MARYLAND INTERINDUSTRY FORECASTING PROJECT

Research Memorandum No. 17

THE EFFECT OF CAPITAL INVESTMENT ON LABOR PRODUCTIVITY

by

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Up until now, the interindustry forecasting model has used exogenous projections of labor productivity which were based on simple extrapolations of past trends. This practice left an awkward hole in the middle of the model. For on the one hand, the endogenous generation of investment by industry was one of the distinguishing features of the model; and on the other hand, the growth in labor productivity essentially determines the overall growth projection given by the model. Even the most casual observation suggests that capital investment has something to do with the increase in labor productivity. Therefore the absence of any connection between the two in the model must strike one as a clear indication of ineptitude or, at least indolence, on our part.

The truth is that it is easier to recognize that there must be some connection than it is to measure that connection. We made a number of false starts on the problem. One-by-one we eliminated a sequence of more-or-less sophisticated methods which failed, at least in our hands, to produce usable, reliable results. We have tried, for example, assuming that all change is embodied in capital and that each year a constant dollar's worth of new equipment counts for more in the production than it did the previous year. This assumption, like others we tried, can explain the trend of productivity; but in most industries, as a simple time trend plus a term for the first difference in output explain it better. This, so-to-speak, null-hypothesis equation may be written

$$\ln\left(\frac{E_t}{Q_t}\right) = a + bt + c(\ln Q_t - \ln Q_{t-1}) \qquad (1)$$

where Q is the industry's output; E is employment; and t, time. This equation proves a stout contender in most industries, and generally substantially out-performs equations we derived from Cobb-Douglas production functions with technological change embodied in new investment. At length, we gave up the production-function approach to labor productivity--although we retain it for capital investment--because we couldn't make it work as well as the simple equation (1) above.

The success of this time-trend equation suggested that what we needed was, essentially, a time variable that advanced at a rate dependent on the rate of investment. In a year of no investment, it should not change; in a normal year, it should increase by about one; in years of unusually high investment, it should increase by more than one. A moment's reflection suggested the average installation data, (AID), as just such a variable. We calculated it by the formula

$$AID_t = \Sigma_{i=0}^{\infty} (V_{t-i})\cdot(t-i)\cdot R_i / \Sigma_{i=0}^{\infty} (V_{t-i})\cdot R_i$$

where V_{t-i} is investment in year t-i and R_i is the fraction of investment remaining in use i years after its installation. (The calculation of R_i is described in the appendix.) Then we used AID_t instead of t in an equation like equation (1), namely

$$\ln\left(\frac{E_t}{Q_t}\right) = a + b\,AID_t + c(\ln Q_t - \ln Q_{t-1}) + d(AID_t - AID_{t-1}). \qquad (2)$$

Basically, this equation says that to get a full year's worth of productivity increase, an industry has to make a full year's worth of investments. We introduced the first difference of AID because not all the benefits of investment arrive in the first year. Indeed, the immediate effect of investment is sometimes desruption, so this first difference sometimes enters with a positive coefficient.

The results of fitting equation (2) to histroical data for the years 1953 through 1966 are shown in the accompaning table and graphs. The last column of the table shows the $\bar{R}^2$ (or fraction of variance explained) by equation (1), that is, with time as the principal explanatory variable. Just to the left is the $\bar{R}^2$ using equation (2) with AID as the principal explainer. The larger of the two is marked with a *. AID gets 35*'s; time, 30. Of the 27 cases in which the difference is more than .02, AID leads in 15 and time in 12. AID takes most of the big investors--Construction, Paper, Basic Chemicals, Plastics and Synthetics, Steel, Copper, Transportation, Communication, and Trade. It comes close but loses in Motor Vehicles, Petroleum Refining, and Electric Utility.

Clearly, we cannot claim to have <u>proved</u> that investment causes changes in productivity. But if we admit this causation from the outset, and are just looking for a way to quantify it, then it appears that we have succeeded rather well. A reasonable and simple formulation produces results better than any of the sophisticated methods we tried.

On the plots, the line of *'s after 1966 shows the previous trend projections; the line of +'s shows the new projections using these equations. When these equations were put into the forecasting model, we did not see much change in aggregate forecasts under assumptions of a return to low interest rates. But when we ran a high interest rate version with the investment tax credit eliminated, the new equations made a big difference. With the old trend projections, unemployment rose from 3.7 percent with the low cost of capital to 5.9 percent with the high cost of capital and the same level of after-tax income. Of course, investment fell off in the high-cost forecast, so with the AID equations, productivity slows down. In fact, we found that unemployment rose only to 4.1 percent--against 5.9 percent with the old trend equations. Or, put another way, 1975 GNP with the high cost of capital comes out .4 percent lower than it does with low cost capital. The difference, of course, is traceable directly to the effect of investment of labor productivity through the new equations.

APPENDIX

THE TWO-BUCKET DISTRIBUTION OF EQUIPMENT RETIREMENT

For calculating the Average Installation Date (AID) we need the factors R_i, the amount of equipment remaining in efficient use i years after its installation. The only indication we have about R_i is the average life allowed for depreciation purposes. From this value we construct R by a process best thought of in terms of two water buckets.

These two buckets are identical, have straight sides, and each has a hole of the same size in the bottom. One bucket is placed above the other. If a gallon of water is dumped into the top bucket, it gradually runs out into the bottom bucket, and then out onto the ground. The rate of leaking from either bucket is proportional to the amount of water in the bucket. If this factor of proportionality is s, then the average stay of water in the system may be shown to be 2/s. Conversely, if the average stay, a, is known, the implied value of s is 2/a.

This average stay, corresponds, of course, to the average life of capital. The rate of pouring water into the top bucket corresponds to rate of investment, and the total volume of water in the two buckets is the stock of capital. To find the R_i, we could just pour a gallon of water into the top bucket and measure the water remaining in the system at unit time intervals. Actually, it is easier to calculate AID from two two-bucket systems directly. Into one system goes investment, V_t, and into the other system goes the product of time with investment, tV_t. Then the AID is equal to the "water" in the second system divided by the "water" in the first.

The great advantage of this pattern for R_i is that the whole past history of investment does not have to be "remembered" and used by the forecasting program. It is sufficient to remember only how much "water" is in each of the four buckets.

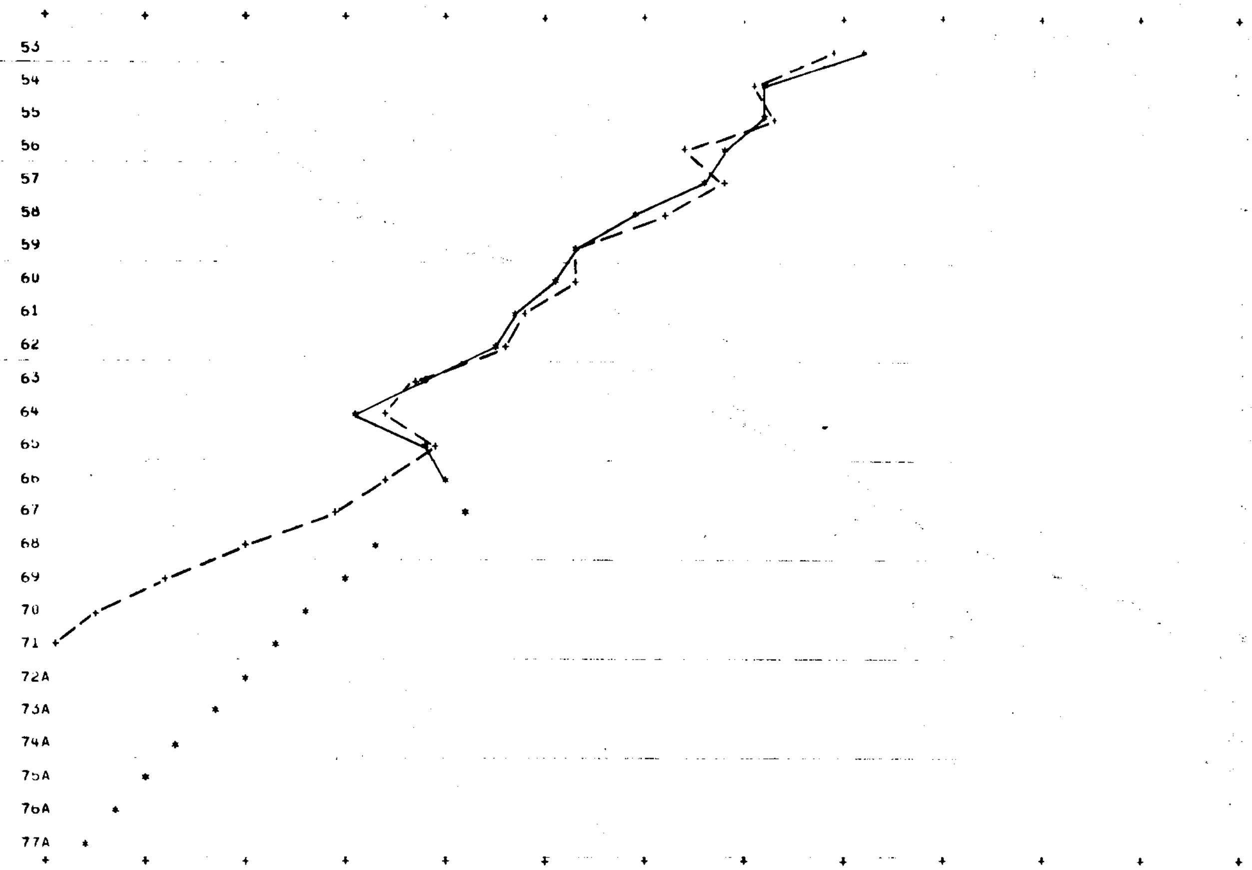
The exponential distribution of retirements also has this advantage, and indeed it corresponds to a one-bucket system. Such a one-bucket system, however, has the disadvantage that it makes retirements fastest in the first year and then gradually tapering off. The two-bucket system has no retirements at first, then they build up, and finally taper off.

LABOR PRODUCTIVITY AND THE AVERAGE
INSTALLATION DATA OF EQUIPMENT

	AID	Δ ln Q	Δ AID	$\bar{R}^2$ AID	$\bar{R}^2$ Time
11 Construction	-.007	-.179	.438	.5668*	.4070
14 Meat Packing	-.043	-.832	---	.9647	.9771*
15 Dairy Products	-.059	-1.37	---	.9419	.9475*
16 Canned & Frozen Food	-.064	-.529	.254	.9398	.9458*
17 Grain Mill Products	-.042	-.856	---	.9430	.9534*
18 Bakery	-.028	-.677	---	.9585*	9572
19 Sugar	-.0186	-.487	---	.6205	.6562*
20 Candy	-.029	-.578	---	.9062	.9997*
21 Beverages	-.028	-.439		.9911*	.9851
22 Misc. Foods	-.046	-.501	.079	.9683	.9744*
23 Tobacco	-.038	-.731	---	.9587	.9619*
24 Fabrics & Yarn	-.039	---	---	.9673	.9912*
25 Rugs & Tirecord	-.106	-.535	.464	.9742	.9822*
26 Apparel	-.024	---	---	.9255	.9539*
27 Household Textiles	-.022	-.395	---	.8621	.8689*
28 Lumber & Products	-.051	-.374	.240	.9667	.9708*
29 Wooden Containers	-.066	---	---	.7690	.9066*
30 Household Furniture	-.014	---	---	.8355	.8599*
31 Office Furniture	-.021	-.767	---	.7876	7942*
32 Paper	-.021	-.747	-.125	.8326*	.8093
33 Paper Containers	-.024	-.237	---	.9538*	9530
34 Printing & Publishing	-.054	-.741	.538	.9253*	.9210
35 Basic Chemicals	-.067	-.647	---	.9903*	.9871
36 Plastics & Synthetics	-.014	-.938	-.235	.7427*	.6947
37 Drugs, Cleaning, & Toilet Items	-.053	---	---	.9609	.9842*
38 Paint & Allied Products	-.040	-.634	---	.9285*	.9262
39 Petroleum Refining	-.094	-.636	.088	.9806	.9925*
40 Rubber & Plastic Products	-.033	-.311	---	.8899	.9135*
41 Leather Tanning	-.021	---	---	.7680	.8100*
42 Shoes & Leather Products	-.014	-.539	---	.8897*	.8858
43 Glass & Glass Products	-.048	-.742	.128	.9442*	.9356
44 Stone & Clay Products	-.063	-.570	.419	.9770*	.9123
45 Iron & Steel	-.016	-.498	.137	.9246*	.8949
46 Copper	-.0005	-.760	.176	.9331*	.9086
49 Metal Containers	-.020	-.636	---	.9044	.9103*
50 Heating, Plumbing & Structural Metal	-.046	-.442	.331	.8876*	.8831
51 Stampings & Screw Machine Products	-.027	-.509	.341	.7919*	.4987
52 Hardware, Plating, Valves, Wire Products	-.031	.167	.067	.9680	.9691*
53 Engines & Turbines	-.014	-.486	---	.6017*	.6132
54 Farm Machinery & Equipment	-.027	-.528	.199	.8874*	.8844
55 Construction & Mining Machinery	-.010	-.252	---	.6481	.6796*
57 Metalworking Machinery & Equipment	-.006	-.202	---	.6346	.6544*
58 Special Industrial Machinery	-.044	-.817	.456	.9537*	.8872
59 General Industrial Machinery	-.035	---	---	.9004	.9024*
60 Machine Shops & Misc. Machinery	-.012	-.184	---	.5237	.5386*

	AID	Δ ln Q	Δ AID	$\bar{R}^2$ AID	$\bar{R}^2$ Time
61 Office & Computing Machines	-.060	-.560	.247	.9464*	.9409
62 Service Industry Machines	-.054	-.196	---	.9709*	.9591
63 Electric Apparatus & Motors	-.007	-.105	-.292	.8182*	.6695
64 Household Appliances	-.050	-.288	-.068	.9423*	.9149
65 Electric Lighting & Wiring Equipment	-.006	---	---	.3999	.4494*
66 Communication Equipment	-.052	---	---	.8720	.8786*
67 Electronic Components	-.014	-.415	---	.5784*	.5609
68 Batteries, X-Ray & Engine Elec. Equip.	-.039	-.270	-.111	.9541*	.9274
69 Motor Vehicles	-.047	-.198	.083	.9571	.9635*
70 Aircraft & Parts	-.042	-.400	.300	.8424*	.7879
71 Ships, Trains, Trailers & Cycles	-.014	-.352	-.121	.9758*	.9448
72 Instruments & Clocks	-.051	-.741	.404	.9284*	.9016
73 Optical & Photographic Equipment	-.041	-.305	-.127	.9528*	.9332
74 Misc. Manufactured Products	-.050	-.378	.150	.9642*	.9640
75 Transportation	-.033	-.475	---	.9901*	.9825
76 Communication	-.061	-.714	.333	.9878*	.9866
78 Electric Utility	-.061	-.798	.055	.9942	.9968*
81 Wholesale & Retail Trade	-.027	-.456	-.057	.9955*	.9905
82 Finance & Insurance	-.024	-.656	-.084	.9961*	.9910
84 Hotels, Personal & Repair Service	-.006	.200	.039	.7960*	.7892

14 00 MEAT PACKING



15 00 DAIRY PRODUCTS