed economy. In it, marginal productivities vary greatly across countries and, therefore, so do the pretax returns to capital. Lucas (1990) argued that these differences in returns create incentives for capital to flow from rich to poor countries. In our model there is little incentive for capital to flow from rich to poor countries. To see this, consider a country that has been in the good regime for a long time and one that has been in the bad regime for a long time. These countries are close to the deterministic steady states associated with their respective distortions. This implies that the after-tax returns in the two countries are close, and thus there is no incentive for capital to flow. In our model there is an incentive for capital to flow from the disasters to the miracles. Recall that both types of countries start at roughly the middle of the world income distribution and move to the extremes. For the miracles, future distortions are expected to be low, and for the disasters, future distortions are expected to be high. Thus expected after-tax returns are high in miracles and low in disasters. We compute these returns as that constant rate of return forever which yields the same present value as the after-tax expected present value of investing in the country. (Actually, we approximate this value by computing the after-tax returns for the first 15 periods and then assuming that the investor can liquidate the investment and obtain one unit of consumption for each unit of depreciated capital.) Figure 21 plots this measure of the returns for the initial period for all countries against their initial relative incomes. The figure shows that there is much greater variance in returns for countries in the middle of the income distribution than for those at the extremes. These returns range from 2.7 to 10.9 percent.

One way to get a feel for the magnitude of these numbers is to consider a world in which there is complete capital mobility, but where countries expropriate the assets of foreign nations with a constant probability over time. As a benchmark, consider a country that is on a deterministic, balanced growth path with no distortions. We can compute the probability of expropriation for each country such that investors in the benchmark country would be indifferent between investing in the given country and in their own country. For the highest return country this probability is 4.9 percent, and for the highest income country this probability is 1.9 percent. This 3 percent difference in expropriation rates does not seem totally implausible. Of course, investors in low rate-of-return countries would like to invest in the benchmark economy, but it is easy to imagine that capital controls would prevent them from doing so.

6. Conclusion

In this paper we have developed a quantitative model to account for seven regularities in the distribution of income and the pattern of investment across countries. The model does well in accounting for patterns in the mobility in income and in accounting for the growth rates and investment-output ratios of miracles and disasters. The main discrepancy between the model and the data is that growth rates are much more persistent in the model than in the data.

In comparing the model with the data we have focused on the implications of unobserved distortions for changes in relative incomes and investment patterns over time. We have found that even though the distortions are unobserved, the model imposes strong restrictions on the panel of incomes and investments. The next step in comparing the model with the data is to obtain measures of the distortions in the data. (For some interesting preliminary work, see Restuccia and Urrutia 1995.) We have also shown that a broad measure of capital is needed to account for the development regularities. (See Barro and Sala-i-Martin 1992 and Mankiw, Romer, and Weil 1992 for similar arguments.) In our model, part of the capital stock consists of human capital that is accumulated in the workplace and is not measured in the data. Also, both physical and human capital are subject to the same distortions. A further step in comparing the model and the data is to obtain better measures of human capital and the distortions that affect investment in such capital.

Our initial reading of the regularities in the data strongly suggested a model with stochastic distortions. Two observations drove us to develop a model in which differences in relative incomes are driven by distortions. The first observation is that 70 percent of the variability in output per worker across countries is accounted for by variations in capital-output ratios. The second observation is that miracle countries have very high investment rates, while disaster countries have very low investment rates. These observations suggest a model in which variations in investment-output ratios play a central role in generating variations in incomes. Distortions seemed like natural candidates to generate variations in investment rates. The lack of persistence in growth rates drove us to make these distortions stochastic. From our findings it is clear that further work should focus on modifying the model to reduce persistence in growth rates. Fluctuations in growth rates in our model are solely driven by stochastic distortions to investment. We have abstracted from other forces that produce fluctuations in growth rates in relative income, such as terms-of-trade shocks or business-cycle shocks. Introducing such forces is likely to reduce the persistence in growth rates. An important direction for future research is to introduce additional forces which induce long-lived fluctuations in growth rates.

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Table 1A

Mobility Matrix for Relative Incomes (Fractions)

% Obs. in 1960	85 / 60	1/8–1/4	1/4–1/2	1/2–1	1–2	2–4	4–8
9	1/8–1/4	.82	.09	.09			
15	1/4–1/2	.37	.47	.11	.05		
26	1/2–1	.09	.22	.41	.28		
25	1–2			.13	.55	.32	
18	2–4				.14	.59	.27
8	4–8					.20	.80
% Obs. in 1985		15	14	16	24	20	11

Table 1B

Mobility Matrix for Relative Incomes (Numbers)

No. of Obs. in 1960	85 / 60	1/8–1/4	1/4–1/2	1/2–1	1–2	2–4	4–8
(11)	1/8–1/4	9	1	1			
(19)	1/4–1/2	7	9	2	1		
(32)	1/2–1	3	7	13	9		
(31)	1–2			4	17	10	
(22)	2–4				3	13	6
(10)	4–8					2	8
No. Obs. in 1985		(19)	(17)	(20)	(30)	(25)	(14)

Table 2A

Statistics for the Miracles (1960–85)

	Average Growth of Relative Income	Average I/Y	Relative Income in 1960
Botswana	4.9	19.8	.33
Romania	4.7	20.7	.20
Hong Kong	3.4	20.3	1.11
Korean Republic	3.3	21.4	.72
Japan	3.3	33.9	1.33
Taiwan	3.3	21.8	.90
Singapore	3.1	30.7	1.34
Lesotho	3.0	9.4	.15
Jordan	2.9	14.1	1.20
Malta	2.6	23.7	1.27
Miracle Average	3.4	21.2	.68
World Average	0	14.1	1.00

Table 2B

Statistics for the Disasters (1960–85)

	Average Growth of Relative Income	Average I/Y	Relative Income in 1960
Chad	−4.3	2.1	.51
Guyana	−4.0	24.8	1.50
Madagascar	−3.5	1.3	.62
Mozambique	−3.4	1.9	.51
Somalia	−3.0	8.5	.51
Venezuela	−2.6	18.6	5.46
Angola	−2.6	3.6	.52
Zambia	−2.6	24.3	.71
Burundi	−2.5	4.4	.28
Uganda	−2.1	2.6	.32
Disaster Average	−3.1	5.4	.68
World Average	0	14.1	1.00

Table 3

Average Investment-Output Ratios in Each Cell

% Obs. in 1960	85 / 60	1/8–1/4	1/4–1/2	1/2–1	1–2	2–4	4–8
9	1/8–1/4	9.4	9.4	29.7			
15	1/4–1/2	4.8	11.2	10.7	19.8		
26	1/2–1	3.3	6.3	12.2	17.1		
25	1–2			15.5	17.9	24.1	
18	2–4				16.6	21.7	22.3
8	4–8					15.3	25.6
% Obs. in 1985		15	14	16	24	20	11

Table 4

Parameters

Preferences	
	$\tilde{\beta} = .94$
	$\sigma = 1.5$
Technology	
	$\alpha_k = \alpha_h = 1/3$
	$\delta_h = \delta_k = .06$
	$g = .023$
	$n = .019$
Policy Parameters	
	$\theta(1) = 0, \quad \theta(20) = .86,$
	for $i = 2, \ldots, 19$
	$(1 - \theta(i+1))/(1 - \theta(i)) = .9$
	$\pi_{BG}(\tau) = \pi_{GB}(\tau)$
	$\pi_{BG}(1) = .6, \pi_{BG}(20) = .0021$

Table 5

Model's Mobility Matrix for Relative Incomes (Fractions)

% Obs. in Period 1	26 / 1	1/8–1/4	1/4–1/2	1/2–1	1–2	2–4	4–8
9	1/8–1/4	.68	.28	.03	.00		
		(.10)	(.11)	(.06)	(.01)		
15	1/4–1/2	.18	.57	.22	.03	.00	
		(.08)	(.12)	(.08)	(.04)	(.01)	
26	1/2–1		.40	.37	.18	.05	
			(.06)	(.08)	(.06)	(.03)	
25	1–2		.05	.27	.38	.29	
			(.03)	(.06)	(.08)	(.06)	
18	2–4			.00	.18	.60	.22
				(.01)	(.06)	(.11)	(.08)
8	4–8				.01	.22	.77
					(.03)	(.10)	(.10)
% Obs. in Period 26		9	23	20	18	21	10
		(.01)	(.03)	(.03)	(.03)	(.03)	(.02)

Table 6

Model's Statistics for the Miracles

A. A Single Realization

Miracle	Average Growth of Relative Income	Average I/Y	Relative Income in Period 1
1	4.9	19.1	.59
2	4.6	22.0	.80
3	4.0	23.6	1.20
4	3.7	13.0	.54
5	3.6	16.6	.76
6	3.6	13.2	.56
7	3.4	24.9	1.59
8	3.4	24.1	1.61
9	3.3	10.3	.39
10	2.9	23.0	1.71
Miracle Average	3.7	18.2	.86
World Average	0	8.4	1.00

B. Across Realizations

	Average Growth of Relative Income	Average I/Y	Relative Income in Period 1
Mean of Miracle Average	3.7 (.30)	16.7 (1.64)	.74 (.14)
Mean of World Average	0	8.4 (.23)	1.00

Table 7

Model's Statistics for Disasters

A. A Single Realization

Disaster	Average Growth of Relative Income	Average I/Y	Relative Income in Period 1
1	−4.3	2.4	1.56
2	−4.1	2.6	1.40
3	−3.7	5.1	2.93
4	−3.6	2.9	1.18
5	−3.6	3.0	1.22
6	−3.2	3.0	.89
7	−3.1	2.9	.75
8	−3.0	3.2	.81
9	−3.0	2.9	.68
10	−2.8	6.3	2.51
Miracle Average	−3.5	3.3	1.24
World Average	0	8.4	1.00

B. Across Realizations

Disaster	Average Growth of Relative Income	Average I/Y	Relative Income in Period 1
Mean of Miracle Average	−3.3	3.5	1.20
	(.18)	(.34)	(.19)
Mean of World Average	0	8.4	1.00
		(.23)	

Table 8

Average Investment-Output Ratios in Model in Each Cell

% Obs. in Period 1	85 / 60	1/8–1/4	1/4–1/2	1/2–1	1–2	2–4	4–8
9	1/8–1/4	3.5	5.4	8.7	13.4		
		(.1)	(.5)	(1.2)	(1.5)		
15	1/4–1/2	3.5	4.8	8.2	14.3		
		(.1)	(.3)	(.7)	(1.9)		
26	1/2–1		3.7	6.9	12.8	21.5	
			(.2)	(.4)	(1.0)	(2.0)	
25	1–2		2.4	5.4	10.6	19.4	30.2
			(.5)	(.5)	(.8)	(1.2)	(.0)
18	2–4			3.8	8.0	17.1	22.0
				(1.5)	(1.3)	(1.0)	(.5)
8	4–8				6.7	14.0	24.6
					(1.2)	(2.3)	(.9)
% Obs. in Period 26		9	23	20	18	21	10

Figure 1: Ratio of the Relative Incomes of the Rich and Poor

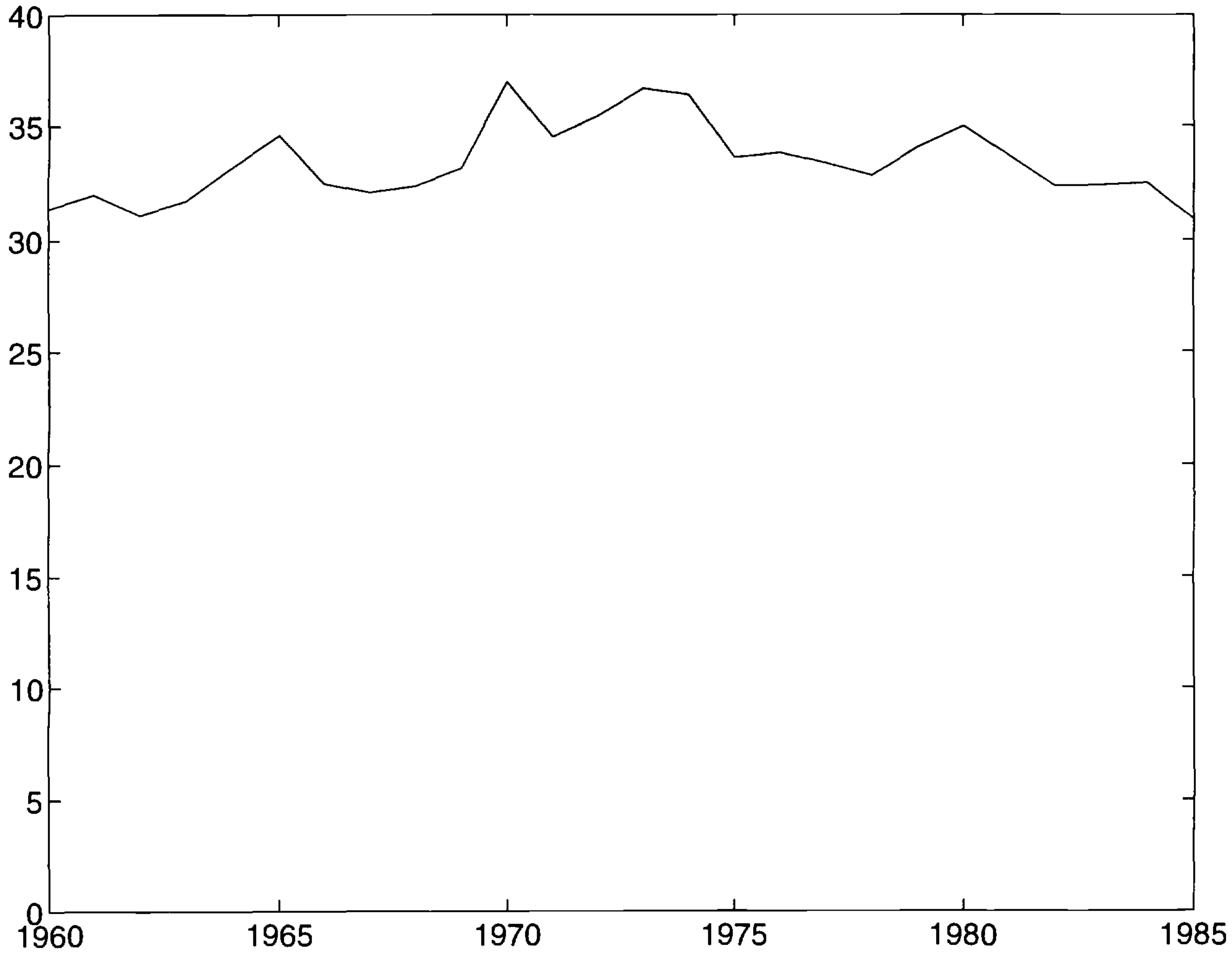


Figure 2: Standard Deviation of Logarithm of Relative Incomes

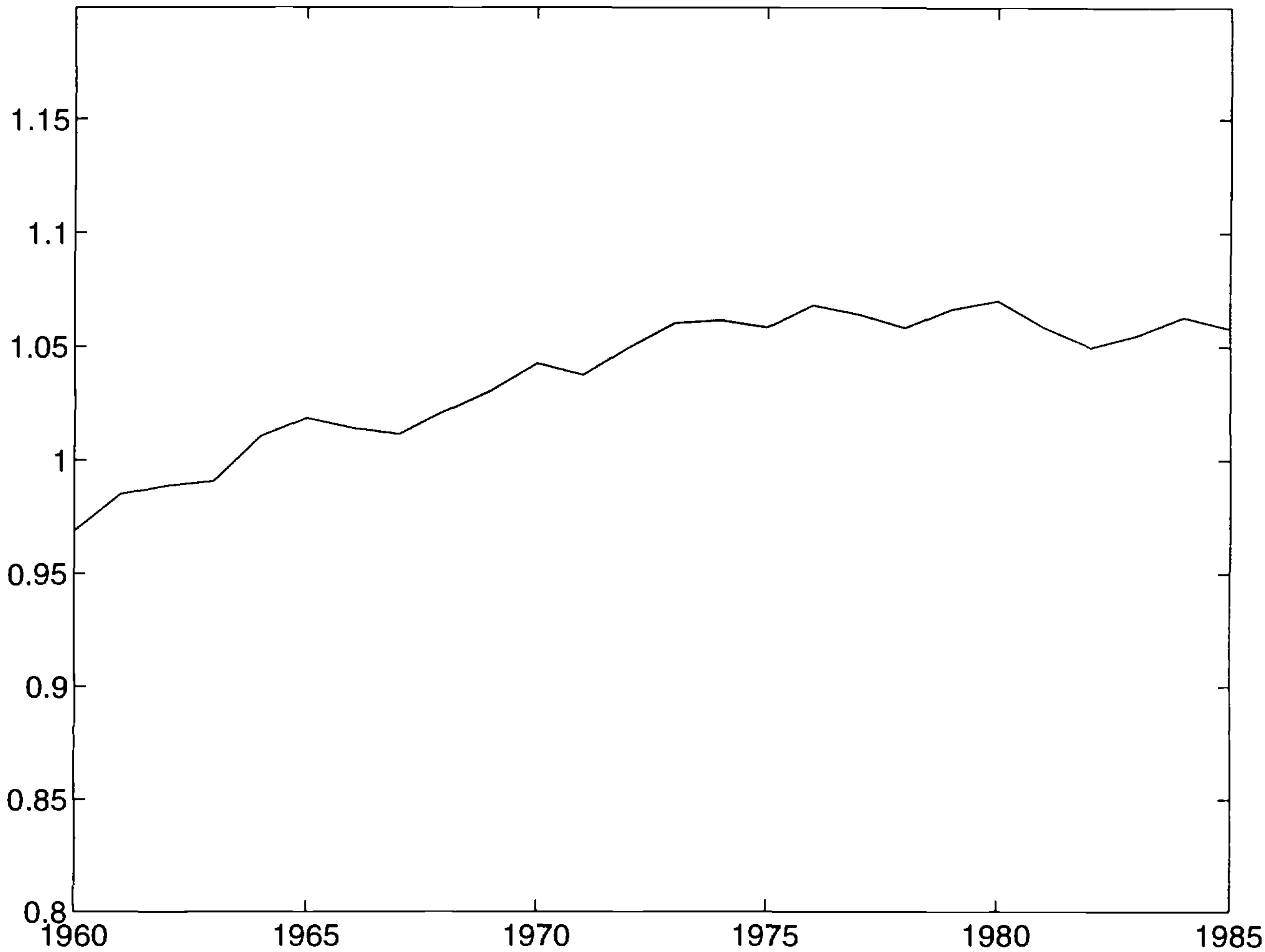


Figure 3A: Distribution of Relative Incomes, 1960

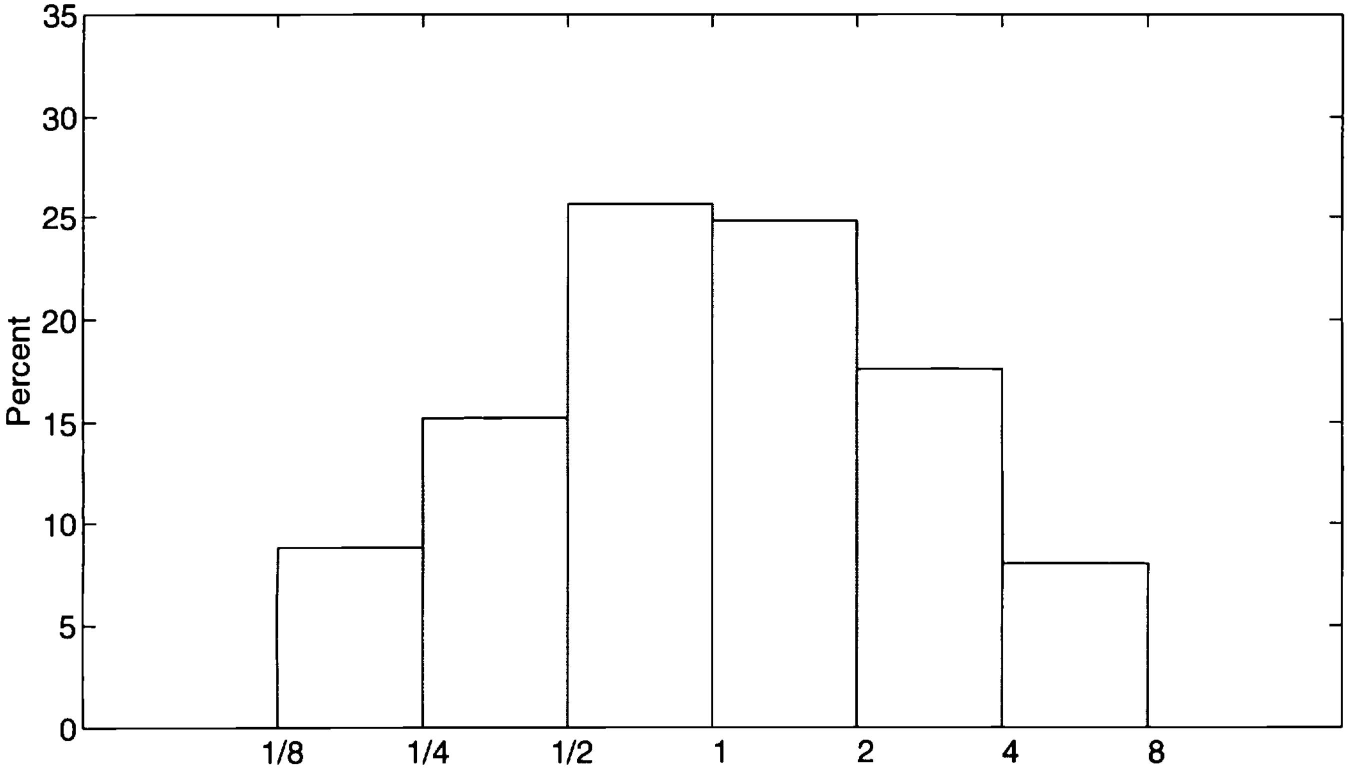


Figure 3B: Distribution of Relative Incomes, 1985

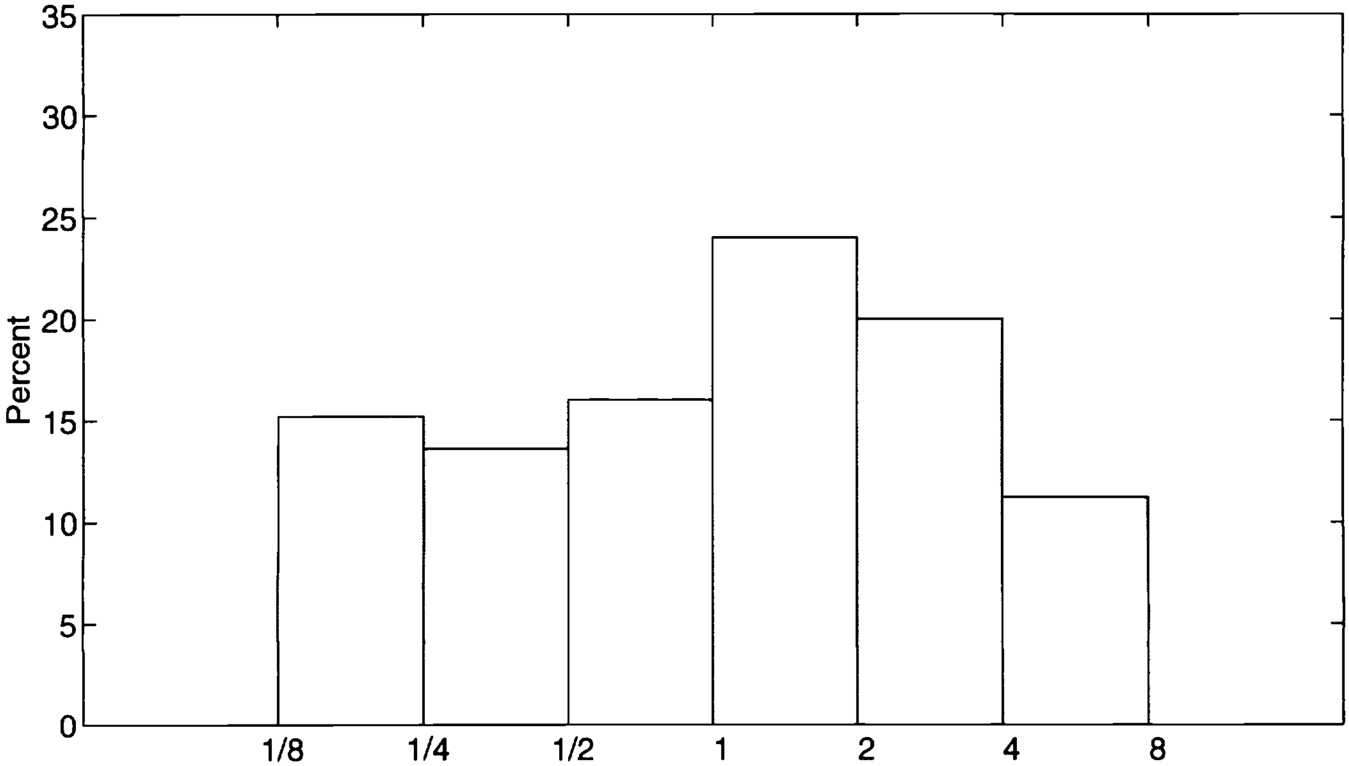


Figure 4: Persistence of Growth Rates

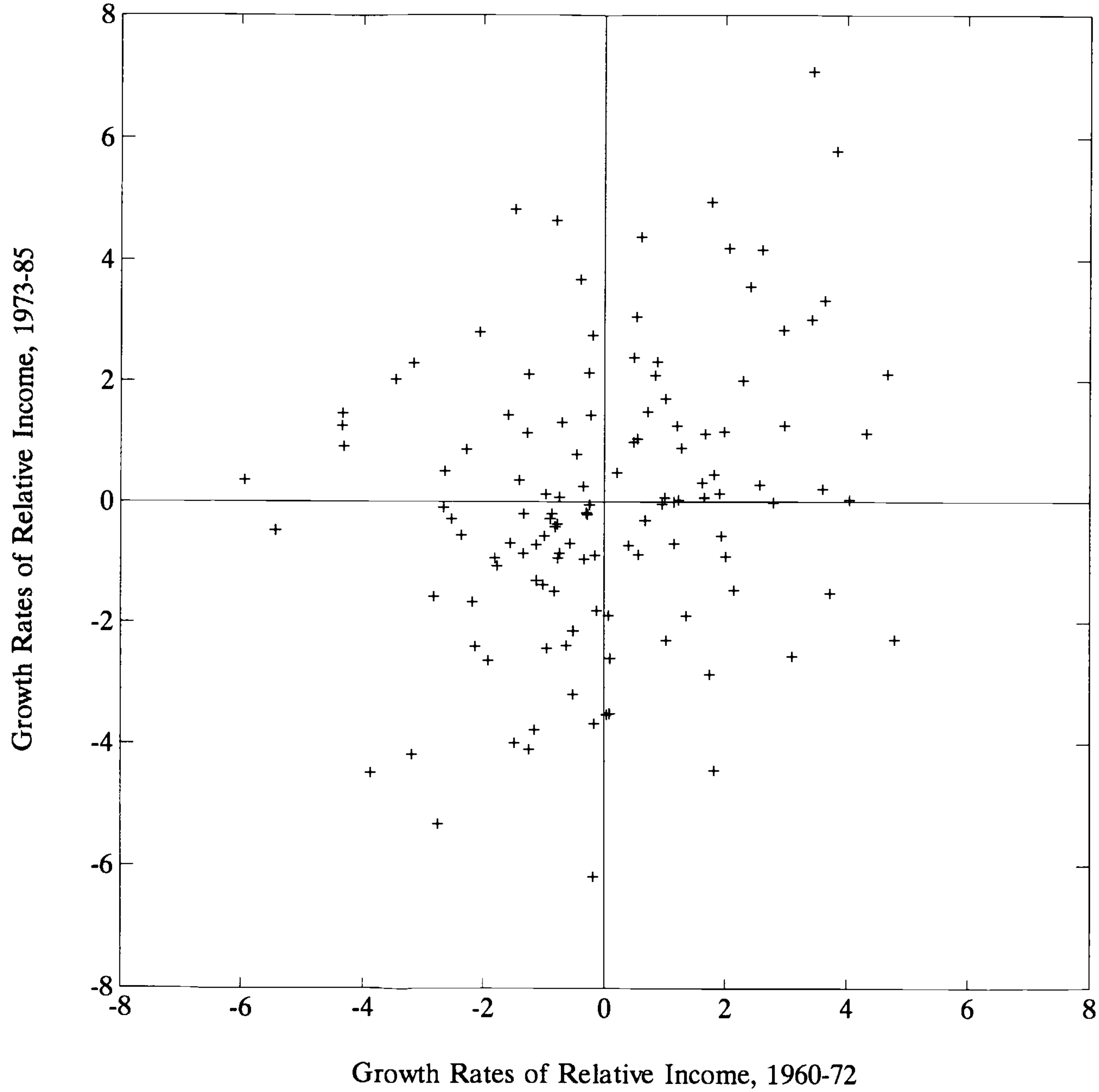


Figure 5: Investment Shares of Miracles

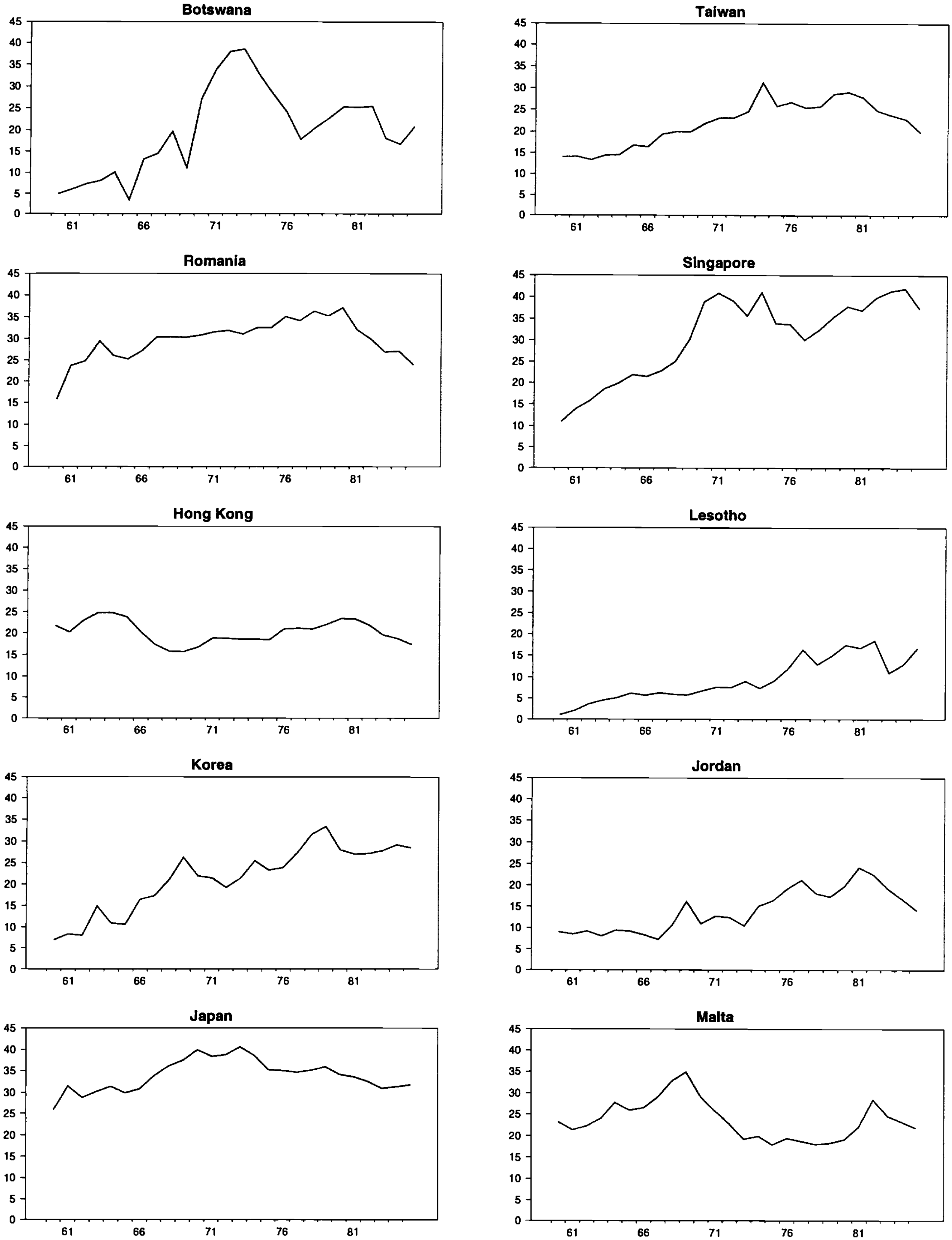


Figure 6: Investment Shares of Disasters

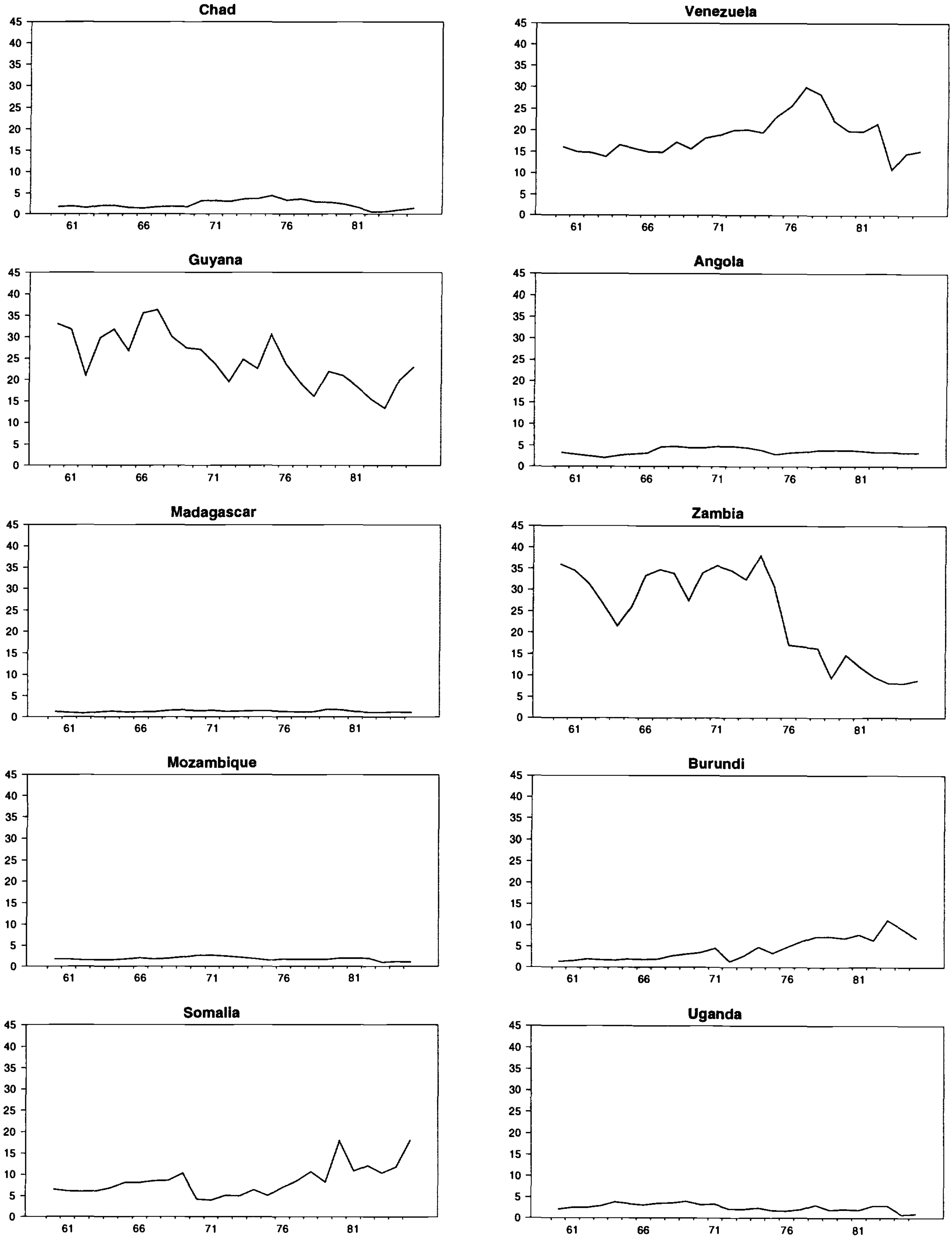


Figure 7: Two Constructions of the Capital-Output Ratios for 1985

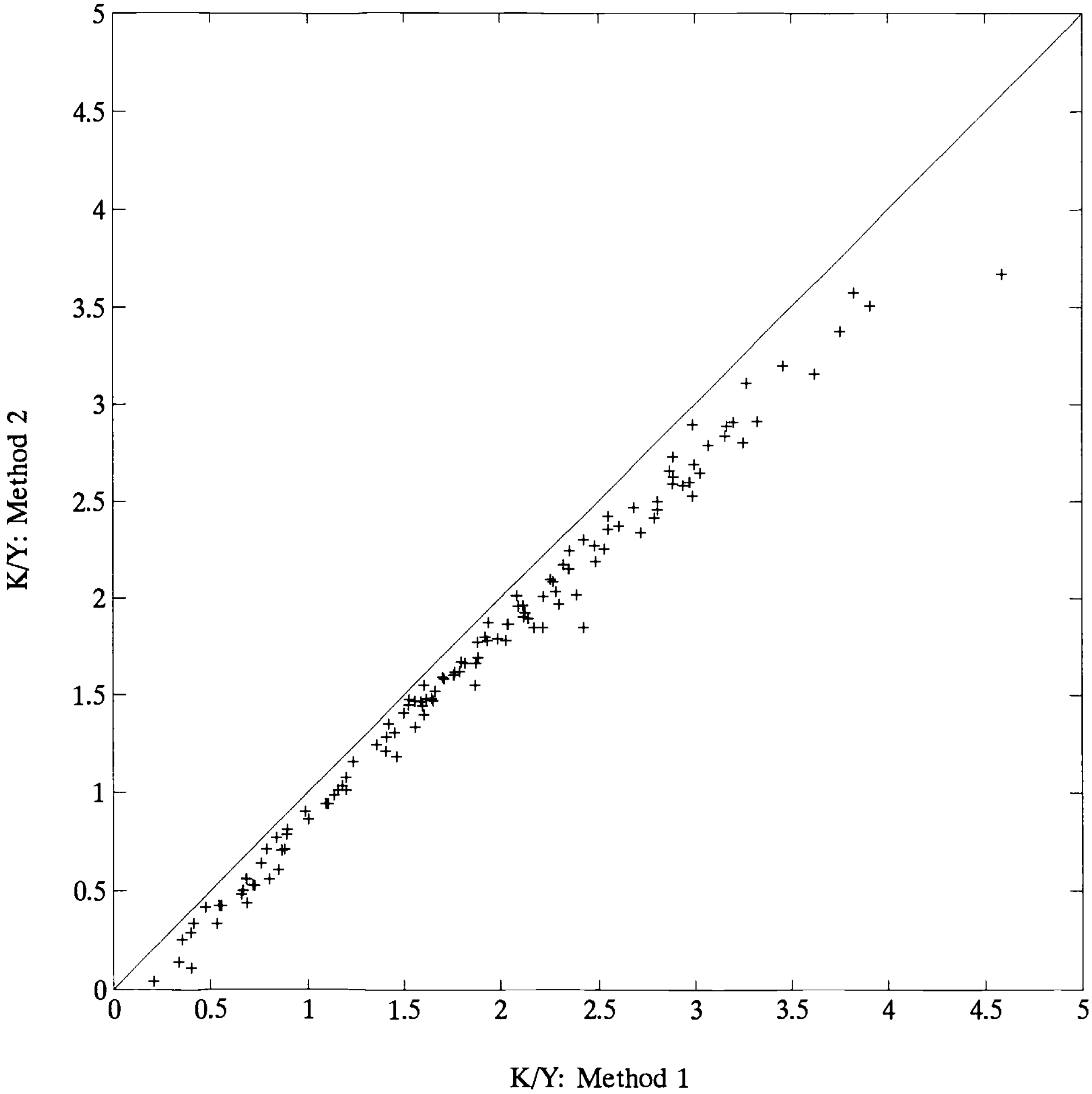


Figure 8: The Cobb-Douglas Production Relation with $\alpha = 1/3$

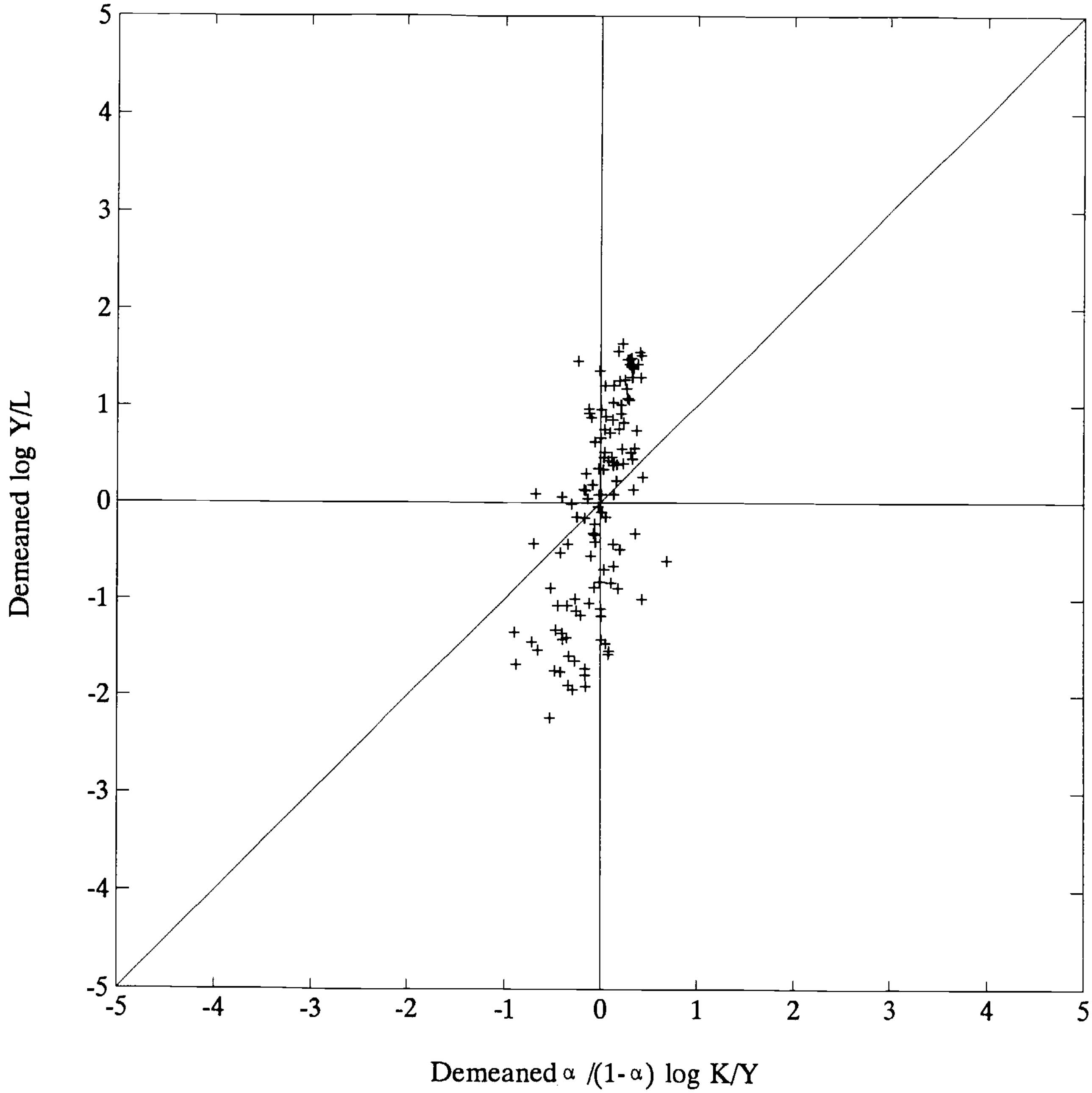


Figure 9: The Cobb-Douglas Production Relation with $\alpha = 2/3$

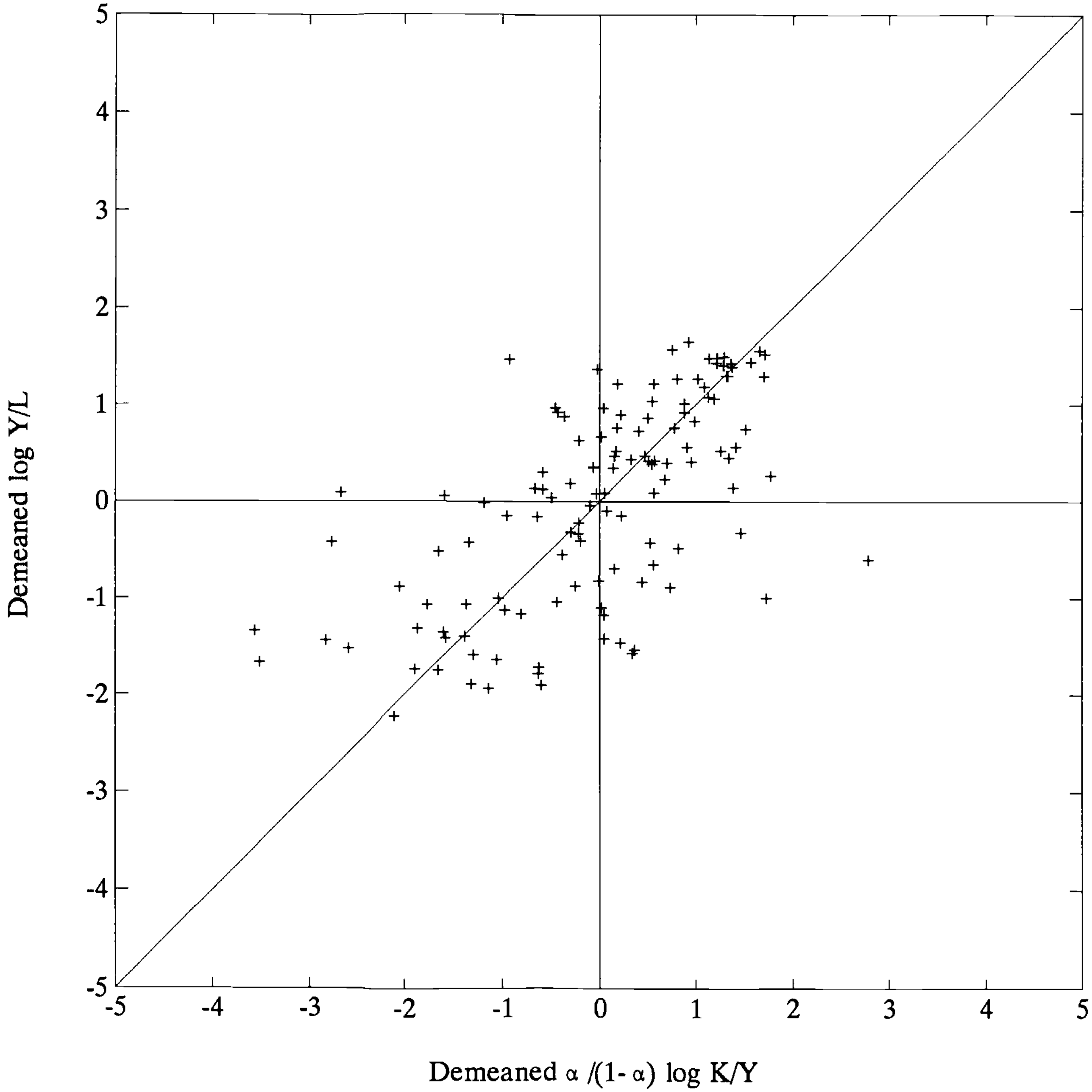


Figure 10: The Cobb-Douglas Production Relation with $\alpha = 0.9$

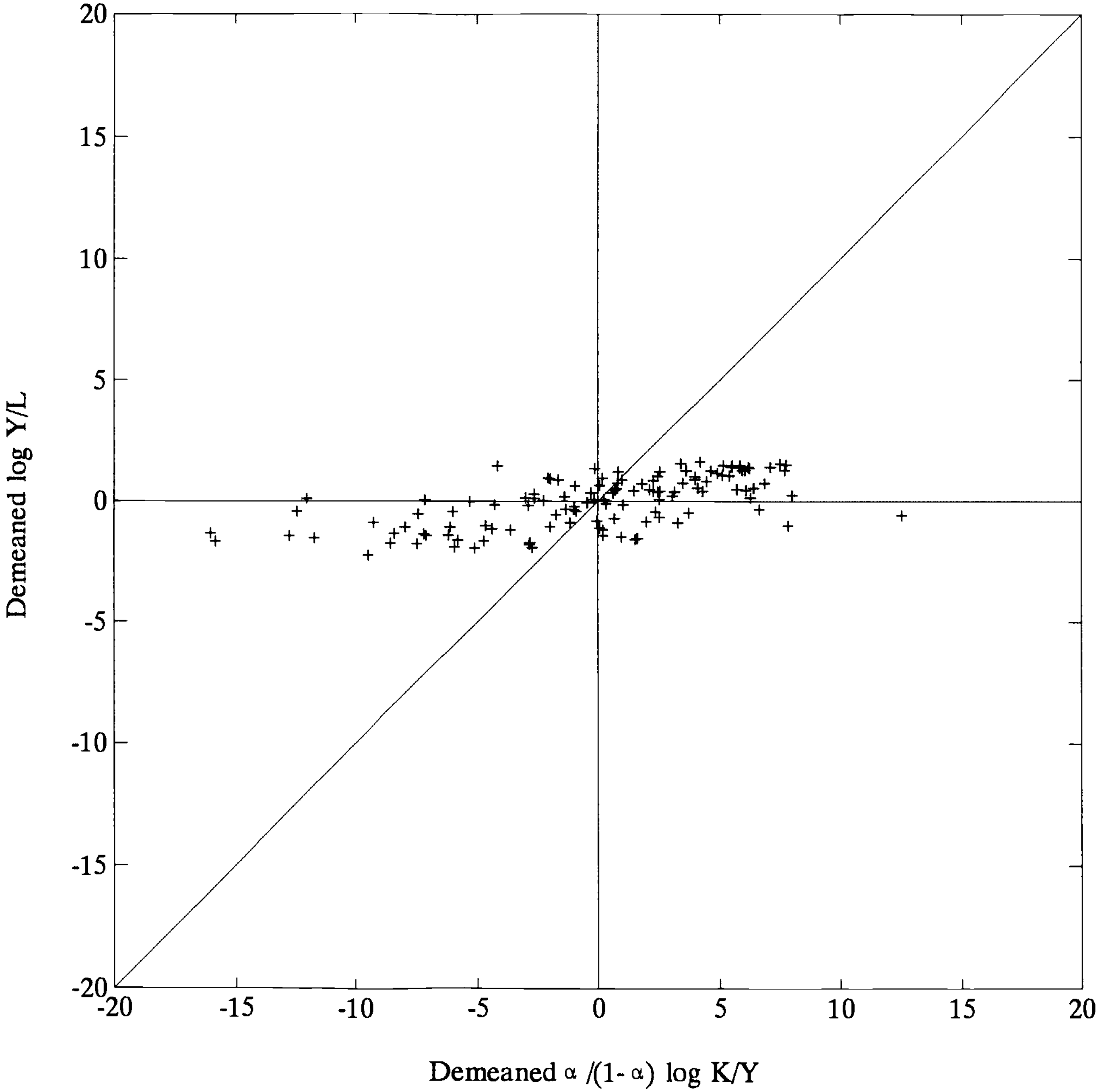


Figure 11: Labor Force Participation Rates of Miracles

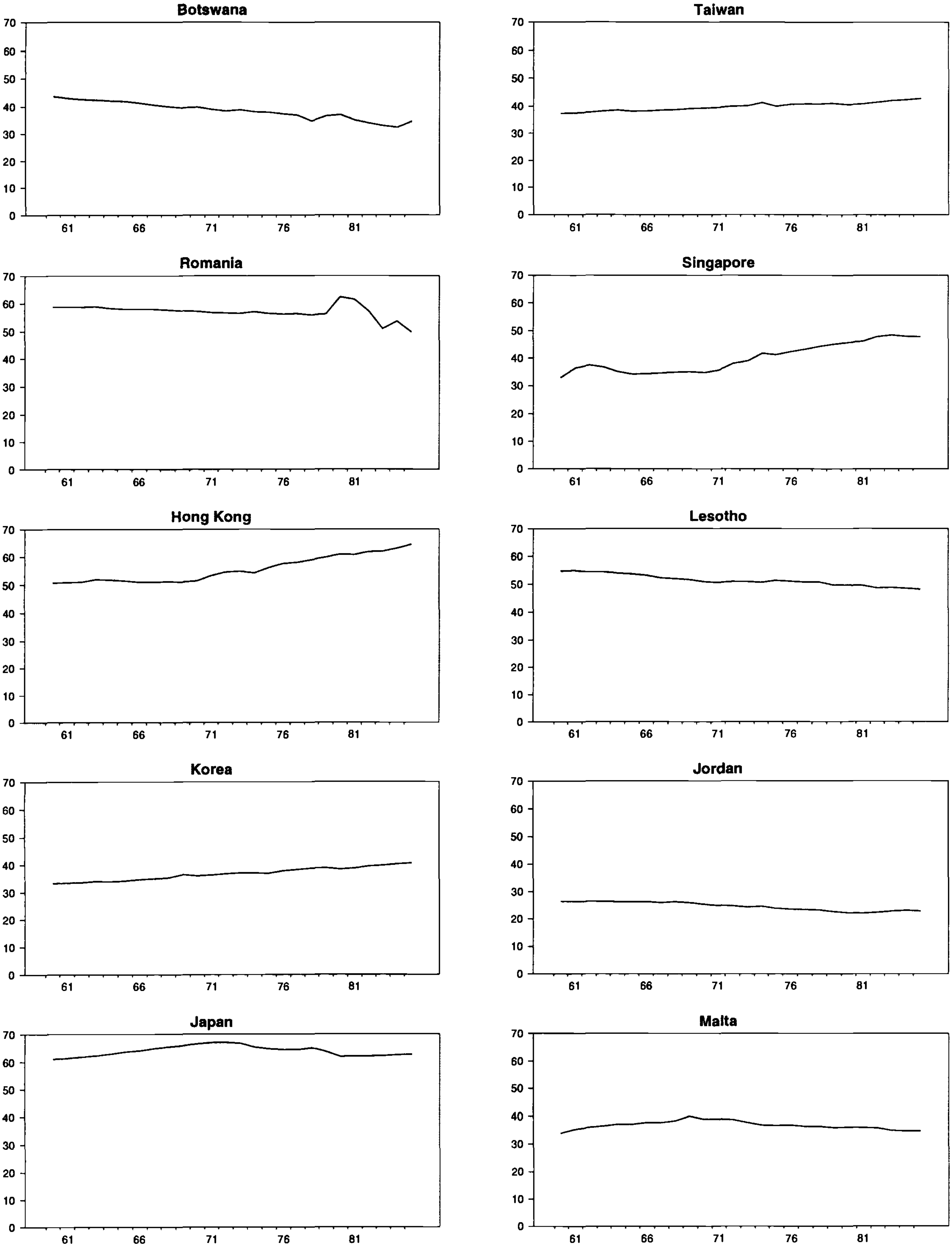


Figure 12: Labor Force Participation Rates of Disasters

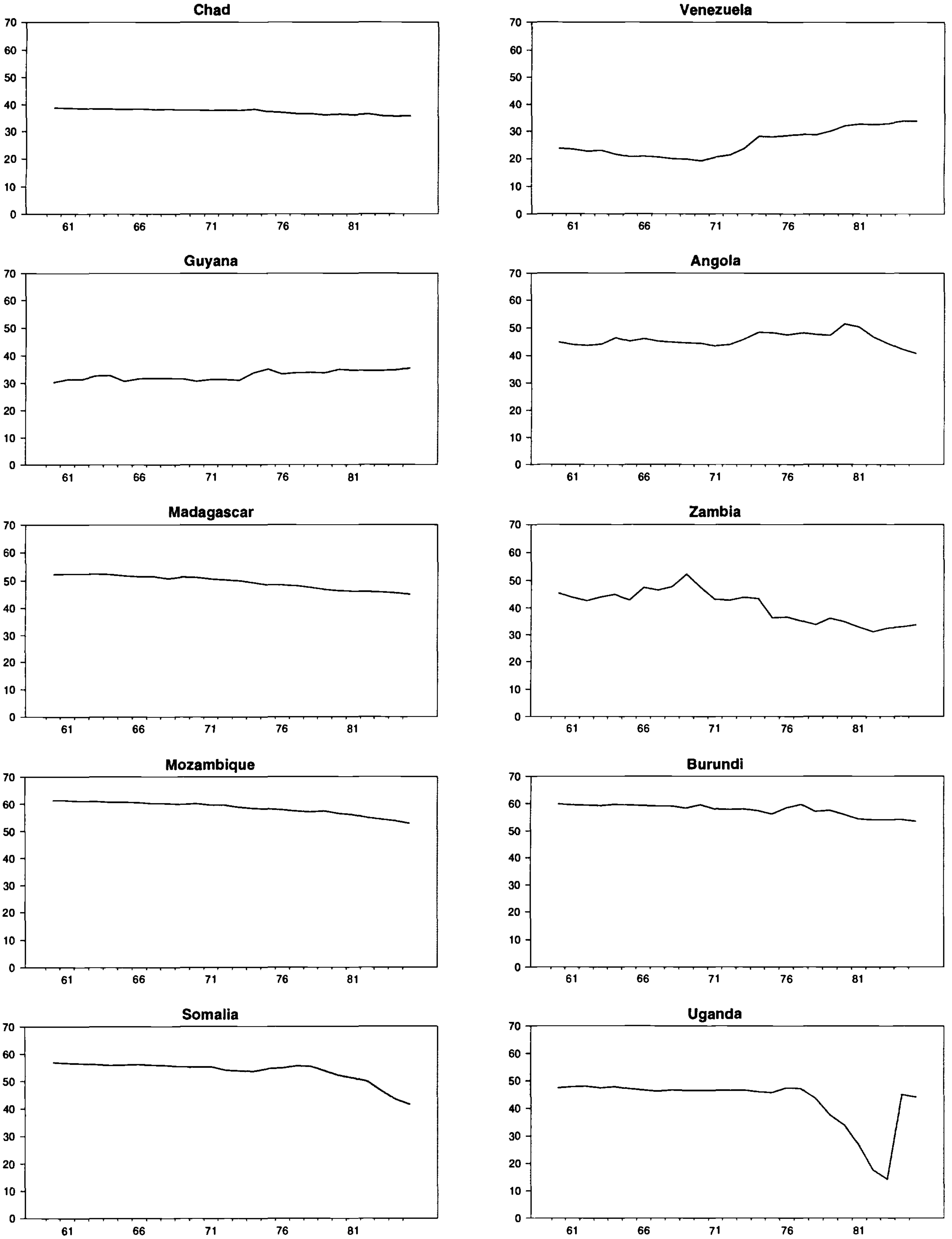


Figure 13: Average Labor Force Participation of the Miracles and Disasters

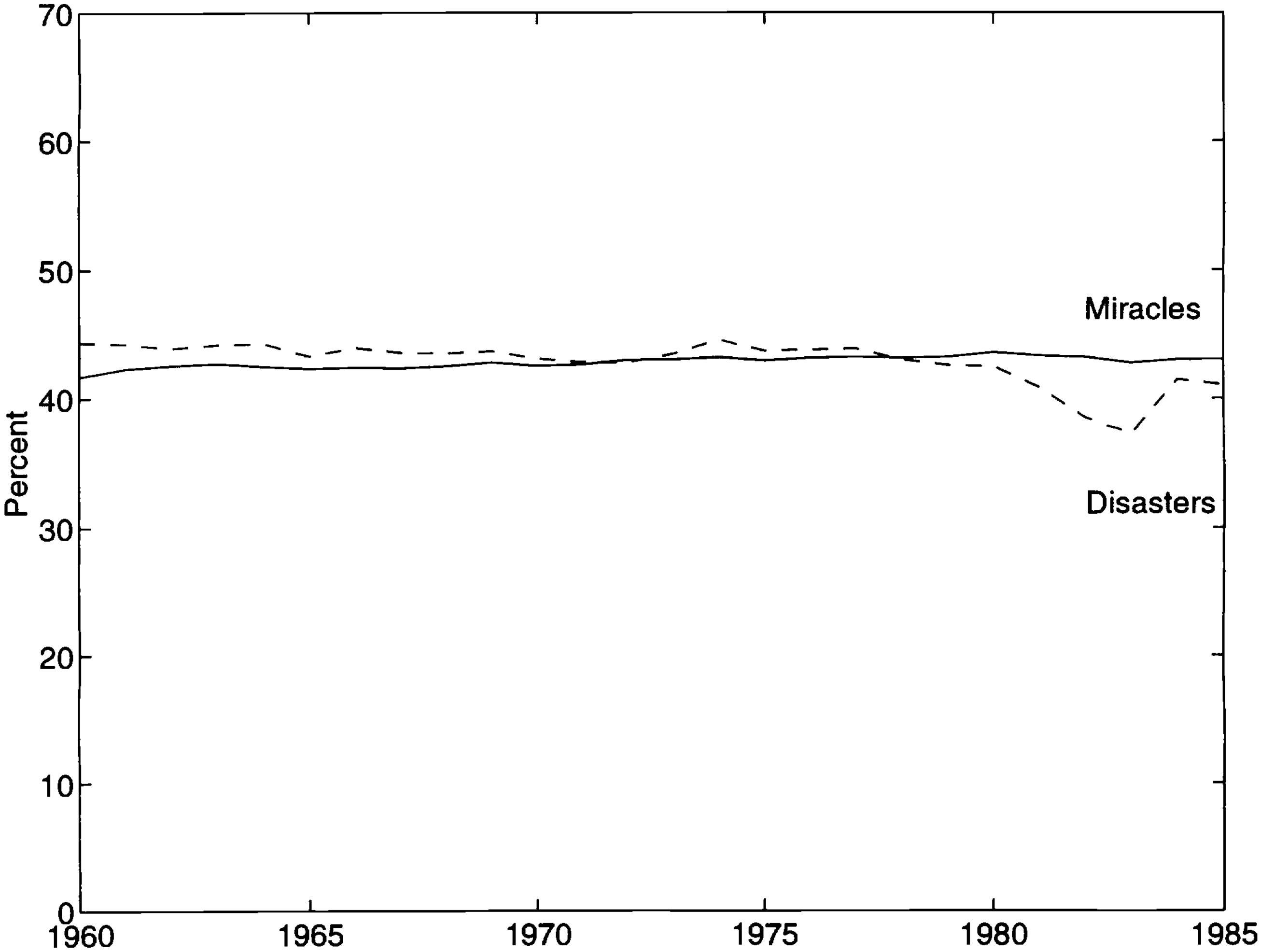


Figure 14: Distortion Levels

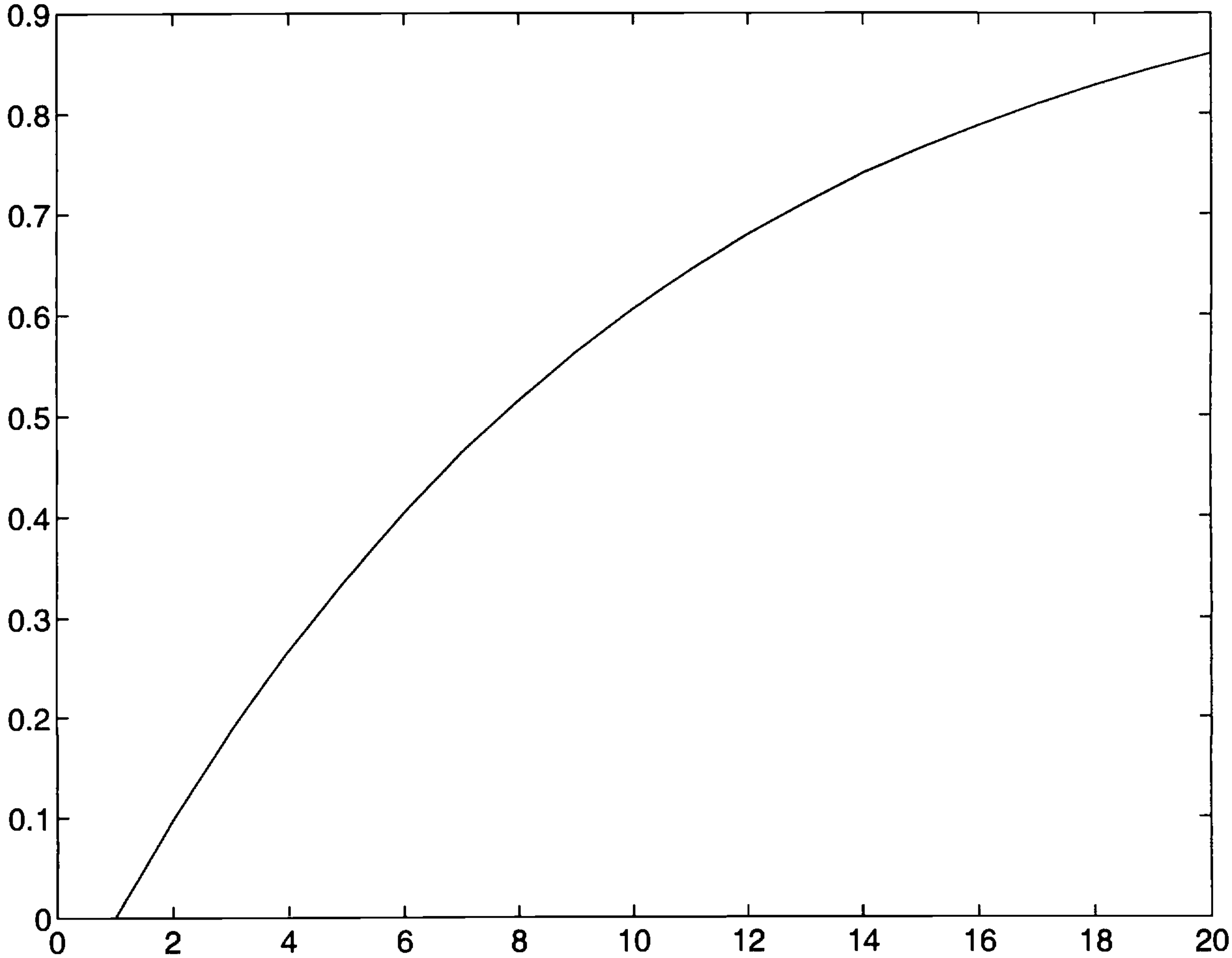


Figure 15: Ratio of the Relative Incomes of the Rich and Poor (from Model)

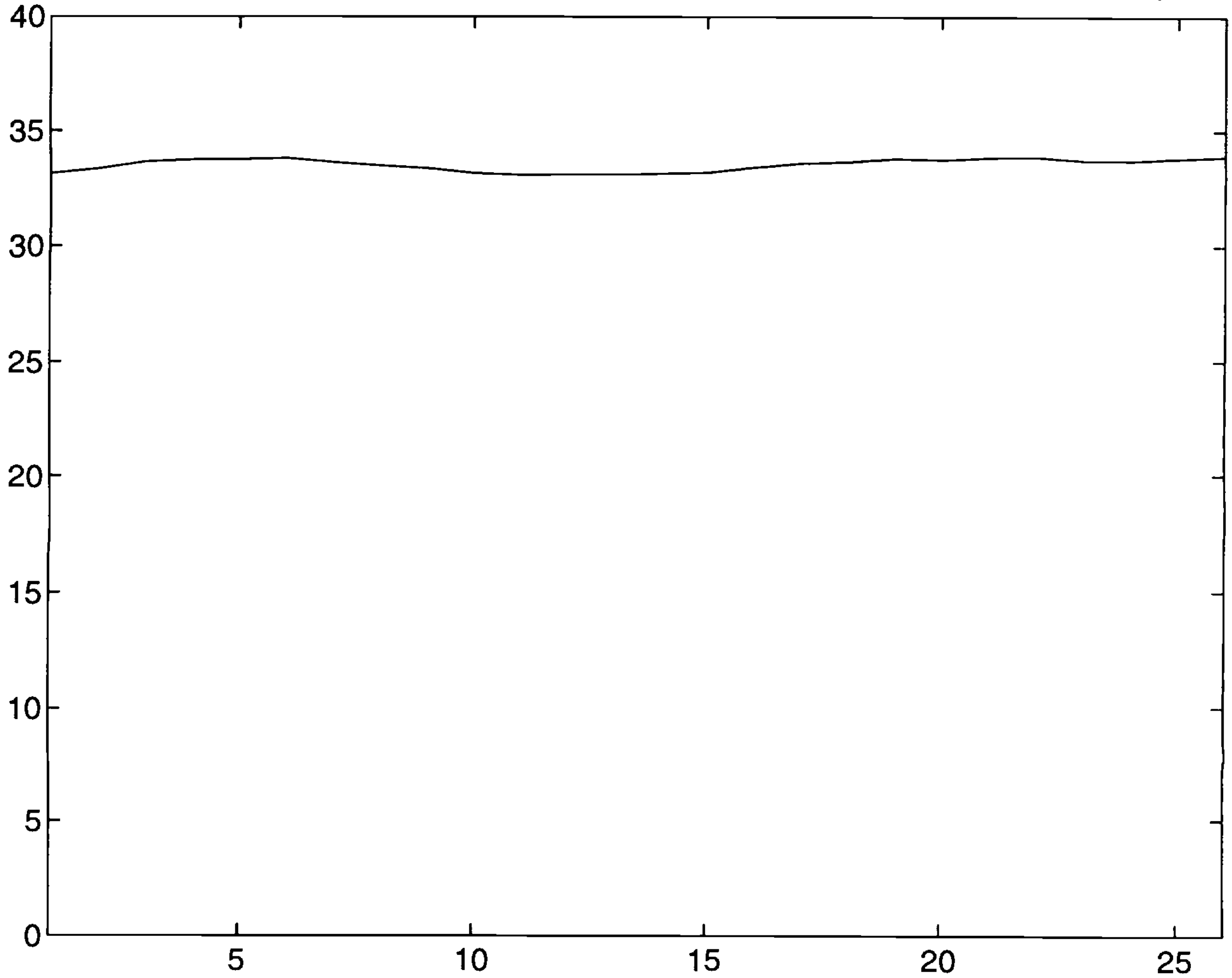


Figure 16: Standard Deviation of Logarithm of Relative Incomes (from Model)

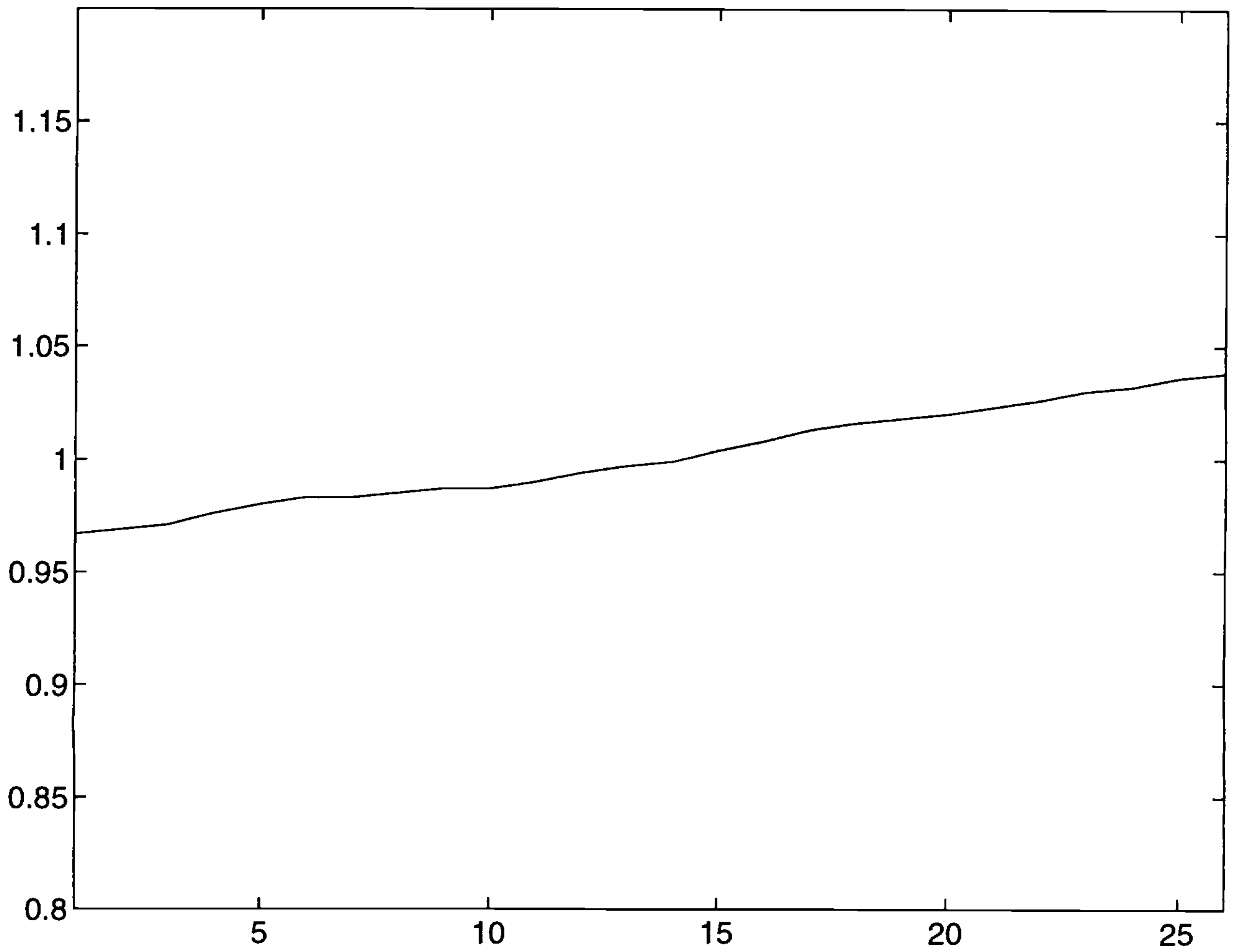


Figure 17A: Distribution of Relative Incomes (Period 1)

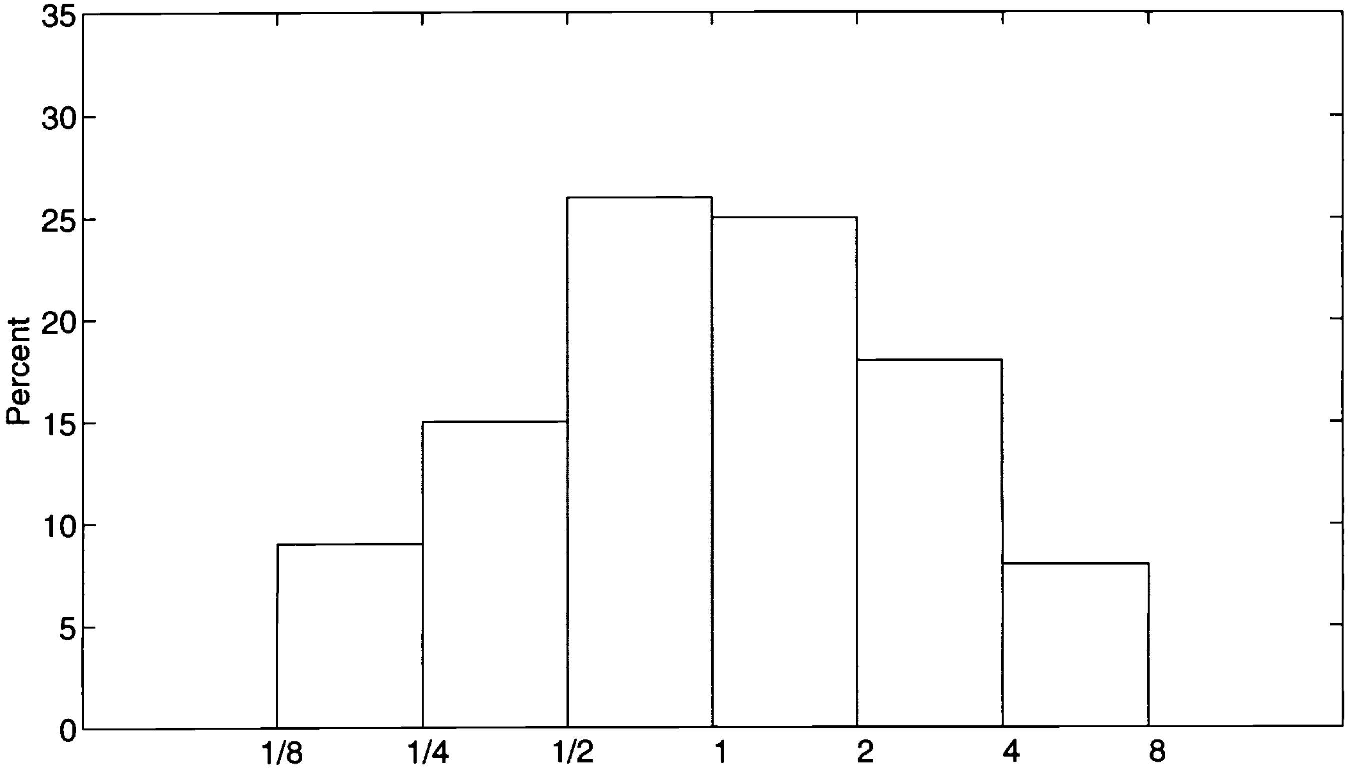


Figure 17B: Distribution of Relative Incomes (Period 26)

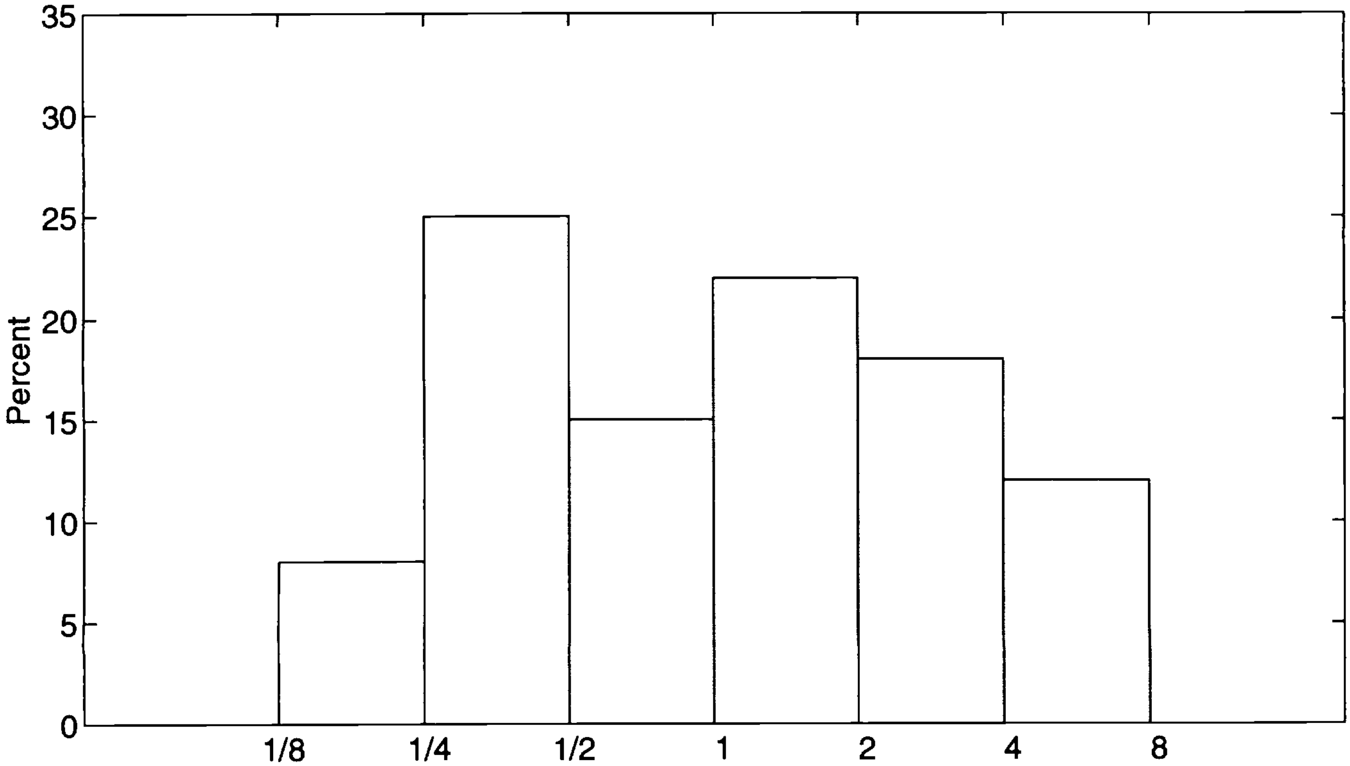


Figure 18: Persistence of Growth Rates in Model

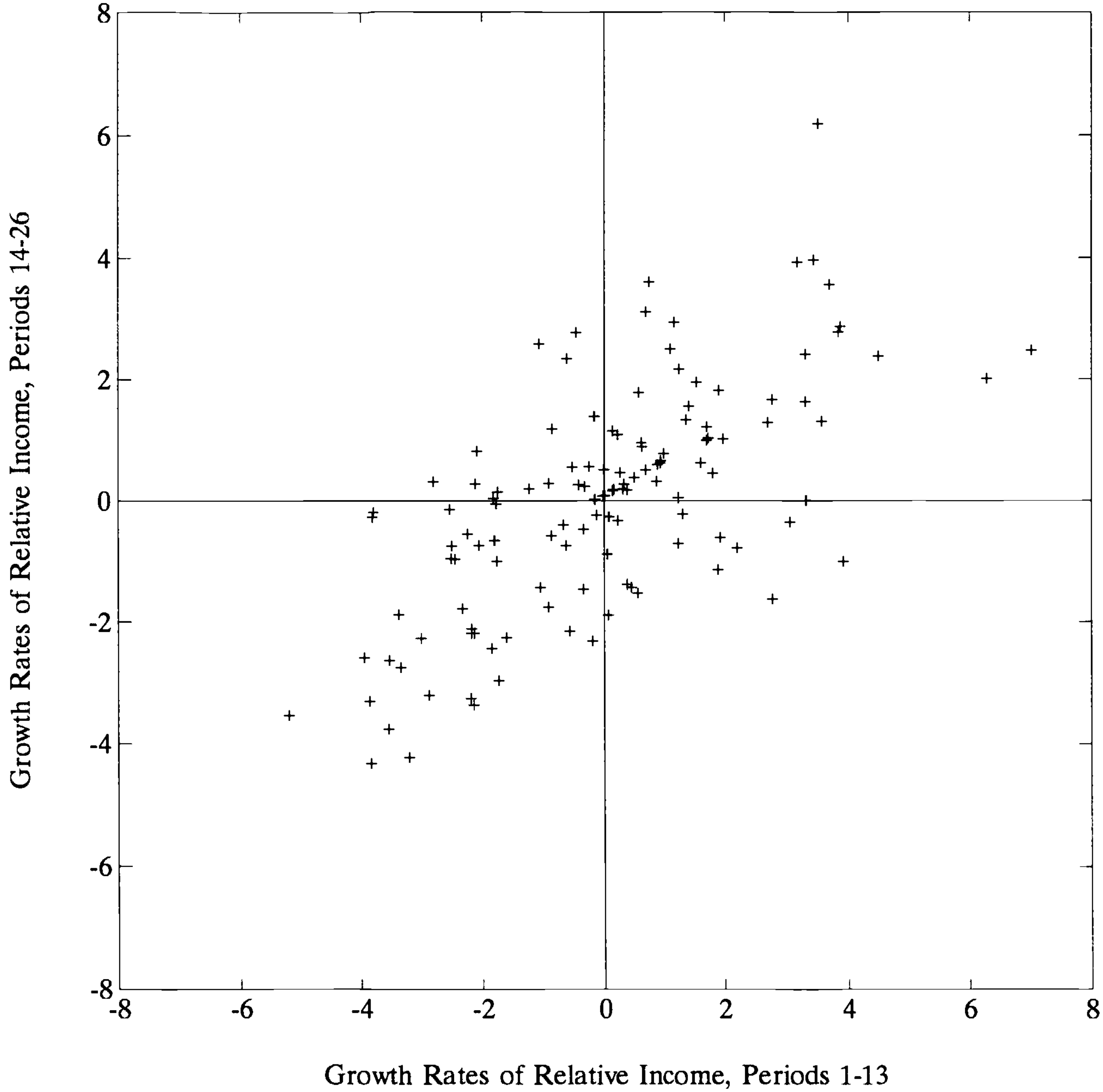


Figure 19: Investment Shares of Miracles (from Model)

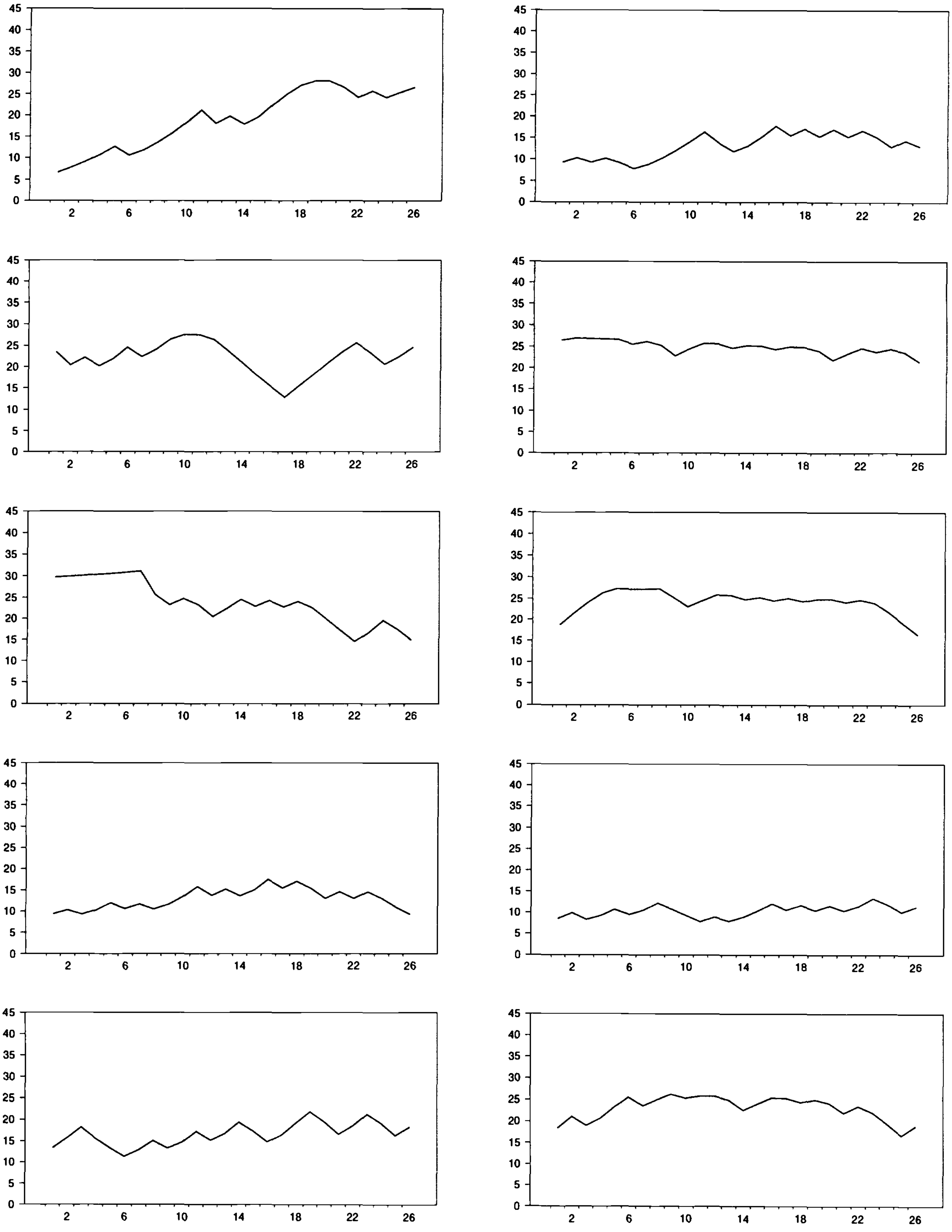


Figure 20: Investment Shares of Disasters (from Model)

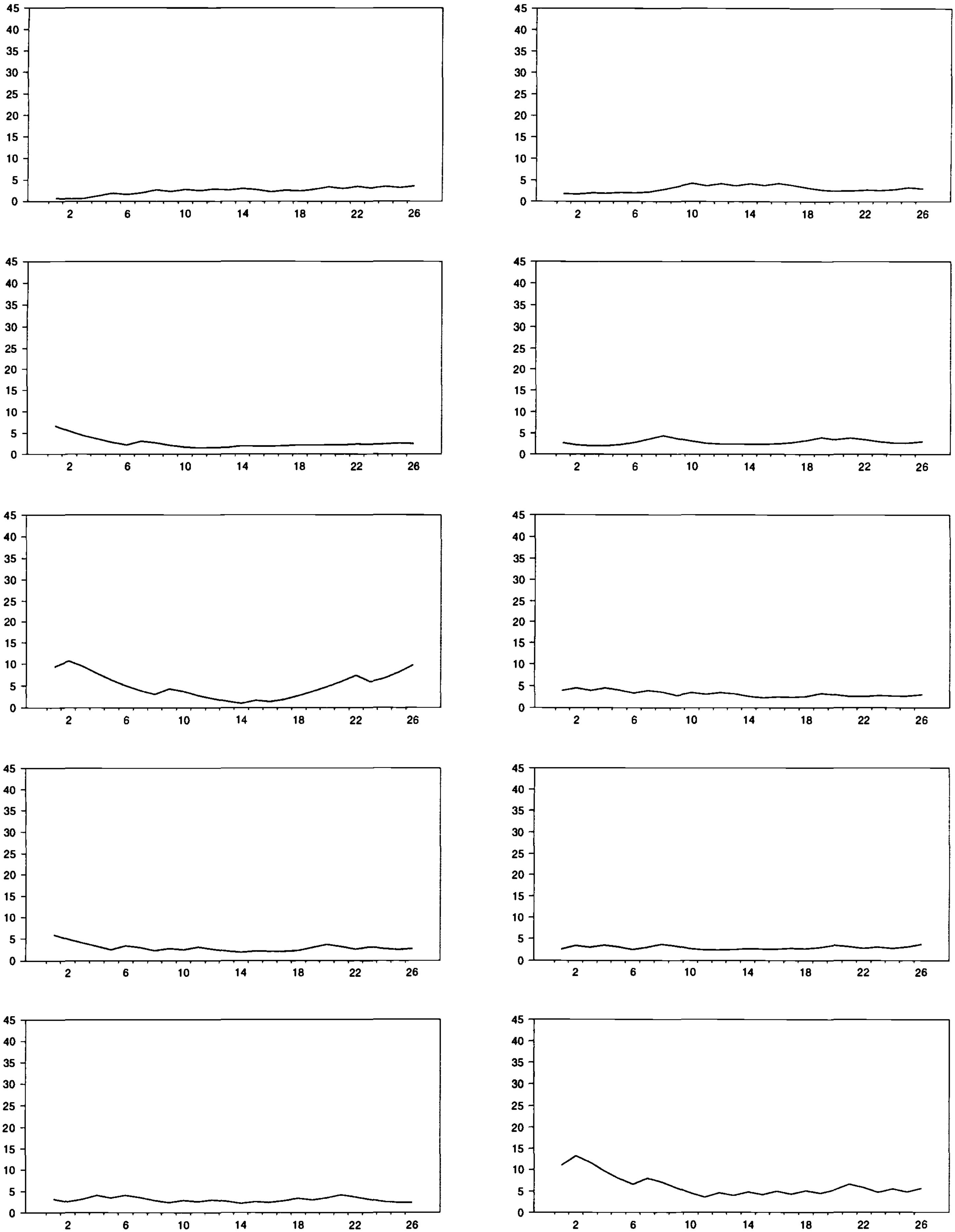
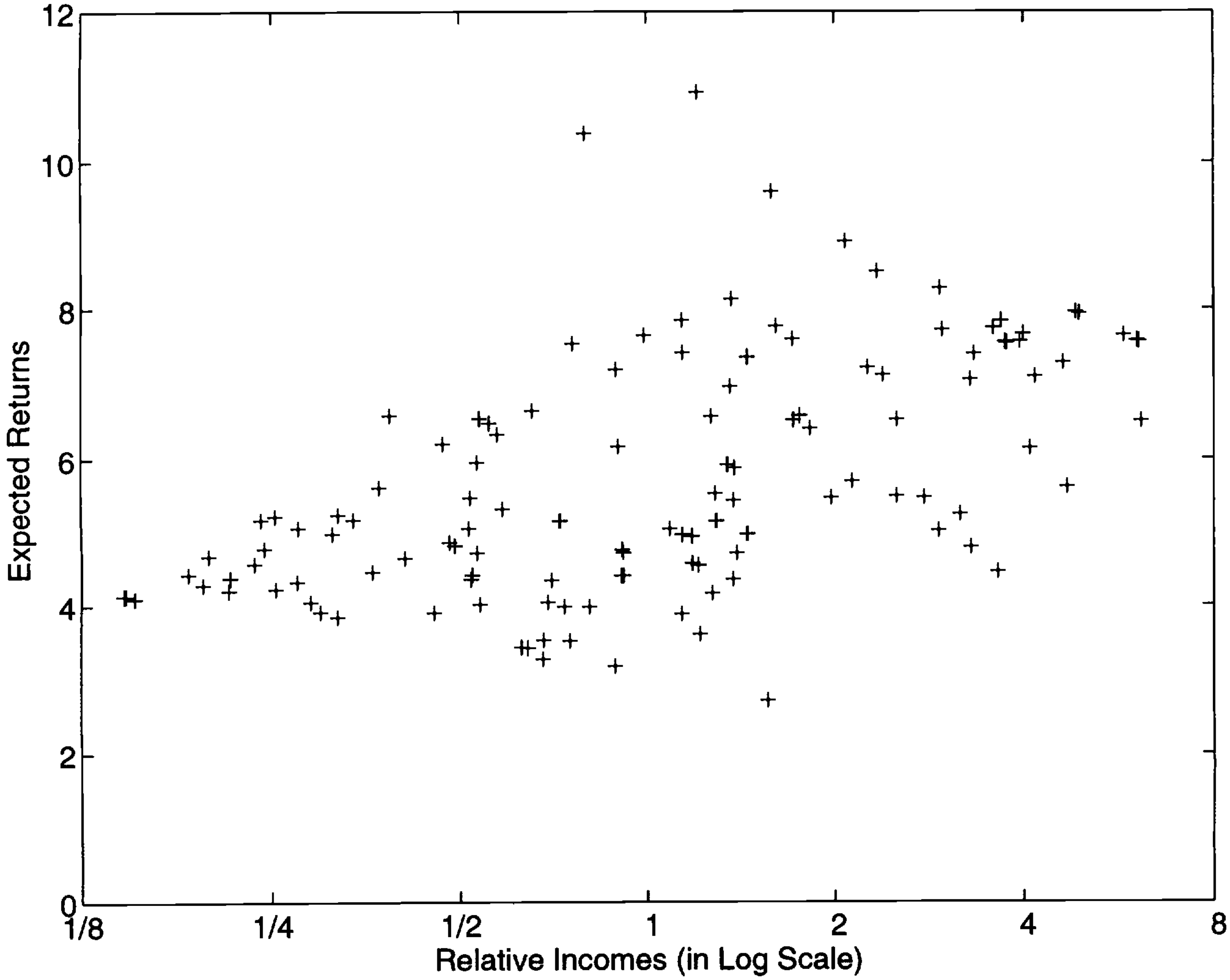


Figure 21: Expected Returns and Relative Incomes (Period 1)



Data Appendix

All our data are from the Penn World Table (PWT), Mark 5.6. Our measure of output per worker in the PWT is denoted by RGDPW. Where necessary, we construct our measure of GDP by multiplying the PWT's real GDP per capita in constant dollars; for this we use a chain index (RGDPCH) by population (POP). We obtain investment data by multiplying the PWT's measure of investment share of GDP (I) by our constructed measure of GDP.

Table A1 of this appendix is a list of the countries in our sample, together with relative incomes in 1960 and 1980, growth rates of relative income from 1960 to 1985, average investment-output ratios, and the capital-output ratio in 1985, which is calculated according to the first method described in the text. Table A2 lists each country by its location in the mobility matrix. The entries in parentheses below the country name give relative starting incomes (in 1960) and ending incomes (in 1985).

Figure A1 repeats the graph of the Cobb-Douglas relation (with $\alpha = 2/3$) in the data, with abbreviations for the names of the countries on the figure. Figure A2 repeats the same graph but drops the African countries.

Table A1

	Relative Income		Growth Rate of		
	1960	1985	Relative Income	I/Y	K/Y
Africa					
Algeria	1.74	2.07	0.69	21.81	2.35
Angola	0.52	0.27	−2.59	3.64	0.54
Benin	0.53	0.37	−1.42	6.49	0.88
Botswana	0.33	1.05	4.76	19.77	1.53
Burkina Faso	0.21	0.14	−1.42	6.88	0.87
Burundi	0.28	0.15	−2.47	4.40	0.69
Cameroon	0.36	0.60	2.04	7.78	0.79
Cape Verde Is.	0.37	0.44	0.66	23.60	2.26
Central Afr. R.	0.31	0.19	−1.86	6.80	0.81
Chad	0.51	0.18	−4.19	2.25	0.41
Comoros	0.29	0.22	−1.17	14.22	1.88
Congo	0.67	1.06	1.87	11.42	0.84
Egypt	0.75	1.10	1.56	4.57	0.48
Ethiopia	0.14	0.11	−1.11	4.95	0.55
Gabon	0.94	1.49	1.84	22.61	2.89
Gambia	0.30	0.25	−0.83	4.36	0.76
Ghana	0.55	0.34	−1.82	6.34	0.72
Guinea	0.25	0.24	−0.07	6.25	0.73
Guinea-Biss	0.25	0.21	−0.68	17.91	1.88
Ivory Coast	0.54	0.58	0.25	12.07	1.41
Kenya	0.39	0.31	−0.89	16.32	1.60
Lesotho	0.15	0.31	2.87	9.38	1.24
Liberia	0.46	0.36	−0.98	13.12	1.14
Madagascar	0.62	0.26	−3.40	1.33	0.21
Malawi	0.20	0.18	−0.50	10.54	1.18
Mali	0.40	0.26	−1.74	5.83	0.67
Mauritania	0.57	0.41	−1.28	15.03	2.17
Mauritius	1.59	1.15	−1.30	10.36	1.11
Morocco	0.76	0.99	1.08	9.02	0.99
Mozambique	0.51	0.22	−3.33	1.85	0.34
Namibia	1.31	1.30	−0.02	27.92	3.91
Niger	0.24	0.17	−1.41	9.11	1.20
Nigeria	0.35	0.44	0.91	13.38	1.80
Reunion	0.98	1.21	0.85	23.96	1.89
Rwanda	0.26	0.24	−0.31	3.28	0.41
Senegal	0.58	0.41	−1.33	5.35	0.56
Seychelles	0.67	1.09	1.93	15.98	1.72
Somalia	0.51	0.24	−2.91	8.48	1.47

	Relative Income		Growth Rate of		
	1960	1985	Relative Income	I/Y	K/Y
South Africa	1.68	1.53	−0.39	19.25	2.22
Swaziland	0.67	0.80	0.76	12.37	1.59
Tanzania	0.15	0.15	−0.12	10.61	1.20
Togo	0.21	0.23	0.40	16.26	1.94
Tunisia	1.05	1.35	1.02	15.61	1.36
Uganda	0.32	0.19	−2.12	2.57	0.36
Zaire	0.27	0.17	−1.77	3.92	0.66
Zambia	0.71	0.37	−2.58	24.28	2.72
Zimbabwe	0.60	0.50	−0.70	18.12	1.65
North and Central America					
Barbados	1.80	1.88	0.19	12.53	1.56
Canada	5.20	4.80	−0.33	23.31	2.48
Costa Rica	1.82	1.41	−1.03	15.65	1.82
Dominican Rep.	1.10	1.09	−0.04	14.43	1.77
El Salvador	1.17	0.85	−1.24	8.45	1.10
Guatemala	1.41	1.13	−0.88	9.40	1.16
Haiti	0.45	0.33	−1.24	4.97	0.85
Honduras	0.87	0.72	−0.79	14.16	1.46
Jamaica	1.16	0.73	−1.84	22.97	2.99
Mexico	2.54	2.62	0.13	16.99	1.80
Nicaragua	1.37	0.91	−1.62	12.00	1.61
Panama	1.27	1.55	0.80	21.90	2.09
Puerto Rico	3.04	3.36	0.40	23.41	2.04
Trinidad & Tobago	4.51	3.93	−0.55	12.59	1.66
U.S.A.	6.52	5.20	−0.90	21.53	2.49
South America					
Argentina	3.03	2.30	−1.09	17.09	2.39
Bolivia	0.89	0.87	−0.10	18.77	1.89
Brazil	1.48	1.69	0.53	19.88	1.93
Chile	2.34	1.50	−1.75	18.69	2.30
Colombia	1.46	1.43	−0.10	16.10	1.67
Ecuador	1.19	1.48	0.88	22.93	2.33
Guyana	1.50	0.55	−3.93	24.78	4.59
Paraguay	0.95	0.96	0.03	12.55	1.62
Peru	1.68	1.25	−1.18	17.82	2.29
Suriname	1.90	1.68	−0.50	19.48	2.15
Uruguay	2.61	1.57	−2.01	13.23	2.43
Venezuela	5.46	2.83	−2.60	18.60	2.53
Asia					
Bangladesh	0.74	0.66	−0.47	4.51	0.40
China	0.29	0.33	0.60	19.61	1.77
Hong Kong	1.11	2.53	3.34	20.26	1.61

	Relative Income		Growth Rate of		
	1960	1985	Relative Income	I/Y	K/Y
India	0.47	0.42	−0.46	13.63	1.41
Indonesia	0.44	0.67	1.70	14.64	1.71
Iran	2.68	2.13	−0.90	14.92	2.05
Iraq	3.43	2.44	−1.35	10.53	1.99
Israel	2.59	3.38	1.08	27.55	2.43
Japan	1.33	2.90	3.15	33.93	3.27
Jordan	1.20	2.41	2.83	14.12	1.50
Korea Rep.	0.72	1.60	3.22	21.44	2.09
Malaysia	1.10	1.61	1.55	22.33	2.36
Myanmar	0.18	0.21	0.44	8.83	0.89
Nepal	0.34	0.35	0.04	5.19	0.69
Pakistan	0.54	0.65	0.76	10.79	0.90
Philippines	0.79	0.65	−0.79	15.44	2.12
Saudi Arabia	3.68	4.34	0.66	7.08	1.42
Singapore	1.34	2.77	2.95	30.65	2.99
Sri Lanka	0.94	0.86	−0.33	8.48	1.01
Syria	1.52	2.64	2.24	15.40	1.53
Taiwan	0.90	1.96	3.15	21.84	1.94
Thailand	0.50	0.73	1.51	16.90	1.56
Europe					
Austria	2.86	3.67	1.00	25.81	3.03
Belgium	3.82	4.21	0.39	24.15	2.81
Cyprus	1.33	2.14	1.94	27.97	2.55
Czechoslovakia	0.89	1.15	1.04	27.80	3.21
Denmark	3.95	3.67	−0.29	26.37	2.94
Finland	3.09	3.65	0.67	35.38	3.75
France	3.60	4.17	0.59	27.47	3.16
Germany—West	3.72	4.20	0.49	28.57	3.33
Greece	1.38	2.50	2.43	25.99	2.69
Iceland	3.36	3.58	0.25	29.60	2.87
Ireland	2.24	2.96	1.11	25.44	2.89
Italy	2.95	4.19	1.40	28.71	3.00
Luxembourg	5.01	4.74	−0.22	29.94	3.26
Malta	1.26	2.37	2.54	23.73	2.12
Netherlands	4.57	4.40	−0.15	25.19	2.81
Norway	3.82	4.43	0.60	31.96	3.17
Portugal	1.30	1.75	1.20	23.67	2.61
Romania	0.20	0.62	4.56	29.67	2.55
Spain	2.19	3.26	1.61	25.17	2.89
Sweden	4.63	4.08	−0.51	23.71	2.79
Switzerland	5.38	4.60	−0.63	28.57	3.62
Turkey	0.85	1.09	0.99	21.02	2.27

	Relative Income		Growth Rate of		
	1960	1985	Relative Income	I/Y	K/Y
U.K.	3.94	3.54	−0.43	18.05	2.22
U.S.S.R.	1.25	2.11	2.13	38.76	3.83
Yugoslavia	1.13	1.76	1.79	30.00	3.46
Oceania					
Australia	5.14	4.46	−0.57	29.05	3.07
Fiji	2.03	1.51	−1.17	18.49	2.13
New Zealand	5.68	4.01	−1.39	24.57	2.98
Papua N. Guinea	0.61	0.52	−0.61	15.75	2.03

Table A2

Countries in the Mobility Matrix

Relative Income 1985

	1/8–1/4	1/4–1/2	1/2–1	1–2
1/8–1/4	Burkina Faso (.21−.14) Ethiopia (.14−.11) Guinea (.25−.24) Guinea Biss (.25−.21) Malawi (.20−.18) Niger (.24−.17) Tanzania (.15−.15) Togo (.21−.23) Myanmar (.18−.21)	Lesotho (.15−.31)	Romania (.20−.62)	
1/4–1/2	Burundi (.28−.15) Central Africa (.31−.19) Comoros (.29−.22) Gambia (.30−.25) Rwanda (.26−.24) Uganda (.32−.19) Zaire (.27−.17)	Cape Verde Is (.37−.44) Kenya (.39−.31) Liberia (.46−.36) Mali (.40−.26) Nigeria (.35−.44) Haiti (.45−.33) China (.29−.33) India (.47−.42) Nepal (.34−.35)	Cameroon (.36−.60) Indonesia (.44−.67)	Botswana (.33−1.05)

	1/8–1/4	1/4–1/2	1/2–1	1–2
1/2–1	Chad (.51 – .18)	Angola (.52 – .27)	Ivory Coast (.54 – .58)	Congo (.67 – 1.06)
	Mozambique (.51 – .22)	Benin (.53 – .37)	Morocco (.76 – .99)	Egypt (.75 – 1.10)
	Somalia (.51 – .24)	Ghana (.55 – .34)	Swaziland (.67 – .80)	Gabon (.94 – 1.49)
		Madagascar (.62 – .26)	Zimbabwe (.60 – .50)	Reunion (.98 – 1.21)
		Mauritania (.57 – .41)	Honduras (.87 – .72)	Seychelles (.67 – 1.09)
		Senegal (.58 – .41)	Bolivia (.89 – .87)	Korea Republic (.72 – 1.60)
		Zambia (.71 – .37)	Paraguay (.95 – .96)	Taiwan (.90 – 1.96)
			Bangladesh (.74 – .66)	Czechoslovakia (.89 – 1.15)
			Pakistan (.54 – .65)	Turkey (.85 – 1.09)
			Philippines (.79 – .65)	
			Sri Lanka (.94 – .86)	
			Thailand (.50 – .73)	
			Papua N. Guinea (.61 – .52)	

Table A2, continued

Countries in the Mobility Matrix

Relative Income 1985

	1/2–1	1–2	2–4	4–8
1–2	El Salvador (1.17–.85) Jamaica (1.16–.73) Nicaragua (1.37–.91) Guyana (1.50–.55)	Mauritius (1.59–1.15) Namibia (1.31–1.30) South Africa (1.68–1.53) Tunisia (1.05–1.35) Barbados (1.80–1.88) Costa Rica (1.82–1.41) Dominican Rep. (1.10–1.09) Guatemala (1.41–1.13) Panama (1.27–1.55) Brazil (1.48–1.69) Colombia (1.46–1.43) Ecuador (1.19–1.48) Peru (1.68–1.25) Suriname (1.90–1.68) Malaysia (1.10–1.61) Portugal (1.30–1.75) Yugoslavia (1.13–1.76)	Algeria (1.74–2.07) Hong Kong (1.11–2.53) Japan (1.33–2.90) Jordan (1.20–2.41) Singapore (1.34–2.77) Syria (1.52–2.64) Cyprus (1.33–2.14) Greece (1.38–2.50) Malta (1.26–2.37) U.S.S.R. (1.25–2.11)	

	1/2–1	1–2	2–4	4–8
2–4		Chile (2.34–1.50) Uruguay (2.61–1.57) Fiji (2.03–1.51)	Mexico (2.54–2.62) Puerto Rico (3.04–3.36) Argentina (3.03–2.30) Iran (2.68–2.13) Iraq (3.43–2.44) Israel (2.59–3.38) Austria (2.86–3.67) Denmark (3.95–3.67) Finland (3.09–3.65) Iceland (3.36–3.58) Ireland (2.24–2.96) Spain (2.19–3.26) United Kingdom (3.94–3.54)	Saudi Arabia (3.68–4.34) Belgium (3.82–4.21) France (3.60–4.17) Germany West (3.72–4.20) Italy (2.95–4.19) Norway (3.82–4.43)
4–8			Trinidad & Tobago (4.51–3.93) Venezuela (5.46–2.83)	Canada (5.20–4.80) United States (6.52–5.20) Luxembourg (5.01–4.74) Netherlands (4.57–4.40) Sweden (4.63–4.08) Switzerland (5.38–4.60) Australia (5.14–4.46) New Zealand (5.68–4.01)

Figure A1: The Cobb-Douglas Production Relation with $\alpha = 2/3$

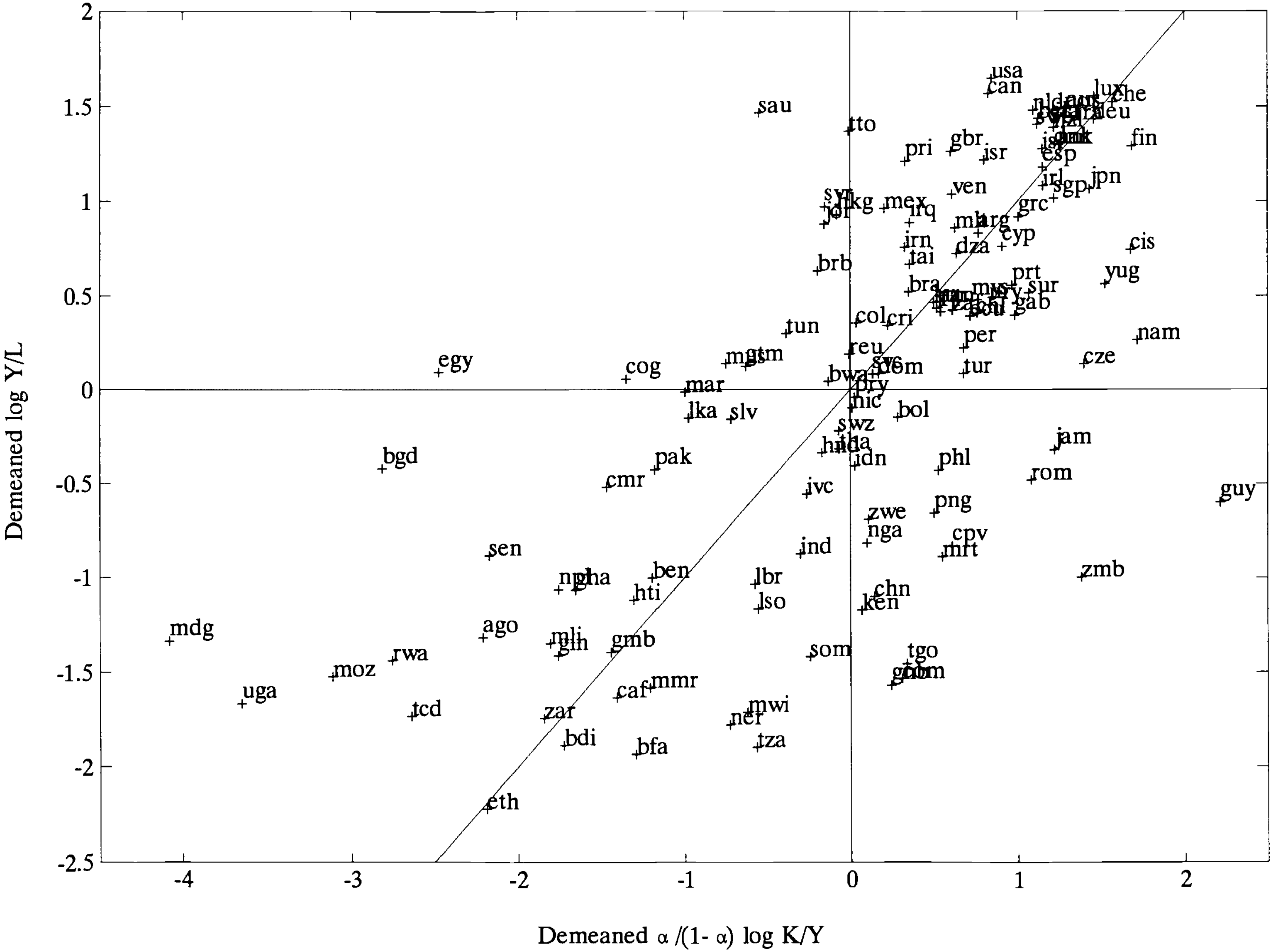


Figure A2: The Cobb-Douglas Production Relation with α = 2/3 (without Africa)