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TECHNICAL PROGRESS AND BRAZILIAN MA NUFACTURING INDUSTRY

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TECHNICAL PROGRESS
AND
BRAZILIAN MANUFACTURING INDUSTRY:
-an exploration on times of miracles *

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* This preliminary version is circulated to stimulate discussion and critical comments.

1- Introduction

It is 20 years now, since Moses Abramovitz took the first step.(1) Aiming at study the long-run behavior of aggregate output per capita and trying to discover how the labor and capital inputs had contributed to this movement, he reached the conclusion that "almost the entire increase in net product per capita is associated with the rise in productivity".

The next milestone was Solow's "Technical Change and the Aggregate Production Function" (2). In his work, representing Y as output, and K and L as capital and labor inputs (our notation) he assumes an aggregate production function like :

$$Y = F\ (K,L;\ t) \qquad (1.1)$$

where "t for time appears in F to allow for technical change". He also assumes "neutral technical change" such that we can write (1.1) as :

$$Y = A\ (t)\ f\ (K,L) \qquad (1.2)$$

Through mathematical manipulation and including the neoclassical hypothesis of $wk = \frac{\partial Y}{\partial K}\frac{K}{Y}$ and $wl = \frac{\partial Y}{\partial L}\frac{L}{Y}$, that corresponds to the relative shares of capital and labor, we get:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + wk\,\frac{\dot{K}}{K} + wl\,\frac{\dot{L}}{L} \qquad (1.3)$$

where dots indicate time derivates.

Expressing (1.3) in per-capita terms:

$$\frac{\dot{y}}{y} = \frac{\dot{A}}{A} + wk\,\frac{\dot{k}}{k} \qquad (1.4) \qquad \text{where} \quad y = Y/L,\quad k = K/L$$

he finds possible to disentangle the rate of growth of the technical change index A (t) as :

(1) M. Abramovitz - "Resource and Output Trends in the U.S. since 1870" - American Economic Review, May 1956 - pp 5-23

(2) R.M. Solow - "Technical Change and the Aggregated Production Function" - Review of Economics and Statistics - Aug. 1957 - pp 312-20

$$\frac{\dot{A}}{A} = \frac{\dot{y}}{y} - wk\frac{\dot{k}}{k} \qquad (1.5)$$

Therefore, setting the initial value of A(t) (in his case 1909) equal to 1, he is able to obtain a series for the increase in productivity not attributable to labor and capital inputs covering the periods 1909 to 1949. Plots of A(t) and $\dot{A}/A$ can be seen in Figures 1.1 and 1.2.

"Correcting" y for this technical change A, and plotting y/A against k, he obtains something like figure 1.3. In fact figure 1.3 should be compared with Chart 4 of Solow's work. There's some evident divergence between our plotting (made by using the same data as Solow) and the presented Chart 4. This is due to some "computational errors" which Solow admittedly committed, as stated in a reply to Hogan's criticism.(3)

Nevertheless, the great conclusion which Solow has reached, was that about 87½% of all the increase in gross output per man-hour was attributable to technical change and only the remaining 12½% could be attributed to increased use of factor inputs.

From then on, a hot polemic has taken place within two extremes : at one point are those who have labelled this residual of "the measure of our ignorance" and feel discouraged to take seriously the neoclassical model as a tool for an explanation for productivity growth; at the other side, are those who tried to "explain" this residual by altering the measurement of factor inputs (4). In-between these two extremes we witnessed an upsurge of articles on classification of technical progress, measurement of factors (including here some of Cambridge Controversy), embodiment hypothesis, induced innovation, learning, invention, research,

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(3) R. M. Solow -"Reply" - Review of Economics and Statistics, November 1958 - pp. 411 -3

(4) D. W. Jorgenson & Z. Griliches in "Explanation of productivity Change" - are able to reduce the residual to a mere 3.3% (Review of Economic Studies - 1967 - pp 249-83). However, E. Denison, in a detailed article charge both with biased and tautological procedures like correcting factors for productivity, when this is just what we want to measure. "Some Major Issues in Productivity Analysis" - Survey of Current Business - May 1969 pp 1-27

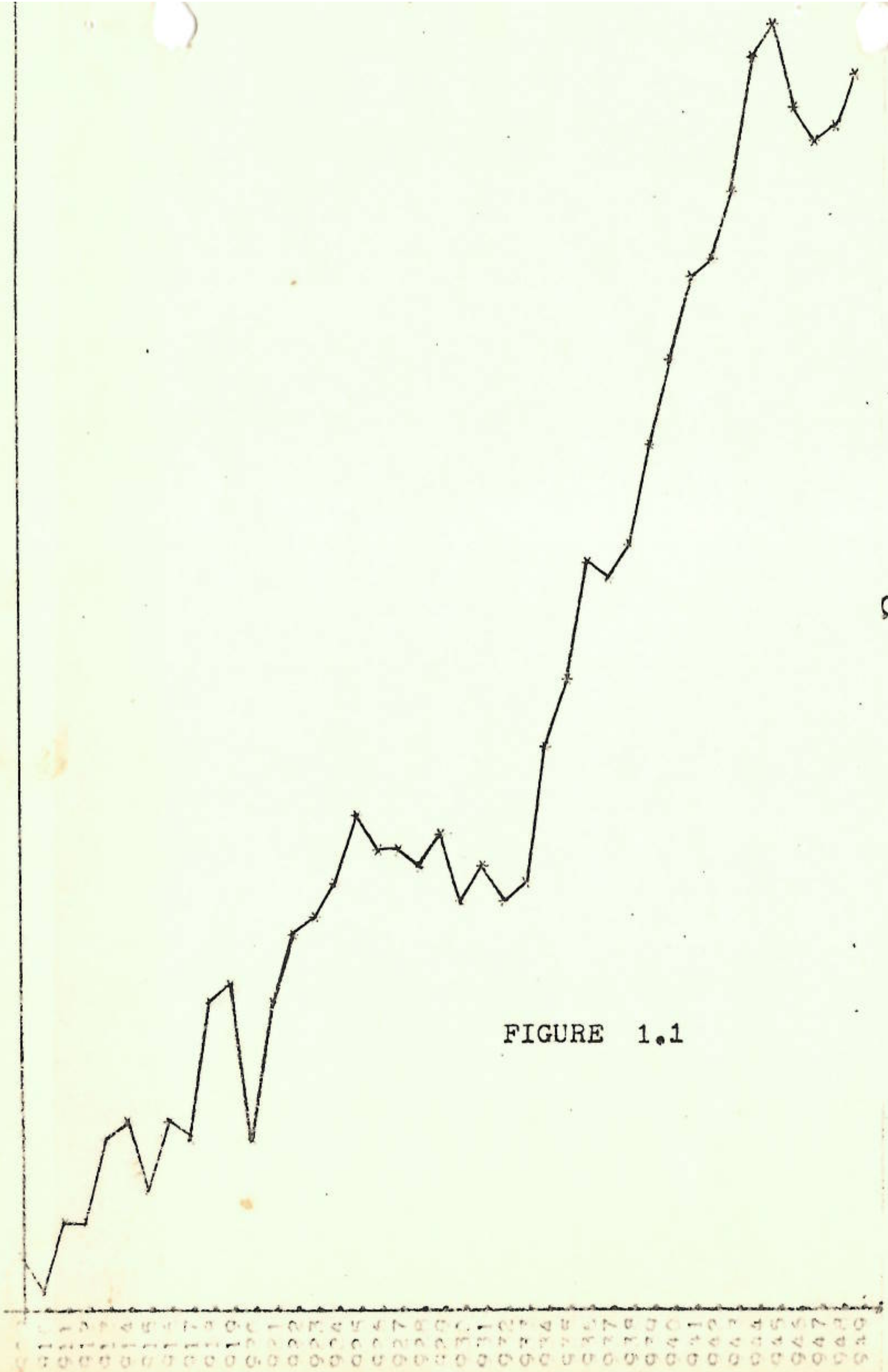


FIGURE 1.1

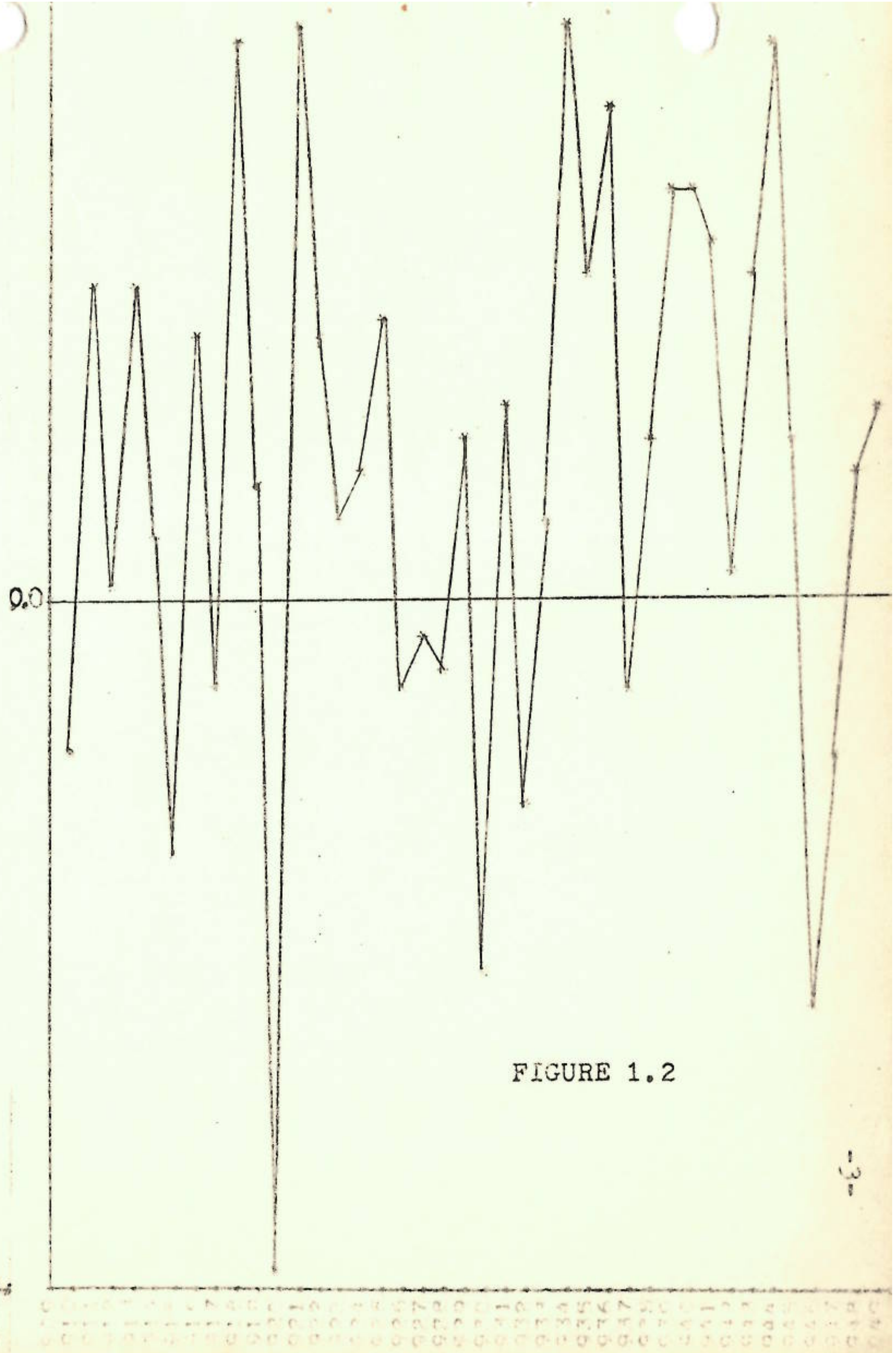


FIGURE 1.2

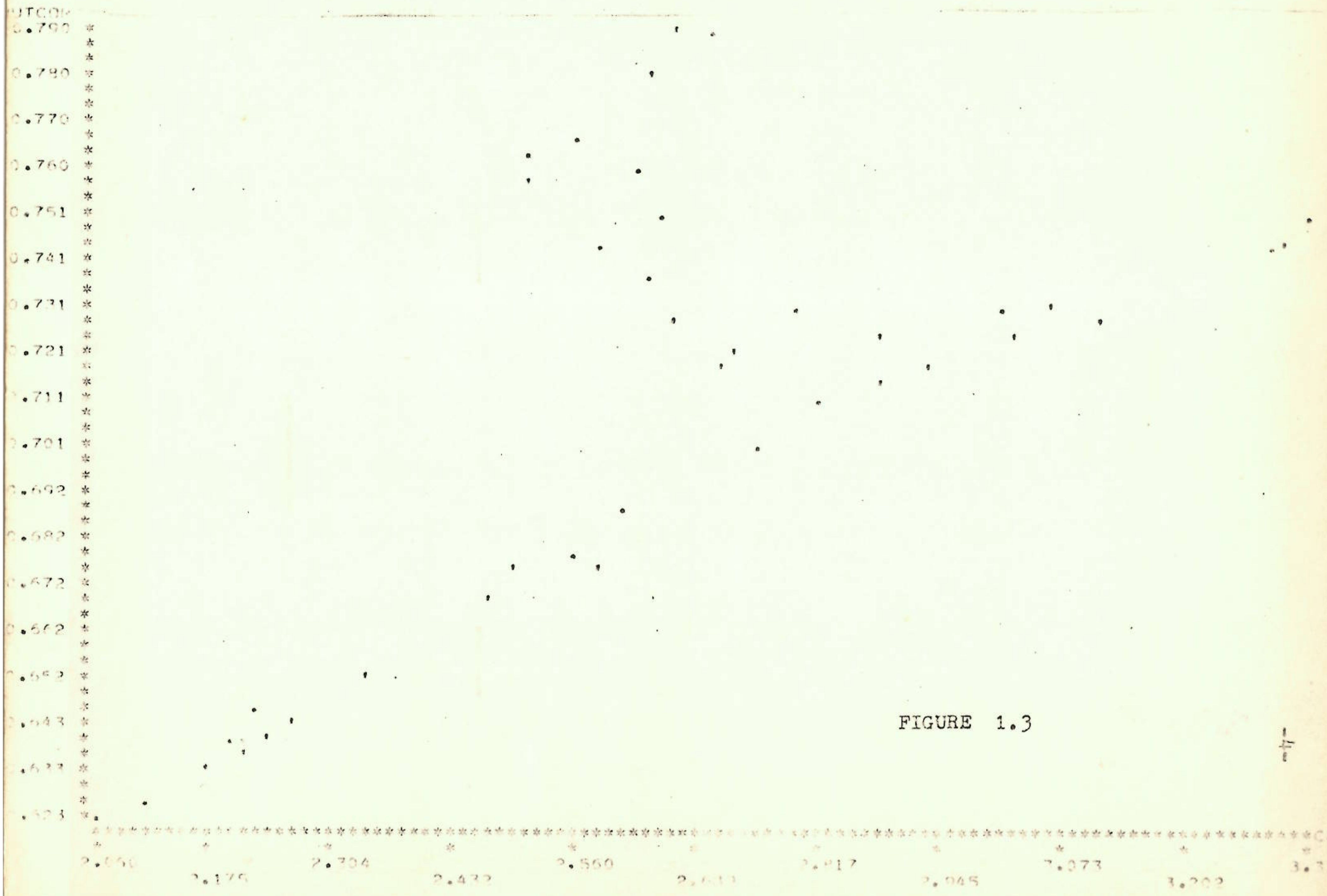


FIGURE 1.3

and related subjects..

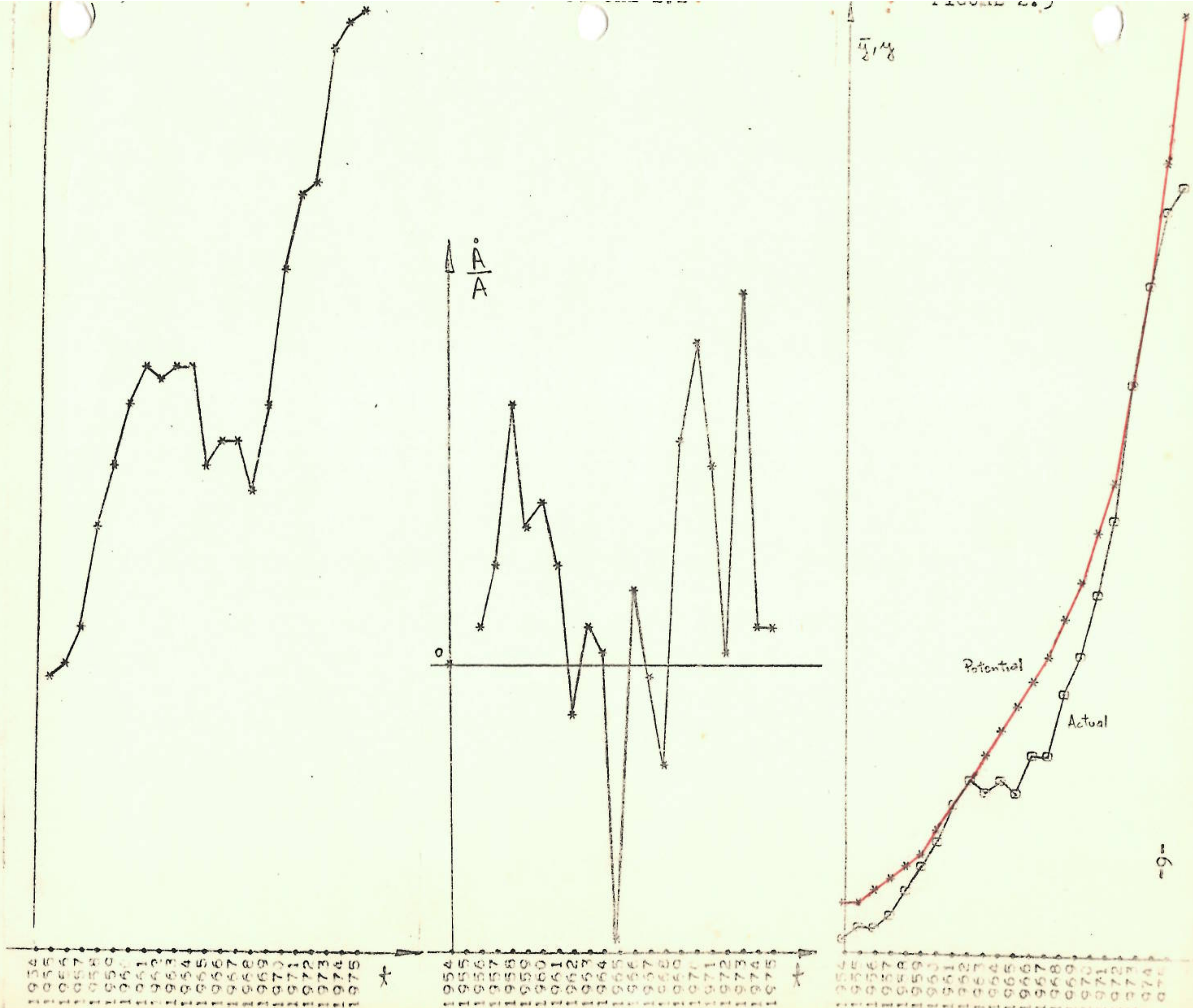
We will have the opportunity to touch on some of them, while presenting our exploration of brazilian data, on a search for informations which could be taken from them.

2- The Brazilian Manufacturing Sector and the "Residual"

We are going to make a rapid analysis on the period 1954-1975 of the brazilian behavior of gross output per capita in the manufacturing sector particularly emphasizing the role of technical progress and increase in productivity.

Using the same methodology as Solow, for the brazilian manufacturing industry for that period we have obtained the plots in figure 2.1 and 2.2 for the growth of productivity and the rate of growth of productivity, respectively. We have added an additional plot of potential and actual output for this period on figure 2.3.

We can therefore observe that from 1954 to 1961 the productivity has increased at 4.4% yearly rate, then slowing down - and even decreasing - during 1962 to 1967, when it decreased 2.7% a year, in a mean, followed by another period of productivity growth, from 1969 to 1975, when it sharply reached a rate of 10% a year, in a mean. At the same time, the capacity utilization that was around 80% in 1954 increased rapidly in the period 1954-1961 and in this latter year was some 98% of the installed capacity. Then we observe an increase in the idle capacity for the period 1962 to 1967, with a peak of 75% of capacity utilization in 1965. From 1968 on, this utilization was improved, until full capacity was achieved by 1972 and 1973. More recently, some signs of decreasing capacity utilization can be felt and the idle capacity, by the end of 1975 was already around 16%. The interesting feature was that from 1962 to 1967, we had increasing idle capacity, without having significant decrease in the real output. In fact, this idle capacity was the consequence of new investments rather than a fall in real



$\dot{A}/A$
0
t
$\bar{y}, y$
Potential
Actual
-6-

output. We will come back to this point later.

Our estimates indicate that some 46% of the growth in gross output per man-hour in the manufacturing industry, during the period 1954 to 1975 was attributable to increase in productivity. Watching more closely, we could see that during the period 1954 - 1961, 72% of this growth of output per-man-hour was explained by productivity increase while in the period 1968 - 1975, productivity was responsible for some 60% of that growth, all measured along Solow's method.

Calculating a "corrected output" as y/A and plotting it against k we obtain the graph in figure 2.4. The evident linearity cannot be surprising : as Hogan has stressed in a reviewing article (5) when the technical progress was assumed to be "neutral" (Harrod neutral) we implicitly have calculated A(t) in such a way that, provided that the relative factor shares remain constant, "the method would automatically produce a perfect Cobb-Douglas fit".

In y/A versus k this is traduced by a straight line. Hogan charges Solow for "not having grasped fully the implications of his model ", while the latter, accepting that his method is tautological, make efforts to show that "not all tautology is bad". (6)

However, there's an important assertion which Hogan has made: the evidence of neutral technical progress can hardly be thought conclusive. Therefore we must examine how well a Cobb-Douglas production function will fit our data, without the above "correction".

3- Fitting a Cobb-Douglas Production Function

Writing our production function as before, Y = F (K,L;t) and assuming now that it has the Cobb-Douglas form

$Y = A K^{\beta} L^{\alpha}$ (3.1) we can apply logarithms and obtain:

$\log Y = \log A + \beta \log K + \alpha \log L$ (3.2) which is the so-

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(5) W. P. Hogan "Technical Progress and Production Functions"- Review of Economic and Statistcs - November 1958 - pp 407 -11

(6) R. M. Solow -"Reply" - op cit. p. 411

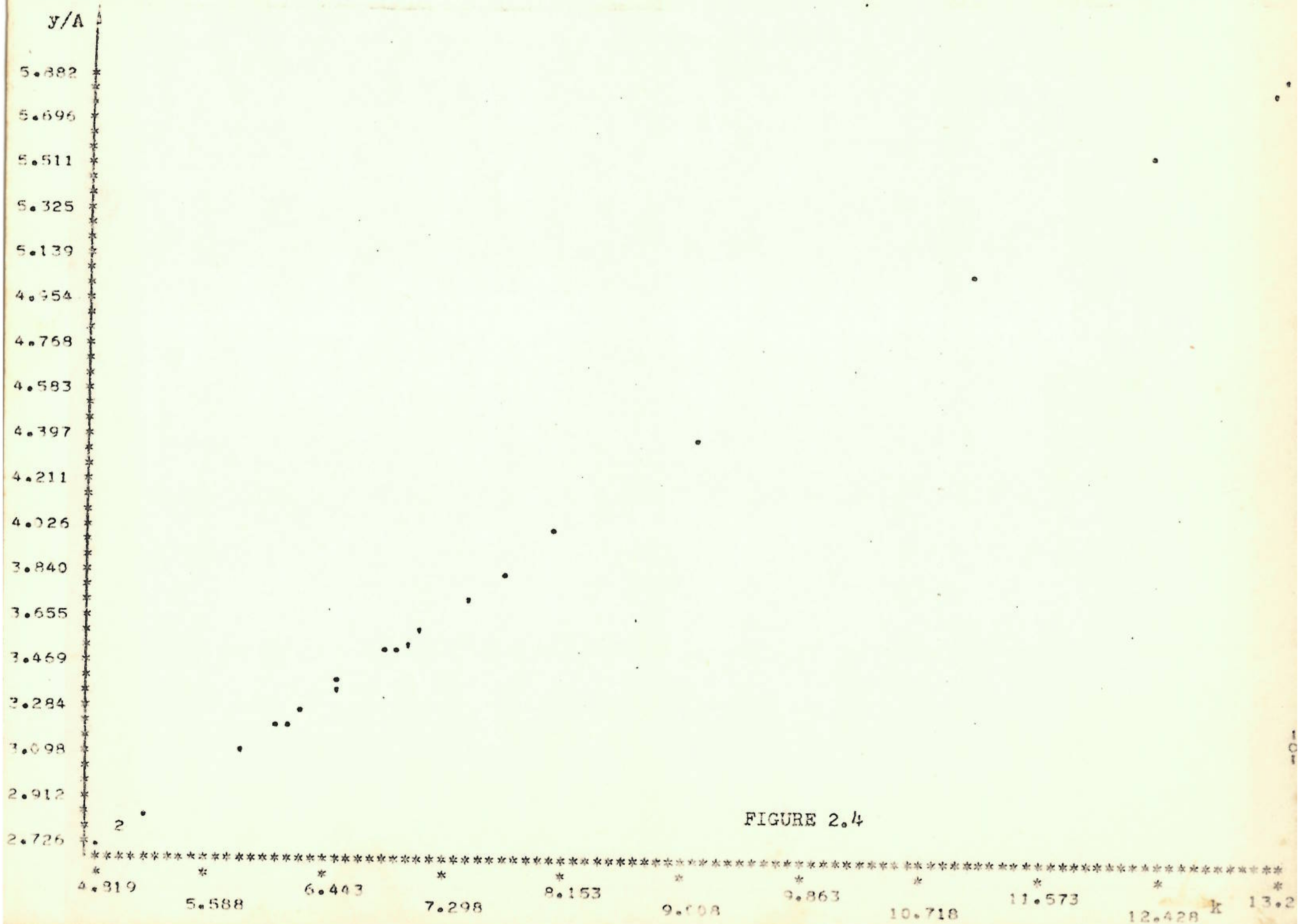
y/A
5.882
5.696
5.511
5.325
5.139
4.954
4.768
4.583
4.397
4.211
4.026
3.840
3.655
3.469
3.284
3.098
2.912
2.726
2
4.819
5.588
6.443
7.298
8.153
9.863
10.718
11.573
12.428
k
13.2

FIGURE 2.4

called unconstrained form for estimating econometrically a Cobb-Douglas production function (α and β are not forced to sum up to one).

If we want the constrained form (where $\alpha + \beta = 1$, and therefoe $\alpha = 1 - \beta$) we have $\log Y = \log A + \beta \log K + \log L - \beta \log L \Rightarrow$ $(\log Y - \log L) = \log A + \beta(\log K - \log L)$ or

$\log y = \log A + \beta \log k$ (3.3) with is the constrained form of estimating econometrically a Cobb-Douglas production function.

Our results are presented in table A.1 in the Appendix. (26 regressions)

We have used three different ways for measuring labor : in man-hours (as Solow), in total employment in manufacturing and in total wages in manufacturing (we denoted it respectively L, L* and W), but this was not an important factor for improving our results. In general we have obtained β's on the range of .875 to .910 for constrained estimation and β's slighly smaller from .780 to .880 for unconstrained estimation and their t-values were large enough to guarantee statistical significance on virtually any level of confidence. On the other hand, the values obtained for α were 5 out of 12 negatives and we could not reject that $\alpha = 0$ for 10 out of 12 estimations.

The introduction of exponential terms on time and half-of-squared-time as

$$\log Y = \log A + \gamma t + \varepsilon \left(\frac{t^2}{2} \right) + \beta \log K + \alpha \log L \qquad (3.4)$$

did not improve our results.

Autocorrelation, if present, was eliminated in all cases, and our values of R - squared were <u>never</u> below .99 .

If we now test the now-estimated share of capital (β) for significant coincidence with the observed values (our time-series wk, used for estimating the productivity curve), we will conclude that the hypothesis will be rejected in all but one case, just ~~an~~ an extremely low estimation for β .

Two conclusions can be drawn from this Cobb-Douglas-fitting exercise : a) The input labor, does not seem to have much importance for explaninig the growth of real output in the brazilian manufacturing industry in the period 1954 to 1975. b) The estimated share of capital is in flagrant conflict with its observed values.

Well, these two conclusions are enough to make us to doubt on the strong assumption's implicitly made when we use a Cobb-Douglas production function (constrained or not) for estimation, with the brazilian data. Solow's "corretion" should not be allowed in our case.

Let us see what else could be done...

4- The Returns to Scale

We have made implicitly the assumption of constant returns to scale when estimating the productivity A(t) along Solow's procedure. But if we do not have constant returns to scale, we would have our "residual" calculation affected, so that an increasing return would diminish the residual and a decreasing return would augment it.

Concerned with this problem, A.A. Walters (7) claims that "the american data discredit the hypothesis of constant returns to scale" and, finding increasing returns to scale estimating an uncosntrained Cobb-Douglas production function, concludes that Solow's residual should be 30% smaller than calculated.

Along his lines, let us test this hypothesis to brazilian case. Walters suggests that additionally to Solow's data we should also use data on gross capital and other ways of measuring labor. Denoting gross capital by K* and employment on manufacturing by L * we estimate :

$$\log Y = \log A + \gamma t + \beta \log K \text{ (or } K^*) + \alpha \log L \text{ (or } L^*)$$

(6 regressions)

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(7) A. A. Walters - "A Note on Economics of Scale" - Review of Economics and Statistics - November - 1963 - pp 425 -7

Our results are presented on table A.2 in the Appendix.

As we can see, our best results were obtained using net capital stock and both labor in man-hours or employment in manufacturing, after correction for autocorrelation. The regressions with gross capital (K*) were not significant at all, with time being the only significative variable.

Calculating Var $(\alpha+\beta)$ = Var (α) + var (β) + 2 Cov (α, β), it is possible to estimate the deviation for $\alpha + \beta$, its t-value and therefore to test for $\alpha + \beta = 1$ at a 95% confidence level. In our 3 significant regressions (Ia, Ib and b in table A2) we can reject the hypothesis that $\alpha + \beta \geq 1$, that is, we found that in the manufacturing sector we had decreasing returns to scale in the period 1954 - 1975.

Therefore, contrary to Walters conclusion for the american economy, we have underestimated our "residual" when we assumed constant returns. This means that we should increase our "residual" in some 18% on the values calculated in section 2.

5- Estimating the Elasticity of Substitution: The CES production function

Probably much of our problem could be hidden in the implicit assumption of elasticity of substitution (σ) equal to one, which we make when using a Cobb-Douglas production function. Let us then estimate this elasticity of substitution, trying to fit a CES and/or to calculate σ in a series of different ways.

As we know, the CES production function is given by

$$Y = \gamma\left[\delta K^{-\rho} + (1-\delta) L^{-\rho}\right]^{-\frac{\mu}{\rho}} \qquad (5.1) \quad \text{where } \sigma = \frac{1}{1+\rho},$$

and cannot be estimated by linear methods without making some simplifying assumptions.

a) When this production function was proposed for the first time (8),

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(8) K. Arrow, et. al., - "Capital - Labor Substitution and Economic Efficiency" - The Review of Economics and Statistics - August 1961 - pp 225 - 50

we were asked to assume that σ may estimated by

$$\log \frac{Y}{L} = \log C + \sigma \log W \qquad (5.2)$$

Estimating this equation, and correcting for autocorrelation we obtain the values stated in table A.3 in the Appendix (2 equations).

By this method we obtain a value for σ clearly greater than one, that is

$\sigma = 1.80$
(20.1) and

$\sigma = 1.75$
(18.5) after eliminating autocorrelation

We have, therefore, some evidence that the Cobb-Douglas production function is not a good guess.

b) An alternative possibility is to regress the logarithm of the capital-labor ratio on the logarithm of the price of labor, relative to price of capital as did Kendrick & Sato (9).

The results are presented in table A.4 and were very significant. After correction for autocorrelation we found $\sigma = 2.43$.
(57.2)

c) On the other line of approach, Richard Nelson, assuming that "technological advance is neutral" proposes to approximate the CES production function by:

$$\frac{\dot{Y}}{Y} = \frac{\dot{A}}{A} + \alpha \frac{\dot{L}}{L} + \beta \frac{\dot{K}}{K} + \alpha\beta \frac{\sigma - 1}{\sigma} \left[\frac{\dot{K}}{K} - \frac{\dot{L}}{L} \right]^2 \qquad (5.3)$$

Estimating this equation (results in table A.5) we find results completely not significatives for σ.

d) Again, trying to clarify which value should be attributed to the elasticity of substitution, we decided to try Kmenta method (10)

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(9) J. Kendrick & R. Sato "Factor Prices, Productivity and Economic Growth" - American Economic Review - December 1963 - pp 974

(10) J. Kmenta - "On Estimation of the CES Production Functions" - October 1964 - University of Wisconsin

$$\log Y = \log \gamma + (\mu \delta) \log \frac{K}{L} + \mu \log L + \rho \mu \frac{\delta (1 - \delta)}{2} \left[\log \frac{K}{L} \right]^2 \qquad (5.4)$$

We have estimated 6 equations and the results are presented in table A.6 in the Appendix. Although our results seem to have been too much variant (we have obtained 3 values greater and 3 values smaller than one) the values greater than one seem to be more reliable, since their t-values are quite high. Particularly the result of (Ia) = σ = 1.46, the better, could give us some more evidence for suggesting that the elasticity of substitution is greater than one.

e) Finally we estimated a CES by iterative non-linear methods and found, for different initial conditions the results:

σ_1 = .936 (.633)*

σ_2 = 2.000 (1.59)* none of them very significant

σ_3 = 2.76 (.362)*

We found ourselves facing a very interesting situation: the CES production function seems not to fit our data, or conversely, when it does, the results are not significant.

It should be remembered now that CES might have a bias in its assumption of constant elasticity of substitution: in fact we can be attributing some changes in the factor proportions to change in technology when we make this assumption.

We can provide a test for the constancy of the elasticity of substitution along: (11)

$$\log \frac{Y}{L} = \log a + b \log \frac{W}{P} + c \log \frac{K}{L} \qquad (5.4)$$

If we can reject that c = 0 we could say that the elasticity of substitution is not constant.

In fact, as the results of our regressions show in table A.7, we can reject that c = 0 virtually at any level of confidence. By ordinary least squares estimation we have obtained c = .884, t-value = 64.4 . After correcting for autocorrelation the new value was c = .885, , t-value = 133.

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(11) M. Nadiri - "Some Approaches to the Theory and Measurement of Total Factor Productivity : A Survey " - Journal of Economic Literature- p. 1157

We could proceed, estimating a new class of production functions : the VES (variable elasticity of substitution), but it would be almost worthless for our purpose. Nadiri expresses himself saying that "the whole empirical evidence on the validity of the VES functions is still very limited". Avoid taking steps larger than our legs is now necessary. We still know little about the "residual" found in section 2 .

6- Bias in Technical Change : Estimating the Elasticity of Substitution Without Capital Stock Data

"The residual has been treated as a consequence of the mismeasurement of the inputs. (...) As this approach is currently being pursued, the object of the game is to make the offending residual disappear by contriving new measures of the growth of labor and capital inputs". This disenchanted claim is made by Paul David and Th. Van de Klundert (12) arguing that all the studies that deal with neoclassical production function assume neutral technical progress, when probably more light could be thrown on the "residual" if we did not make that assumption.

Allowing for the technical progress to be non-neutral they advance a method for estimating the elasticity of substitution, without capital stock data, along:

$$\ln wl = \ln C + (1 - \sigma) \ln W + \lambda_L (\sigma - 1) t \quad (6.1)$$

where ωl is the share of labor in the product.

λ_L is the rate of growth of labor efficiency.

Our estimates for σ (presented in Table A.8) were

$\sigma = 1.074 \quad (3.32)$

$\sigma = 1.067 \quad (2.43)$

and interesting we cannot reject that $\sigma = 1$ at a 95% confidence level. The rate of growth of labor efficiency were found to be not significantly different from zero.

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(12) P. A. David & Th. Van de Klundert - "Biased Efficiency Growth and Capital - Labor Substitution in the U.S., 1899 - 1960 - The American Economic Review - June 1965 - pp 357 - 94

Therefore, we were not able yet to determine the bias, if any, of the technical progress. Something completely different should be tried ...

7- A Broader Classification of Exogenous Technical Progress

Up to now, much of our difficulties throughout this paper seems to come from the hidden assumptions which are made when we addopt a particular type of production function. Therefore we should look for a way to relax some of the assumptions, specially the assumption in "neutrality" (Harrod-neutrality) to allow for non-neutral technical change.

In a paper released in March 1969, Martin Beckmann and Ryuzo Sato (13) put the question in the following way: "the problems of specification of the form of a production function and the form of technical progress are not indpendent, for some forms of a production function necessarily preclude some types of technical progress".

Looking for other principles of invariance, B & S add : "We have generalized the concept of technical neutrality by formulating and extending this principle of invariance to all other relationships between variables : a technical progress is neutral in some sense when the relationship in which a certain economic variable stands to some other variable remains unchanged through time, that is, through technical progress".

Concluding that the direct estimation of the (new) production functions then defined would be more difficult because of nonlinearity and the additional problem of estimating the constants of integration, they decide to estimate directly the "principles of invariance".

Those principles, expressed both in linear and logarithmic form were defined to be:

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(13) M. J. Beckmann & R. Sato -"Aggregate Production Functions and Types of Technical Progress; A Statistical Analysis"- The American Economic Review - March 1969 - pp 88-101

I - Hicks	$\left(\frac{r}{W}\right) = a + b \left(\frac{L}{K}\right)$	(7.1a)	$\log \left(\frac{r}{W}\right) = \log a + b \log \left(\frac{L}{K}\right)$	(7.1b)
II - Harrod	$r = a + b \left(\frac{Y}{K}\right)$	(7.2a)	$\log r = \log a + b \log \left(\frac{Y}{K}\right)$	(7.2b)
III - Solow	$W = a + b \left(\frac{Y}{L}\right)$	(7.3a)	$\log W = \log a + b \log \left(\frac{Y}{L}\right)$	(7.3b)
IV - Labor Combining	$W = a + b \left(\frac{Y}{K}\right)$	(7.4a)	$\log W = \log a + b\ \mathrm{lof} \left(\frac{Y}{K}\right)$	(7.4b)
V - CAPITAL COMBINING ~~Labor Decreasing~~	$r = a + b \left(\frac{Y}{L}\right)$	(7.5a)	$\log r = \log a + b \log \left(\frac{Y}{L}\right)$	(7.5b)
VI - Labor Decreasing	$\left(\frac{r}{W}\right) = a + b \left(\frac{Y}{K}\right)$	(7.6a)	$\log \left(\frac{r}{W}\right) = \log a\ b \log \left(\frac{Y}{K}\right)$	(7.6b)
VII - Capital Decreasing	$\left(\frac{r}{W}\right) = a + b \left(\frac{Y}{L}\right)$	(7.7a)	$\log \left(\frac{r}{W}\right) = \log a + b \log \left(\frac{Y}{L}\right)$	(7.7b)
VIII - Capital Additive	$w = a + b \left(\frac{L}{K}\right)$	(7.8a)	$\log W = \log a + b \log \left(\frac{L}{K}\right)$	(7.8b)
IX - Labor Additive	$r = a + b \left(\frac{K}{L}\right)$	(7.9a)	$\log r = \log a + b \log \left(\frac{K}{L}\right)$	(7.9b)

We could guess also the variable time into these principles-

Our estimates for these "principles of invariance are presented in TABLE A.9. (36 regressions)

Those results could be summarized by paying attention on how did the several principles perform for each established relation:

Linear Regression No Time Variable			Linear Regression Time Variable Included			Log-Linear Regression No Time Variable			Log-Linear Regression Time Variable Included		
Rank	Type	R^2	Rank	Type	R^2	Rank	Type	R^2	Rank	Type	R^2
1	IX	.937	1	III	.977	1	I	.953	1	IX	.993
2	V	.930	2	VIII	.957	2	V	.945	2	V	.990
3	VII	.919	3	IV	.954	3	IX	.941	3	II	.972
4	VI	.771	4	IX	.938	4	VII	.939	4	I	.959
5	I	.747	5	VII	.933	5	VI	.843	5	IV	.949
6	II	.739	6	V	.931	6	II	.698	6	VIII	.948
7	VIII	.559	7	II	.850	7	III	.523	7	VII	.946
8	III	.467	8	VI	.812	8	VIII	.500	8	III	.944
9	IV	.267	9	I	.747	9	IV	.232	9	VI	.902

In general, if we take a mean of the R-squared we could rank the principles of invariance as:

1) IX - Labor-Additive = .952
2) V - Capital-Combining = .949
3) VII - Capital-Decreasing = .934
4) I - Hicks = . 852
5) VI - Labor-Decreasing = .832
6) II - Harrod = .815
7) III - Solow = .728
8) VIII - Capital-Additive = .741
9) IV - Labor-Combining = .601

We can see then how misleading it was being to assume that technical progress in brazilian manufacturing industries was Harrod-neutral in the period 1954-1975. Contrary to Beckmann & Sato estimation for the U.S and Japan, in our results Harrod-neutraly has poorly ranked 6th among 9. The reason why we have opted for a mean index of R-squared was because the inclusion of the variable time on the regressions, although improving the results in all occasions, did improve the worst ones much more than the best ones.. As regularly one includes and excludes the time variable when analysing a model, the natural way of ranking seems to be by the average performance.

Curiously, we can observe that the 3 best principles of invariance state that:
a) the returns to capital remain in constant ratio (or constant log-ratio) to the capital-labor ratio through time, that is, through technical progress. b) the second-best, states that the returns to capital remain in constant ratio (or log-ratio) to the output-labor ratio through time. c) the third-best states that the cost-of-factors-ratio (r/w) remain in constant ratio to the output-labor ratio. These principles are very similar in essence, since they state that, as we had had a process of capital deepening in the period, with increasing output-labor ratio, the return per unit of capital had increased parallelly. Although meaning somewhat different things, these three principles are quite compatible and amount to a general increase in the returns to capital during the period 1954-1975.

Correspondently, the three worst principles, were exactly the ones which could be thought as the opposite situation of the stated above. Therefore, we seem to have evidence enough for saying that:
a) It is not advisable to assume that the technical progress was Harrod-neutral in the period 1954-1975 as is implicitly assumed when we use neoclassical aggregate production functions as Cobb-Douglas and CES. b) it is suggested that the process of import substitution in the manufacturing industry in Brazil, in the late 50' and the so-called "miracle" of late 60' and early 70' has brought about, coupled with a capital-deepening process and an increase in the output-labor ratio, a parallel increase in the returns to capital.

8- Testing the Embodiment Hypothesis and Induced Technical Change

We should therefore try to test the embodiment hypothesis, so that we could find any more objective explanation for technical progress. Trying to relate bouts of investment with the average "quality of capital", Massel has tested a model for determining the interaction between investment and technical change. (14) Calling InA(t) the induced technical change in time t, and assuming that it depends on a lagged series of investments (now consideres as sources of improvement of capital, therefore meriting dating), we can establish - after an application of Koyck transformation to the distributed lag equation - to:

$$\ln A(t) = C_{\circ} + \gamma t + \alpha \ln A(t-1) + \beta I(t-1) \qquad (8.1)$$

Estimating this equation (results on table A.10) we find significant coefficients for the investment term and non-significant coefficients for time (here representing some "residual" exogenous technical progress). Therefore we have indications - contrary to Massel's conclusions for the U.S. economy - that the embodiment hypothesis does seem to hold for the brazilian manufacturing industry in the period 1954-1975.

9- Is there Any Endogenous Technical Progress Function in Brazilian Manufacturing?

At this point, it would be good to see what can be said about the evidences on the existence of an "endogenous technical progress function" for brazilian manufacturing in the analysed period.

Following in general, the lines layed by Edward Chen (15) let us test initially Arrow's learning-by-doing hypothesis (16).

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(14) B. F. Massel -"Is investment Really Unimportant?" Metroeconomia-1962

(15) E. K. Chen - "The Empirical Relevance of the Endogenous Technical Progress Function" - Kyklos - Vol 29 - 1976 - pp 256 -71

(16) Arrow K. J. "The Economic Implications of Learning by Doing" - Review of Economic Studies - June 1962 - pp. 155 -73

We could express Arrow's technical progress function as :

$A(t) = A_o . e^{\gamma t} E(t)^c$ (9.1), where $E(t)$ is an index of experience and c is the learning coefficient and $e^{\gamma t}$ stands for exogenous technical progress.

The results of our estimations are presented in TABLE A.11 (6 regressions). We have used as indeces of experience cumulative gross investment (as Arrow does) and alternatively cumulative gross output. We still follow Chen, recalling a Cobb-Douglas production function for these estimations.

We could not find significant coefficients for the experience index, whether taking it as cumulative output or cumulative investment although our statistical fits show high R-squared. For Brazil (as for the asian countries which Chen has analysed) the learning by doing hypothesis seems to be unimportant as an explanation of technical progress.

Next, we will test some endogenous technical progress hypothesis, as advanced by Kaldor (17), Kaldor and Mirrlees (18) and Eltis (19). In each case we have tested also the effects of import of capital goods (as proportion of total imports) and foreign investment.

To begin with, let us express Kaldor hypothesis for estimation purposes as:

$$\ln Y/L = C + \beta \ln K/L + \gamma t + \varepsilon(\dot{k})t \quad (9.2)$$

, Kaldor-Mirrlees Hypothesis as :

$$\ln Y/L = C + \beta \ln K/L + \gamma t + \varepsilon(I/L)t \quad (9.3)$$

, and Eltis hypothesis as:

$$\ln Y/L = C + \beta \ln K/L + \gamma t + \varepsilon(I/Y)t \quad (9.4)$$

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(17) N. Kaldor - "A Model of Economic Growth" - Economic Journal - December 1957

(18) N. Kaldor & Mirrlees:"A New Model of Economic Growth" - Review of Economic Studies - June 1962

(19) W. Eltis -"The Determination of the Rate of Technical Progress" Economic Journal - September 1971

The results obtained are presented respectivelly in tables A.12 (9regressions), A.13 (8 regressions) and A.14 (8 regressions)

In all of these 25 regressions we did not succeed to find any significant coefficient for the endogenous technical progress, whether along Kaldor, Kaldor-Mirrlees or Eltis hypothesis.

On the other hand, the coefficient of the time variable (here again meaning an exogenous technical progress component) is always significantly different from zero.

The introduction of terms representing proportion of capital goods on imports and foreign investment did not alter this situation very much, even because these terms failed to present any significant coefficient.

Of course these conclusions are somewhat biased by our assumption of Cobb-Douglas aggregate production function which, as we have seen, is not proper for brazilian manufacturing data. Even so, it is noted that the endogenous technical progress function, whether tested along Arrow's learning-by-doing hypothesis or Kaldor, Kaldor-Mirrlees or Eltis hypothesis seems not to conform with the brazilian experience, contrary to some of the fidings of Chen for Japan, Taiwan, Korea, Singapore and Hong-Kong.

10- Conclusions

Several conclusions could be drawn after our explorative survey aiming to explain technical progress in Brazil. We could resume them in the following way:

a) Although Solow's "residual" calculated in section 2 seems to be much smaller than Sollow's estimates for U.S. economy (20) the

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(20) In fact, if we take into consideration J. Levine's ("A Small Problem in the Analysis of Growth" - Review of Economics and Statistics- May 1960 - pp 225 -8) and B. Massel's ("Another Small Problem in the Analysis of Growth" - Review of Economics and Statistics - August 1962 - pp 330-2) objections to Solow's work, concerning on how to transform in a sum a multiplicative relation of factors, we would find for the brazilian case that the "residual" would be reduced to just 20% of total growth..

fact that we have estimated decreasing returns to scale on section 4 should make it somewhat greater..

b) Being more precise, even conclusion (a) could be of limited confidence, if we take in consideration the more striking conclusions of sections 5 and 6 , where we found that not only is the elasticity of substitution significantly different from 1 but it is also variable through time.

c) More important, indeed, is the conclusion of section 7: for the brazilian case, the rate of returns to capital seems to follow the capital-deepening process, denying validity for the implicit assumption of Harrod-neutral technical progress, and consequently, denying validity for the application of Cobb-Douglas and CES production functions.

d) There's some evidence that, although the embodiment hypothesis hold, the learning-by-doing and endogenous technical progress hypothesis do not.

e) Summing up, and turning out to be somewhat more concrete: the rapid growth that brazilian manufacturing industry has experienced in the last 20 years seems to be strongly linked to technical progress. We can distinguish two bouts : one, during Kubistchek government (1955-1960) when we have observed the first massive penetration of foreign capital which corresponds to the first phase of imports substitution; the second, after the military coup, when the "economy-opening" policies has attracted new foreign investment and technology. It must be understood that in these two periods, with a difference of degree (conditioned by non-economic variables as "security", social unrest and political stability) these bouts were obtained to a large extent by the implementation of advanced technology (penultimate technology - in relation to industrialized nations - in the 1st period, reaching even the ultimate technology in the second) and wage compression, more evident from 1965 on. We should pay attention also, although not overemphasizing, to figure 2.3 where we see during Quadros and Goulart governments (1961-1964) this new technology although not applied, was also bought, leading to an increasing idle capacity which has eventually been used for manufacturing skyrocketting indeces of growth during the "miracle" period (1968-1974).

Another important fact: our estimations suggest that it is time to avoid the endless claim that brazilian labor has low productivity when compared to industrialized countries, just because, a Cobb-Douglas production function leads to low estimates of output-labor elasticity, giving very high R-squared in its fits. This procedure, more than just naïve, should be understood as politically - and ideologically - dangerous.

To finalize, we think that it is time also to face the sad reality : the brazilian miracle has came to an end. The period of easy profits from new technology introduction has finished. The firms are now facing new cost curves and technology imports are a heavy burden for them. The apologetical works along the neoclassical tradition, estimating Cobb-Douglas and CES production functions as a religion, unfortunately are of no help -albeit having its political functions - for making us aware of the real nature of the "miracle".

COBB-DOUGLAS PRODUCTION FUNCTIONS

L is measured in man-hours, W in total wages, L* in labor force in manufacturing.
Numbers between parentheses are t-values. An asterisk means that it is not significant at 95% C.L.

Inputs	Specification	ρ	D-W	R^2	$\beta \log K$ or $\beta \log k$	$\alpha \log L$ or $\alpha \log L^*$ or $\alpha \log W$	γt	$\varepsilon \left(\frac{t^2}{2}\right)$
K L	Constrained	—	1.26	.997	.906 (84.9)	—	—	—
K L	Constrained + autocorr.	.048 (.22)*	2.33	.999	.893 (158)	—	—	—
K L	Constrained	—	1.41	.999	.875 (44.4)	—	.0017 ([illegible])	—
K L	Constrained + autocorr.	.20 (.935)*	2.68	.999	.877 (69.9)	—	.00074 (1.18)*	—
K L	Constrained	—	1.70	.998	.895 (44.4)	—	.0052 (2.85)	-.00037 (-2.16)
K L	Constrained + autocorr.	-.049 (-.223)*	2.52	.999	.880 (83.0)	—	.0013 (1.22)*	$-.4 \times 10^{-4}$ (-.40)*
K L*	Constrained	—	1.17	.997	.910 (83.9)	—	—	—
K L*	Constrained + autocorr.	.100 (.462)*	2.38	.999	.894 (150.0)	—	—	—
K L*	Constrained	—	1.28	.997	.879 (42.5)	—	.0017 ([illegible])	—
K L*	Constrained + autocorr.	.035 (.16)*	2.57	.999	.878 (88.2)	—	.0010 (1.98)	—
K W	Constrained	—	1.85	.998	.896 (63.7)	—	.0007 (1.06)*	—
K W	Constrained + autocorr.	.20 (.935)*	1.99	.999	.909 (64.5)	—	-.0004 (-.507)*	—
K W	Constrained	—	1.87	.998	.893 (43.3)	—	-.0017 (-.14)*	$.45 \times 10^{-4}$ (.21)*
K W	Constrained + autocorr.	-.030 (-.140)*	2.42	.999	.882 (70.4)	—	-.019 (-2.45)	$.35 \times 10^{-3}$ (2.45)
K L	Unconstrained	—	1.66	.999	.785 (22.3)	-.081 (-1.11)*	.019 (3.16)	—
K L	Unconstrained + autocorr.	.200 (.935)*	2.62	.999	.840 (34.9)	.037 (.74)*	.008 (1.93)	—
K L	Unconstrained	—	1.81	.999	.813 (21.5)	-.064 (-.90)*	.019 (3.04)	$-.26 \times 10^{-3}$ (-1.15)*
K L	Unconstrained + autocorr.	-.097 (-.444)*	2.46	.999	.840 (41.1)	.030 (.74)*	.009 (2.6)	$-.3 \times 10^{-4}$ (-.34)*
K L*	Unconstrained	—	1.26	.999	.893 (53.4)	.129 (3.99)	—	—
K L*	Unconstrained + autocorr.	.050 (.23)*	2.57	.999	.885 (103)	.129 (8.24)	—	—
K L*	Unconstrained	—	1.77	.999	.781 (24.6)	-.098 (-1.55)*	.023 (3.88)	—
K L*	Unconstrained + autocorr.	-.070 (-.32)*	2.46	.999	.835 (46.62)	.023 (.634)*	.009 (3.04)	—
K W	Unconstrained	—	1.73	.999	.842 (27.1)	.044 (1.30)*	-.008 (2.06)	—
K W	Unconstrained + autocorr.	.200 (.935)*	2.51	.999	.826 (39.5)	-.002 (-.10)*	-.011 (4.24)	—
K W	Unconstrained	—	1.78	.999	.837 (26.9)	-.005 (-.09)*	.028 (1.66)*	-.0003 (-1.4)*
K W	Unconstrained + autocorr.	-.107 (-.495)*	2.35	.999	.832 (51.5)	.010 (.35)*	.010 (1.03)*	$.8 \times 10^{-5}$ (.056)*

TABLE A.1

	WALTERS RETURNS TO SCALE		ρ	D-W	R^2	γT	β (log K or K*)	α (log L or L*)	$\alpha + \beta$
Ia	K L	OLSQ	—	1.66	.999	.194 (3.16)	.785 (22.3)	−.084 (−1.14) *	.701 (6.8)
Ib	K L	Autocorrelation	−.080 (−.37)*	2.48	.999	.809 (.261) *	.838 (44.6)	.031 (.767) *	.869 (19.7)
IIa	K* L	OLSQ	—	1.21	.989	.107 (3.66)	.334 (1.41) *	−1.08 (−3.61)	−.746 (−1.57) *
IIb	K* L	Autocorrelation	.156 (4.45)	1.64	.991	.038 (.654) *	.625 (1.34) *	−.205 (−.473) *	.420 (.53) *
IIIa	K L*	OLSQ	—	1.77	.999	.020 (3.38)	.781 (24.6)	−.098 (−1.55) *	.683 (1.27) *
IIIb	K L*	Autocorrelation	−.070 (−.325)*	2.46	.999	.809 (3.04)	.835 (46.6)	.023 (.634) *	.858 (16.5)

TABLE A.2

	ACMS CES P.F. – σ ESTIMATION log k = log Θ + σ log w	σ	R^2	D-W
I	OLSQ	1.80 (20.1)	.950	1.10
Ia	Autocorrelation	1.75 (18.5)	.967	2.20

TABLE A.3

	KENDRICK & SATO σ ESTIMATION	σ	ε	ρ	DW	R^2
I	OLSQ	2.49 (85.0)	−.55 (−20.1)	—	.897	.953
Ia	Autocorrelation	2.43 (57.2)	−.46 (−11.5)	.650 ([illegible])	2.11	.975

TABLE A.4

	NELSON	ρ	D-W	R^2	β $\dot{K}/K$	α $\dot{L}/L$	$\alpha\beta\frac{(1-\sigma)}{\sigma}[\dot{K}/K - \dot{L}/L]^2$
I	OLSQ	—	1.89	.944	.839 (15.9)	−.111 (−1.05) *	−.717 (−1.52)
Ia	Autocorrelation	−.221 (−1.01)*	2.71	.981	.845 (26.2)	−.029 (−.46) *	−.350 (−1.20)

TABLE A.5

	KMENTA σ ESTIMATION	σ	D-W	R^2	εt	$(\nu\delta)\log(K/L)$	$\nu \log L$	$\rho\nu\delta\frac{(1-\delta)}{2}[\log K/L]^2$
I	OLSQ	6.5	1.59	.999	—	1.14 (8.04)	1.02 (64.1)	-.0578 (-1.76)
Ia	Autocorrelation	1.46	2.51	.999	—	.93 (12.5)	1.01 (130)	-.0114 (-.658) *
II	OLSQ	8.7	1.59	.998	.0013 (1.38) *	1.11 (7.9)		-.054 (-1.63) *
III	OLSQ	.	1.22	.999	.018 (3.02)	.985 (7.7)	-.28 (-2.83)	-.045 (-1.63) *
IV	OLSQ	.802	1.86	.998	.0008 (1.10) *	.835 (6.56)		.017 (.476) *
V	OLSQ	.	1.73	.999	.0083 (1.94)	.847 (7.02)	-.114 (-1.78)	-.0013 (-.038) *

TABLE A.6

	TEST OF CONSTANCY OF THE ELASTICITY OF SUBSTITUTION	$b \log\left(\frac{W}{P}\right)$	$c \log\left(\frac{K}{L}\right)$	ρ	d	R^2
I	OLSQ	.029 (2.27)	.834 (64.4)	—	1.55	.998
Ia	Autocorrelation	.013 (1.99)	.835 (133)	-.049 (-.237) *	2.54	.999

TABLE A.7

	DAVID & VAN DE KLUNDERT σ ESTIMATION FOR NON-NEUTRAL TECHNICAL PROGRESS	D-W	R^2	$(1-\sigma)\ln W$	$\lambda_L(\sigma-1)t$	σ	λ_L
I	OLSQ	1.29	.816	-.074 (-3.32)	.00054 (.482) *	1.074 (3.32)	.007 (.33) *
Ia	Autocorrelation	1.64	.829	-.067 (-2.43)	.00006 (.046) *	1.067 (2.43)	.0009 (.03) *

TABLE A.8

a1 = linear, no time variable | b1 = logarithmic, no time variable
a2 = linear plus time variable | b2 = logarithmic plus time variable

	BECKMANN & SATO		b	t	R^2
I a1	OLSQ -	Harrod	-7.11 (-7.07)		.747
I a2	OLSQ -	Harrod	-7.95 (-3.83)	-.0023 (-.198)*	.747
I b1	OLSQ -	Harrod	-1.72 (-20.1)		.958
I b2	OLSQ -	Harrod	-1.75 (-12.1)	-.012 (1.62)*	.959
II a1	OLSQ -	Hicks	-220.4 (-7.5)		.739
II a2	OLSQ -	Hicks	-142.2 (-4.6)	.328 (3.76)	.850
II b1	OLSQ -	Hicks	-20.3 (-6.8)		.698
II b2	OLSQ -	Hicks	-8.66 (-6.8)	.085 (13.6)	.972
III a1	OLSQ -	Solow	1.51 (4.19)		.467
III a2	OLSQ -	Solow	-.956 (-6.67)	.595 (20.4)	.977
III b1	OLSQ -	Solow	.854 (4.68)		.523
III b2	OLSQ -	Solow	-.488 (-3.79)	.066 (11.9)	.944
IV a1	OLSQ -	L - Continuing	-81.9 (-2.7)		.267
IV a2	OLSQ -	L - Continuing	38.32 (3.6)	.504 (16.9)	.954
IV b1	OLSQ -	L - Continuing	-4.90 (-2.5)		.232
IV b2	OLSQ -	L - Continuing	2.99 (4.19)	.058 (16.4)	.949
V a1	OLSQ -	K - Continuing	+3.45 (16.4)		.930
V a2	OLSQ -	K - Continuing	3.30 (8.3)	.034 (.42)*	.931
V b1	OLSQ -	K - Continuing	2.74 (18.5)		.945
V b2	OLSQ -	K - Continuing	1.68 (13.2)	.052 (9.5)	.990
VI a1	OLSQ -	L - Decreasing	-15.7 (-8.2)		.771
VI a2	OLSQ -	L - Decreasing	-12.3 (-5.1)	.014 (2.05)	.812
VI b1	OLSQ -	L - Decreasing	-15.4 (-10.3)		.843
VI b2	OLSQ -	L - Decreasing	-11.7 (-7.14)	.028 (3.40)	.902
VII a1	OLSQ -	K - Decreasing	.239 (15.1)		.919
VII a2	OLSQ -	K - Decreasing	.285 (10.4)	-.011 (-2.03)	.933
VII b1	OLSQ -	K - Decreasing	1.88 (17.6)		.939
VII b2	OLSQ -	K - Decreasing	2.17 (10.4)	-.142 (-1.59)*	.946
VIII a1	OLSQ -	K - Additive	-54.7 (-5.03)		.559
VIII a2	OLSQ -	K - Additive	27.7 (3.88)	.579 (13.3)	.957
VIII b1	OLSQ -	K - Additive	-.757 (-4.47)		.500
VIII b2	OLSQ -	K - Additive	.446 (4.06)	.066 (12.8)	.948
IX a1	OLSQ -	L - Additive	1.76 (17.2)		.937
IX a2	OLSQ -	L - Additive	1.65 (8.89)	.054 (.729)*	.938
IX b1	OLSQ -	L - Additive	2.48 (17.8)		.941
IX b2	OLSQ -	L - Additive	1.50 (15.4)	.054 (11.7)	.993

TABLE A.9

MASSEL — TEST OF EMBODIMENT

		γt	$\alpha \cdot \ln A(t-1)$	$\beta \cdot I(t-1)$	ρ	D-W	R^2
I	OLSQ	.004 (.809)*	.462 (3.51)	.0037 (3.02)	—	1.52	.930
Ia	Autocorrelation	.007 (.257)*	-.0950 (-.429)*	.0066 (2.44)	.702 (4.4)	1.63	.934

TABLE A.10

ARROW'S LEARNING BY DOING HYPOTHESIS

		D-W	R^2	$\ln K/L$	t	ΣI	ΣY
I	OLSQ	1.42	.998	.972 (13.2)	.005 (2.00)	-.648 (-1.63)*	—
Ia	Autocorrelation	2.57	.999	.894 (24.3)	.0015 (1.10)*	-.109 (-.461)*	—
Ib	OLSQ	1.38	.997	.856 (19.7)	—	.020 (1.19)*	—
II	OLSQ	1.62	.998	.907 (37.3)	.0096 (2.55)	—	-.110 (-1.98)
IIa	Autocorrelation	2.51	.999	.882 (68.9)	.0021 (.034)*	—	-.147 (-.465)*
IIb	OLSQ	1.34	.998	.878 (37.6)	—	—	.012 (1.36)*

TABLE A.11

KALDOR — ENDOGENOUS TECH. PROGRESS

		D-W	R^2	$\ln K/L$	t	$\dot{k}/k$ or $\dot{k}$	(CG) or FI: Cap. Goods or Fixed Inv.
— I	OLSQ	1.36	.998	.883 (44.1)	.0017 (1.29)	-.438 (-1.13)*	—
— Ia	Autocorrelation	2.47	.999	.880 (89.3)	.0009 (2.06)	-.111 (-.706)*	—
CG II	OLSQ	1.51	.998	.878 (43.7)	.0023 (2.30)	-.0065 (-1.81)	.921 (1.29)*
CG IIa	Autocorrelation	2.47	.999	.880 (85.3)	.0009 (1.16)*	-.001 (-.513)*	$-.1\times10^{-4}$ (.011)*
FI III	OLSQ	1.45	.998	.894 (31.3)	[illegible] (1.70)	-.005 (-1.46)*	-10^{-5} (-.547)*
FI IIIa	Autocorrelation	2.45	.999	.878 (60.7)	.0010 (1.99)	-.001 (-.65)*	-2×10^{-6} (-.161)*
— IV	OLSQ	1.17	.998	.915 (75.2)	—	-.004 (-1.34)*	—
— IVa	Autocorrelation	2.50	.999	.903 (80.0)	—	-.001 (.83)*	—
— V	OLSQ without time term	1.42	.999	.900 (160)	—	-.059 (-7.42)*	—

TABLE A.12

	KALDOR – MIRRLEES ENDOG. TECHNICAL PROGRESS	D-W	R^2	ln K/L	t	$(\dot{I/L})$	CG or FI Cap. Goods or For. Inv.
— I	OLSQ	1.45	.998	.886 (40.8)	.0017 (1.83)	-.245 (-1.16) *	
— Ia	Autocorrelation	1.54	.999	.879 (83.4)	.0009 (2.04)	-.332 (-.310) *	
CG II	OLSQ	1.50	.998	.883 (39.1)	.0020 (1.71)	-.003 (-1.25) *	.432 (.638) *
CG IIa	Autocorrelation	2.53	.999	.880 (79.6)	.0008 (1.6)	-.0002 (-.195) *	-.0001 (-.317) *
FI III	OLSQ	1.15	.998	.886 (31.1)	.0017 (1.74)	-.0024 (-1.07) *	-3×10^{-6} (-.014) *
FI IIIa	Autocorrelation	2.48	.999	.876 (62.6)	.0009 (1.94)	-.0004 (-.31) *	$+4\times10^{-5}$ (.373) *
— IV	OLSQ	1.28	.997	.917 (63.8)	—	-.0044 (-1.34) *	—
— V	OLSQ without time term.	1.77	.999	.900 (160)	—	-.059 (-.742)	—

TABLE A.13

	ELTIS ENDOGENOUS TECHNICAL PROGRESS	D-W	R^2	ln K/L	t	I/y	CG or FI Cap. Goods or For. Inv.
I	OLSQ	1.52	.998	.877 (30.0)	.0025 (2.05)	-.730 (-.989) *	—
Ia	Autocorrelation	2.54	.999	.877 (59.6)	.0009 (1.44) *	.218 (.055) *	—
CG II	OLSQ	1.53	.998	.900 (23.6)	.0025 (1.99)	-.0084 (-.877) *	$.4\times10^{-4}$ (-.12) *
CG IIa	Autocorrelation	2.54	.999	.883 (47.6)	.0009 (1.45) *	-.0012 (-.242) *	$.2\times10^{-7}$ (-.516) *
FI III	OLSQ	1.48	.998	.895 (21.8)	.003 (1.81)	-.012 (-1.001) *	$.11\times10^{-4}$ (.462) *
FI IIIa	Autocorrelation	2.48	.999	.876 (56.9)	.0011 (1.24) *	-.001 (-.166) *	$.5\times10^{-5}$ (.311) *
IV	OLSQ	1.25	.997	.891 (27.7)	—	.0026 (.315) *	—
V	OLSQ without time term	1.40	.998	.951 (31.8)	—	-.350 (-1.61) *	—

TABLE A.14

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