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How strongly do developing economies benefit from equipment investment?*

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We extend and improve the database used in De Long and Summers (1991) and, focusing on developing economies, find that there is a very strong growth–equipment investment association even when rich industrialized economies are not considered. Rapid growth is found where equipment investment is high, and slow growth where equipment investment is low. If there is a region where the post-WWII growth–equipment nexus is weak, it is the well-integrated and very rich region of western Europe – not the developing world.

Key words: Growth; Aggregate productivity; Development; Investment

JEL classification: O11; O30; O40

1. Introduction

This paper continues the research project we began in 'Equipment Investment and Economic Growth' [De Long and Summers (1991)]. Our 1991 paper used data from Summers and Heston (1988, 1991) and from detailed benchmark estimates of national economy price and quantity structures from the U.N. International Comparison Project [see Kravis, Heston, and Summers

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(1978, 1982) to show that in the post-World War II era there is a strong cross-economy association between output per worker growth and investment in machinery and equipment.

Here we extend and improve our database, focusing on developing economies, and find that the growth–equipment association remains strong when the rich industrialized economies are excluded from the sample.

One might think that it would not: rich economies can make productive use of the equipment that embodies modern machine technologies because they have already developed the 'human infrastructure' of literacy, technology-handling skills, and organizational practices. Perhaps poorer developing economies lack the human infrastructure to support machine technology and are unable to benefit from high rates of accumulation.

We believe this fear is overdrawn. Relatively poor economies appear to benefit as much as do richer economies from an investment effort concentrated on machinery and equipment. Rapid growth is found where equipment investment is high, and slow growth where equipment investment is low. If there is a region where the post-WWII growth–equipment nexus is weak, it is the well-integrated and very rich region of western Europe – not the developing world.

We believe that the strength of the growth–equipment nexus that we find among the developing economies is especially impressive because of the indifferent quality of much of national income and growth data covering the world's poorer economies. Both growth rates and investment rates are measured with considerable error, much more error than is found in data covering the richer economies that have well-developed government statistical departments. Substantial measurement error tends to degrade the strength of estimated statistical relationships. But even though the data are of relatively poor quality, there remains strong statistical evidence of a powerful equipment–growth association among developing economies.

Much of the effort that we have put into this project since we wrote De Long and Summers (1991) has been devoted to sharpening our estimates of equipment investment rates. Our previous estimates of the division of investment between equipment and structures rested very heavily on benchmark year observations. In this paper we use a much broader range of data to construct our estimates of investment rates. This improvement in the database does provide us with substantial payoffs: our results are sharper and more precise with the new than they were with our old database.

Section 2 of this paper describes our data. It documents the extraordinarily wide variation across economies in relative price and quantity structures, and the associations between these variations and economic policies. We stress the distinction between investment effort – share of national product saved, plus capital inflows – and investment – buildings constructed and machines put into productive use. Many of the policies that have been followed in the post-WWII period, especially in the developing world, seem designed to maximize 'investment effort', while ensuring that each unit of 'investment effort' translates into as little actual investment as possible.

Section 3 presents evidence on the strong association of equipment investment and growth, on the robustness of this association to the inclusion or exclusion of different ranges of the cross-country distribution of per capita productivity levels, and on tests of whether growth might be the cause and equipment investment the effect. It concludes that the growth–equipment nexus among developing economies is strong, and in all likelihood arises because the returns on equipment investments are very high, but that it is not the sole or overwhelming determinant of relative growth rates.

Section 4 presents speculative conclusions about economic policy that we draw from our studies. We believe that policies to boost equipment investment above what might be thought of as *laissez-faire* levels might produce large economic growth benefits. We are much more confident that policies that reduce equipment investment below what might be thought of as *laissez-faire* levels destroy economic growth.

2. Assessing economic structures

2.1. Estimating equipment investment rates

De Long and Summers (1991) found a strong association between the growth rate of GDP per worker over 1960–85 [in international dollars as estimated by Summers and Heston (1991)] and our estimates of the share of GDP devoted to machinery investment over 1960–85. The study covered a sample of sixty-odd non-oil-exporting economies that had been at some point or other closely studied by the U.N. International Comparison Project (ICP), which had constructed estimates of national relative price and quantity structures for specific benchmark years denominated in a common 'international dollar' unit.

As we noted, the estimates of the share of equipment investment in GDP used were not especially good. They depended heavily on the ratio of equipment to total investment in benchmark years being good proxies for the average ratio of equipment to total investment on average over the sample. Our use of benchmark estimates confined our cross-country sample to those economies that had served as benchmarks in the ICP: Singapore and Taiwan, for example, were omitted from our database.

In this paper we use a broader range of sources of information to construct our estimates of equipment investment rates. This improvement in the database does provide substantial payoffs: our results are sharper and more precise with the new than they were with our old database. First, we improve our estimates of real rates of equipment investment by using sources of information on real equipment investment besides national income accounts. The bulk of machinery and equipment are imported. Trade statistics are a fruitful source of data on equipment investment. In addition, the relative price of equipment has a strong negative correlation with equipment investment. Aitken (1991) has constructed estimates of the relative price of equipment in the 1980s. Lee (1992) has compiled estimates of real equipment imports over 1960–85.

We determined the relationship in our 1991 sample between our estimates of equipment investment rates over 1960–85, the Lee estimates of real equipment imports from the OECD over 1960–85, the Aitken estimates of the relative price of capital, and two additional variables – the total investment share and the average ratio of national product per worker to the U.S., both from Summers and Heston (1991). We then used this relationship to project equipment investment rates over 1960–85 for non-oil-exporting economies omitted from our 1991 sample. In estimating the relationship between equipment investment and our proxies, we exclude the equipment-exporting economies of the G-7 that produce domestically the bulk of their equipment investment. We also exclude the three largest outliers – the African economies Tanzania, Zambia, and Zimbabwe, which we estimated in De Long and Summers (1991) to have high shares of equipment investment in GDP, but which have little capacity to produce capital goods and low recorded equipment imports.

By far the best predictor of equipment investment was the share of equipment imports in GDP, which do move one-for-one with our 1991 estimates of national equipment investment rates.

For OECD nations, and for thirteen others for which unpublished data was kindly provided by Robert Summers, we sharpen our estimates of equipment investment by estimating the share of equipment investment in total investment not from one benchmark year but for all years in the 1960–85 sample. We find, however, that this improvement on our earlier benchmark procedure has only small effects.

These improvements in our data generate substantial benefits. For our full sample, the t-statistics on equipment investment that we report below are more than two-thirds higher than the t-statistics in the analogous regressions in our earlier work.

2.2. *Price and quantity structures*

Fig. 1 documents that the price of investment goods relative to the deflator for GDP as a whole is much greater in poor than in rich economies. This shows one of the major benefits of using ICP data: because of the divergence in relative price structures, it is hazardous to attribute the same meaning in terms of additions to the physical capital stock to savings in poor as in rich economies. Poor economies require a greater 'investment effort', in terms of foregone consumption, to produce the same physical investment.

Also noteworthy in fig. 1 is the wide divergence in relative price structures among the poorer economies. Richer economies have similar price structures. But the relative price of investment goods can vary by a factor of three in the bottom quartile of the distribution of national average output per worker.

This pattern is present even more strongly in the pattern across nations of the real relative price of *equipment*. Fig. 2 plots the price of machinery and equipment relative to GDP for the year 1980 against 1980 output per worker. The downward slope of relative equipment prices as output per capita levels rises is not surprising. Equipment is highly tradable: the relative price of equipment is close to the inverse of the national product deflator. Again we see divergence in price structures among poorer economies. We believe that a large part of these divergences must be traced to differences in economic policies: differences in exchange rate policy that affect the gap between the current exchange rate and the PPP exchange rate, or differences in trade policy that drive a wedge between the internal price and the world price of equipment.

The wedge between investment and investment effort is especially important because many have pointed to the lack of correlation between a developing economy's investment effort and its growth rate. Krueger (1990) argues that physical investment cannot have a very high social marginal product because India – which Krueger estimates has raised its (nominal) gross investment share from 14 to 22 percent over the post-independence period – has exhibited poor growth performance. But examine fig. 2. In India, like in Argentina, the savings rate is relatively high but equipment is expensive – more than twice as expensive in relative terms as in Korea in 1980. Thus equipment investment as a share of GDP in India over 1960–85 is about half of the sample average even though the savings share is near the mean. India demonstrates not that boosting investment is unproductive, but that policies that boost saving while simultaneously raising the relative price of investment in equipment and structures are unproductive. We suspect that restrictions on imports of capital goods have ensured that the Indian government's attempts to support investment have had effects not on quantities but on prices: India's policies have managed to enrich *industrialists* instead of encouraging *industry*.[1]

Fig. 3 shows how high relative prices of equipment go with a low real share of equipment investment in GDP. To some degree the association shown in fig. 3 is spurious, especially among the poorest economies for which data are of lower quality. For a given level of nominal spending on equipment investment in the

[1]We owe our interpretation of India to Charles Jones. See Jones (1991) for a more complete discussion. Given the high relative prices of capital goods in India, and the fears that Indian trade policy has become little more than a mechanism for rent extraction, we find it puzzling that slow Indian growth is at times attributed to the acceptance of development economists' advice to increase investment. It seems to us that slow growth in India over the post-World War II period probably has much to do with policies that have kept a substantial investment effort from generating a healthy rate of investment.

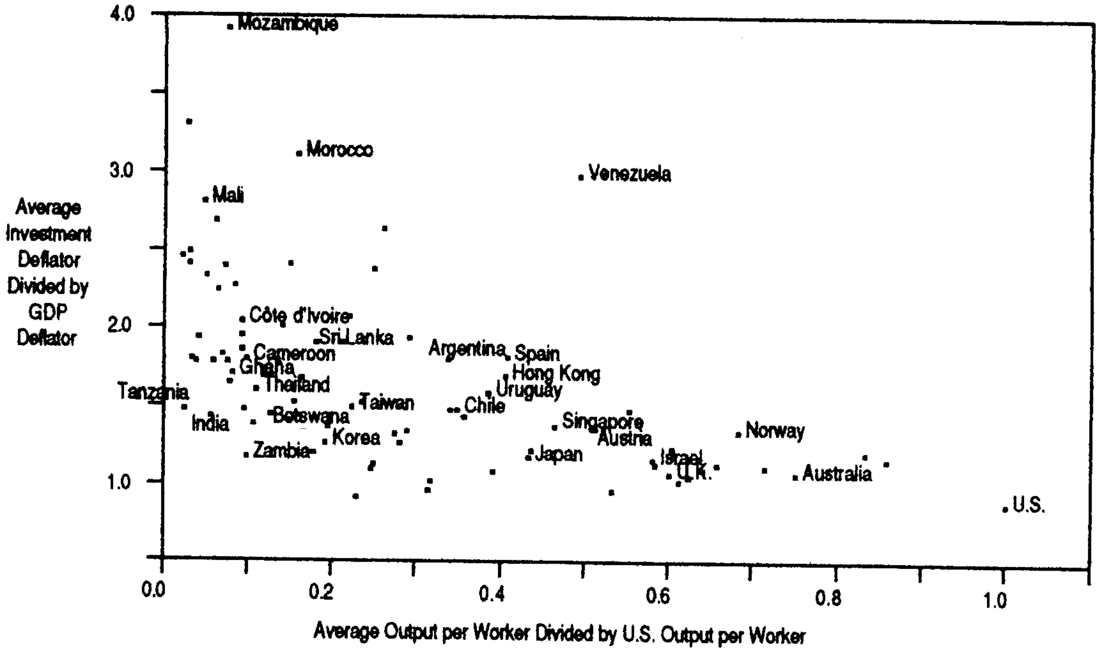

Fig. 1. Relative prices of investment goods and relative levels of output per worker, 1960–85.

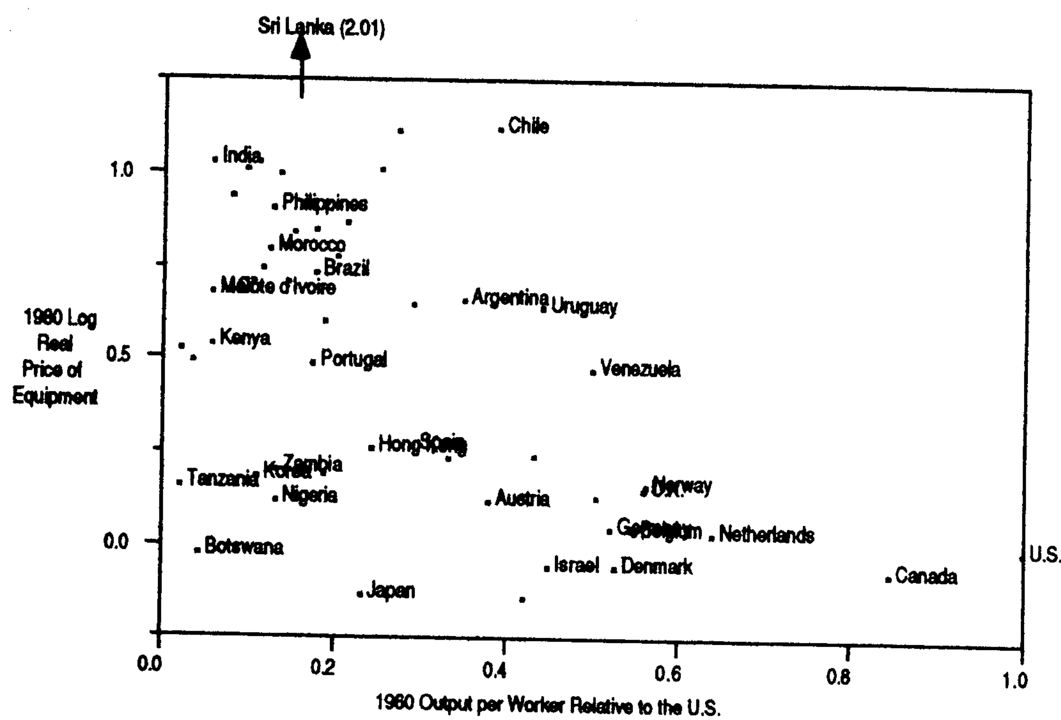

Fig. 2. Relative prices of machinery and equipment and levels of output per worker, 1980.

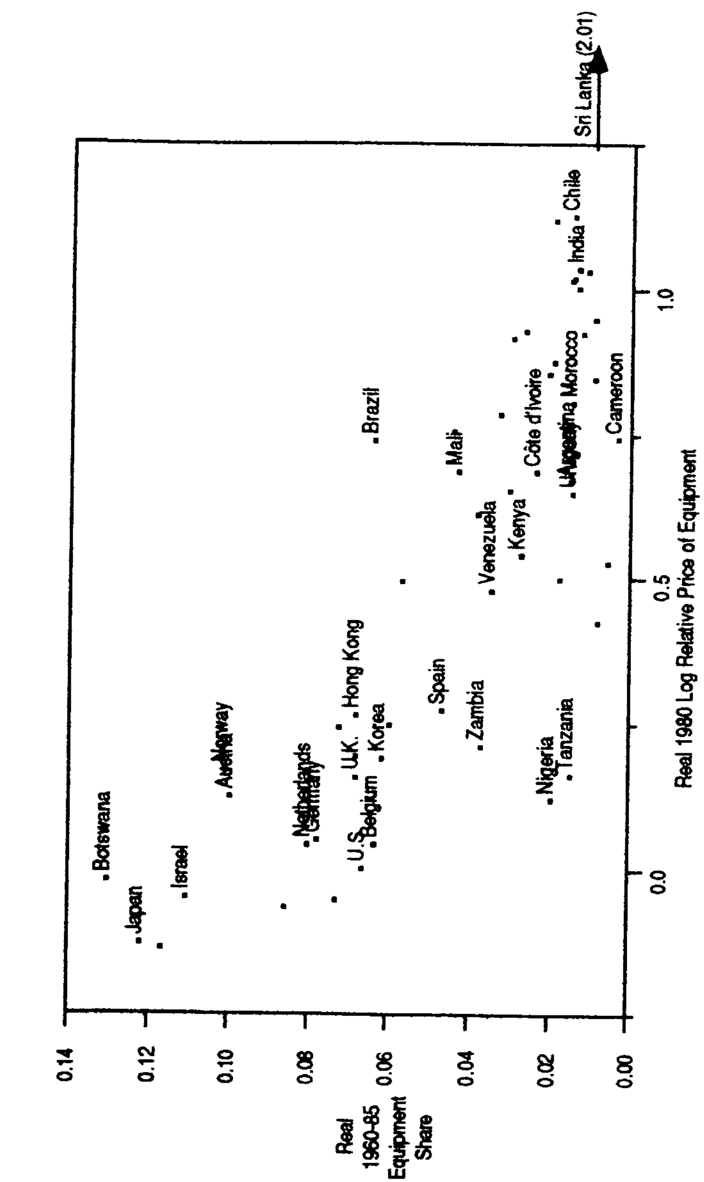

Fig. 3. Estimated equipment investment and equipment prices.

nominal national product accounts, a lower (*measured*) relative price of equipment leads to a higher (*estimated*) share of equipment investment in GDP. Discounting for measurement error, fig. 3 provides powerful evidence that a good way to reduce one's investment in equipment is to pursue policies that elevate the relative price of equipment.

3. The growth–equipment nexus

Table 1 presents basic regressions of GDP per worker growth rates over 1960–85 on average rates of estimated equipment investment, other investment, on the log of output per worker in 1960, and on the labor force growth rate. The sample consists of 88 non-oil-exporting nations, up from the 61 in our 1991 sample. While our estimates of output per worker growth, initial output per worker levels, and labor force growth are the same as in De Long and Summers (1991), our estimates of equipment and other investment rates are significantly improved.

The first line of table 1 reports the regression using our standard specification on the entire 88 economy sample. The four right-hand-side variables account for nearly half of the variation in growth rates over 1960–85 in the database. And there is a very strong partial association between equipment investment and growth: each extra 1 percentage point devoted to equipment investment is associated with an 0.302 percentage point increase in the annual GDP per worker growth rate.

Fig. 4 presents the leverage plot – the partial scatter diagram – of equipment investment and growth corresponding to the regression in the first line of table 1. The fit is significantly better than in the analogous regression of our earlier work. There the four independent variables accounted for 29 percent of the variation in output per worker growth rates. Here the four independent variables account for almost half.

3.1. *Stratified samples*

Abramovitz (1986) discussed the problems of development in a framework in which 'convergence' – the ability of poorer countries to catch-up to the richer by adopting modern technologies and investing in capital-intensive production methods – was limited by 'social capability' – whether an economy had the human infrastructure of skills, formal educational attainments, and organizational practices necessary to take advantage of the machines and techniques of the industrial revolution. Landes (1990) writes of how the task of catching-up to the industrial leaders in productivity levels requires 'the creation and acceptance of a new ethic of personal behavior' and how development has 'been most readily effected in those societies, like the Japanese, which had already developed appropriate time and work values before the coming of modern

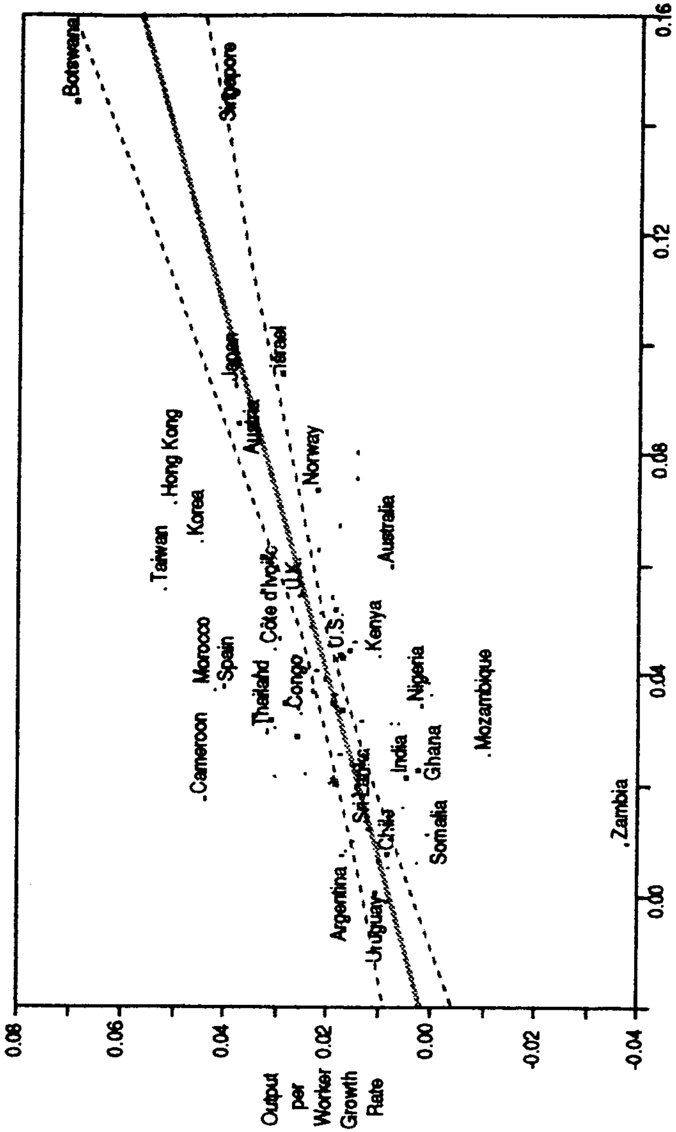

Fig. 4. Partial scatter of equipment investment and growth: Full sample.

Table 1

Equipment investment and growth: Regressions using different stratified subsamples.

Percentage of U.S. GDP/wkr in 1960	Equipment investment	Other investment	Log output per worker (1960)	Labor force growth	R^2	*SEE*	*n*
All obs.	0.305 (0.052)	0.092 (0.029)	– 0.007 (0.002)	0.085 (0.159)	0.468	0.0124	88
< 60%	0.316 (0.054)	0.091 (0.031)	– 0.005 (0.002)	0.114 (0.164)	0.494	0.0125	82
< 40%	0.365 (0.062)	0.091 (0.034)	– 0.005 (0.002)	0.052 (0.210)	0.519	0.0131	69
< 30%	0.376 (0.067)	0.085 (0.036)	– 0.003 (0.003)	– 0.070 (0.246)	0.519	0.0134	64
< 20%	0.470 (0.098)	0.098 (0.043)	– 0.006 (0.004)	0.020 (0.321)	0.491	0.0142	49
< 10%	0.401 (0.091)	0.147 (0.049)	– 0.006 (0.005)	– 0.126 (0.385)	0.662	0.0111	27

industry'. This line of argument raises the possibility that structural relationships that hold for the relatively rich already industrialized nations of the world economy's core may not hold for those economies at the periphery. Perhaps the strong growth–equipment nexus that we have found in earlier work does not hold if the richer, industrialized economies are excluded from our cross-country sample.

Lines two through five of table 1 successively exclude from the sample those economies in the sample of the row above with the highest initial levels of output per worker, focusing on poorer and poorer slices of the distribution, until line five examines only those economies with 1960 GDP per worker levels less than 10 percent of the U.S. level. But the equipment investment coefficient does not fall – if anything, it rises (although not by statistically significant amounts).

It is not the case that the strong equipment investment coefficient is being driven by one or two outliers. Some observations – chiefly Botswana and Singapore – do have enormous identifying variance, and their inclusion or exclusion can shift the magnitude of the equipment investment coefficient by a fifth. But these extremely influential data points corresponding to very poor economies neutralize each other. For every Botswana, a poor outlier economy that our regression fits extremely well, there is a Zambia: a poor economy that our regression fits relatively badly. Table 2 excludes the range of the distribution in which Botswana falls – the range of economies with 1960 GDP per worker levels less than 5 percent of the U.S.[2] But the exclusion of these very poorest

[2]This removes Botswana, Burma, Burundi, Ethiopia, Gambia, Guinea, Lesotho, Malawi, Nepal, Niger, Rwanda, Tanzania, Togo, Uganda, and Zaire from the sample.

Table 2

Equipment investment and growth: Regressions using different stratified subsamples and omitting the very poorest economies.

Percentage of U.S. GDP/wkr in 1960	Equipment investment	Other investment	Log output per worker (1960)	Labor force growth	R^2	*SEE*	*n*
> 5%	0.269 (0.062)	0.094 (0.033)	− 0.007 (0.002)	0.047 (0.172)	0.396	0.0129	78
< 60%& > 5%	0.280 (0.066)	0.096 (0.034)	− 0.005 (0.003)	0.085 (0.180)	0.426	0.0131	71
< 40%& > 5%	0.320 (0.078)	0.097 (0.039)	− 0.003 (0.004)	0.024 (0.235)	0.44	0.0139	59
< 30%& > 5%	0.318 (0.087)	0.090 (0.041)	0.000 (0.005)	− 0.131 (0.282)	0.441	0.0144	54
< 20%& > 5%	0.449 (0.165)	0.086 (0.054)	− 0.005 (0.008)	− 0.001 (0.398)	0.355	0.0164	39
< 15%& > 5%	0.401 (0.091)	0.147 (0.049)	− 0.006 (0.005)	− 0.126 (0.385)	0.662	0.0111	27

economies does not appreciably shift the equipment investment coefficient. Botswana's exclusion lowers the coefficient: removing it alone reduces the coefficient from 0.305 to 0.263 in the full sample. But the exclusion of Zaire, Mozambique, and Tanzania from the sample raises the coefficient. The net effect is nearly zero: it is not the case that the very poorest economies in the sample are in any real sense atypical.

Pritchett (1990) pointed out that the existence of a strong relationship between growth and equipment investment among poorer developing countries is difficult to find in the database underlying our 1991 paper. Using our earlier database, coefficients are sensitive to the exact specification: no one can say with confidence that the strong growth–equipment association found in the sample as a whole applies to the developing economy subsample. Here, with better data, we can make stronger statements: the same growth–equipment nexus *does* hold in the developing economy subsample.

3.2. Continent effects

The set of independent variables we use in our basic specification is parsimonious. We have experimented with adding to the right-hand side other variables that are plausible determinants of growth, and failed to find an alternative specification with a greater number of independent variables that produces a markedly smaller coefficient on equipment investment. Our failure does not prove that the equipment–growth nexus is a structural one: it could be the case that equipment investment is a good proxy for some other factor, perhaps related to education or to what Abramovitz calls 'social capability', for which we possess no good measures.

Table 3

Continent-specific effects.

Continent	Africa	Asia	Europe	N. America	Oceana	S. America
Regression with continent effects						
Intercept	− 0.027 (0.009)	− 0.013 (0.009)	− 0.016 (0.007)	− 0.022 (0.008)	− 0.028 (0.012)	− 0.017 (0.008)
(Single) eq. inv. coefficient			0.278 (0.054)			
P (no continent-specific effects) = 0.0229						
Regression with continent effects and continent–equipment interaction						
Intercept	− 0.025 (0.010)	− 0.007 (0.010)	0.008 (0.013)	− 0.015 (0.012)	− 0.011 (0.020)	− 0.014 (0.009)
Eq. inv. coefficient	0.450 (0.089)	0.243 (0.077)	0.006 (0.148)	0.180 (0.176)	0.080 (0.256)	0.302 (0.208)
P (no continent-specific effects) = 0.0126						
P (no continent–equipment investment interaction) = 0.1610						

An alternative way of exploring these questions would start from the proposition that location – the continent on which on economy is located – has a strong connection with at least the culturally-determined factors that are placed under the category of 'social capability'. It could well be that because of cultural or other factors some continents have had much more favorable opportunities for growth than have others, or that economies in some continents receive more growth from investments in equipment than others. And perhaps the strong growth–equipment associations that we find in our cross-economy regressions are to some degree the result of the omission of factors correlated with location.

Table 3 reports key coefficients from a regression that includes continent-specific effects and from a regression that includes both continent-specific effects and allows for an interaction of continent with equipment investment. There are statistically significant continent-specific effects: the null that the regression intercepts are the same across continents is rejected at the 0.023 level. But allowing for these continent-specific differences in growth has little effect on the equipment investment coefficient: the coefficient estimated is 0.278, as opposed to 0.305 using our full sample and the basic specification. Omission of growth-causing factors correlated with location is not a source of the strong equipment investment coefficient we estimate.

Table 3 also examines whether the strength of the growth–equipment association varies from one continent to another. The table shows no statistically significant sign that the strength of the growth–equipment nexus varies across continents. The null hypothesis that all of the continent–equipment interaction terms are zero fails to be rejected, with a marginal significance level of 0.161. However, the differences in the point estimates of the strength of the growth–equipment association across continents are large – varying from a high of 0.450 for Africa to a low of 0.006 for Europe. Table 3 does suggest that the growth–equipment nexus is, of anything, potentially stronger in regions containing developing economies: the three continents – Africa, Asia, and Latin America – in which developing economies are most heavily concentrated have the three highest point estimates of the continent-specific strength of the growth–equipment association.

3.3. *Total factor productivity growth*

How much of the growth–equipment nexus is associated with total factor productivity growth, and how much with capital deepening holding total factor productivity constant? The lack of accurate estimates of investment rates in the 1950s, and thus of capital–output ratios as of 1960, provides a substantial obstacle to calculating good estimates of total factor productivity growth for our cross-section samples.

We prefer to take another approach that calculates a lower bound to the proportion of the growth–equipment nexus that is attributable to a correlation between equipment investment and total factor productivity growth. Countries that had high investment shares after 1960 had, in all likelihood, high investment shares before 1960 and high capital–output ratios in 1960 as well. If we assume that capital–output ratios in 1960 were uncorrelated with post-1960 investment rates – and with other right-hand side variables in our regressions – then we overstate the average change in the capital–output ratio and the proportion of relative differences in growth rates that can be attributed to differences in capital deepening.

Table 4 reports estimates of total factor productivity growth regressed on our standard four variables, including equipment investment, under the assumption that 1960 and 1985 capital–output ratios are uncorrelated. The first two lines report regressions using our developing economies sample, including only economies with GDP per worker levels less than 30 percent of the U.S. The second two lines include all our data. Lines one and three assume a 15 percent per year net rate of return on capital at the sample mean in 1985.[3] Lines two and four assume a 30 percent per year net rate of return at the sample mean.[4]

[3]Corresponding to an equipment capital share of 5 percent and a structures capital share of 30 percent in the production function.

[4]Corresponding to an equipment capital share of 7.5 percent and a structures capital share of 55 percent in the production function.

Table 4

Estimates of total factor productivity growth regressed on equipment investment.

Sample	Equipment investment	Other investment	Log 1960 output/wkr	Labor force growth	R^2	*SEE*	*n*
Developing: $r = 15\%$	0.274 (0.053)	− 0.024 (0.028)	− 0.0034 (0.002)	0.055 (0.193)	0.329	0.0105	64
Developing: $r = 30\%$	0.204 (0.042)	− 0.112 (0.023)	− 0.0034 (0.002)	0.157 (0.158)	0.430	0.0085	64
All: $r = 15\%$	0.221 (0.041)	− 0.015 (0.023)	− 0.006 (0.014)	0.203 (0.124)	0.319	0.0078	88
All: $r = 30\%$	0.165 (0.026)	− 0.103 (0.015)	− 0.0055 (0.001)	0.301 (0.077)	0.356	0.0062	88

All four lines of table 4 show a strong correlation between equipment investment and total factor productivity (TFP) growth.[5] The positive correlation of equipment investment and TFP growth is lower for the high rate of return case, but the high rate of return case also contains a strong *negative* correlation between structures investment and TFP growth. Fig. 5 shows the partial scatter of equipment investment and estimates of TFP growth, calculated assuming that 1960 and 1985 capital–output ratios are uncorrelated, corresponding to the final row of table 4. Fig. 5 is very similar to earlier figures in this paper: countries that have experienced rapid output growth have done so because of rapid TFP growth, even if we attribute a high share of the product to capital.

Should anyone be surprised at our finding that effectively all of the growth–machinery nexus is due to the correlation between equipment investment and TFP growth? No. This conclusion could have been reached through theoretical reasoning alone: standard models that equate the rate of return on investment to the marginal product of capital contain a profound 'investment pessimism'. Even large shifts in investment rates have next to no effects on long-run growth rates.

In the case of equipment investment, the investment pessimism of standard models is amplified by the high rate at which equipment depreciates. Differences in equipment investment rates on the order of 5 percent of GDP boost the steady-state equipment capital stock by only a quarter of annual GDP or so. At standard rates of return, this increment can support only a boost to GDP of less than 10 percent, and boosts GDP growth rates over the quarter century of our sample by only a third of a percentage point per year.

[5]Similar results are found under the polar opposite assumption that capital–output ratios in 1960 were perfectly correlated with and equal to 1985 capital–output ratios. The difference in the equipment investment coefficient is less than one-sixth of the coefficient's magnitude.

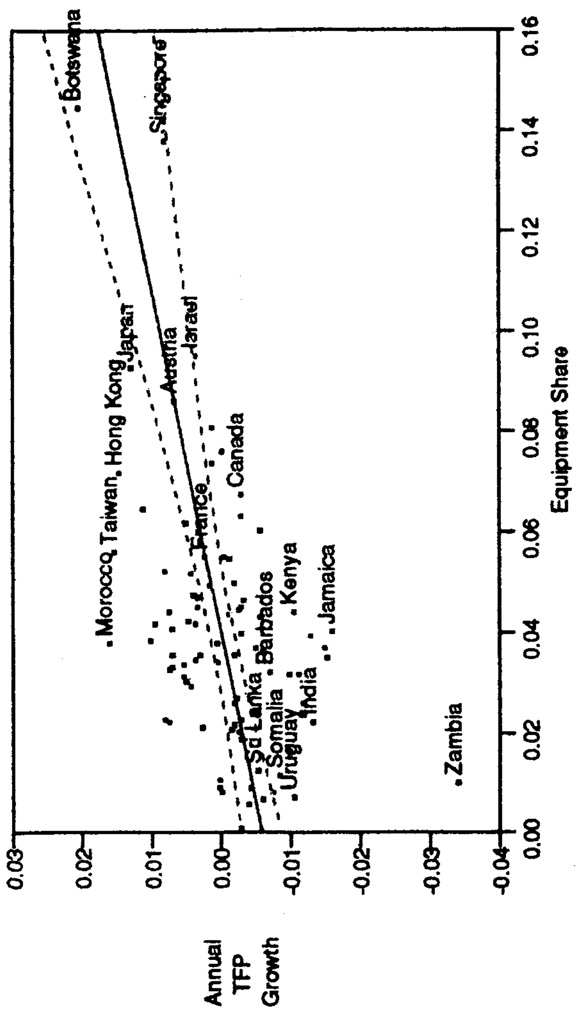

Fig. 5. Partial scatter of equipment investment and total factor productivity growth.

Table 5

Instrumental variables estimates of the growth–equipment nexus in the developing economy sample.

Instruments	Equipment investment	Other investment	Log output per worker (1960)	Labor force growth	R^2	*SEE*	*n*
Savings rates	0.395 (0.117)	0.082 (0.045)	− 0.004 (0.003)	− 0.066 (0.280)	0.384	0.0152	63
Trade barriers	0.051 (0.409)	0.132 (0.095)	0.001 (0.007)	− 0.030 (0.362)	0.250	0.0158	52
Equipment prices	0.417 (0.152)	0.023 (0.056)	− 0.002 (0.004)	− 0.232 (0.419)	0.344	0.0158	36

3.4. Instrumental variables estimates using developing economy samples

Either equipment investment leads to processes that boost TFP or there are some other variables omitted from our analysis that boost TFP and equipment investment together. We suspect that the principal causal chain runs from equipment investment to growth. Here we examine the instrumental variables relationship between growth and equipment in developing countries for three sets of instruments: tariff and nontariff barriers to trade, savings rates, or relative equipment prices.

Table 5 presents results, using a sample, of developing economies that corresponds to the fourth line of table 1. For two of the three sets of instruments – savings shares of national product and relative equipment prices – the instrumental variables regressions show an association between growth and equipment investment as strong as did the ordinary least squares regression. For the third set of instruments – tariff and nontariff barriers to trade – the point estimate of the equipment investment coefficient is near zero. However, the standard error is extremely large.

A strong growth–equipment investment connection in ordinary least squares regressions might be due to reverse causation – fast growth might be the cause and equipment investment the effect. It is more difficult to make this argument for the instrumental variables regressions in lines one and three of table 5. If rapid growth were the cause of high equipment investment, then equipment investment would be high in economies where demand for equipment was high – and so equipment prices would be high. But in the first-stage regression underlying line one of table 5, there is a negative relationship between equipment prices and equipment quantities, suggesting that equipment investment is high when the supply is favorable, and thus that equipment investment is the cause, not the effect of high growth. A similar argument could be made for line three. Standard theory predicts that where growth is strong for exogenous reasons savings should be low – not high.

The failure of line two of table 5 to produce a strong equipment investment coefficient is, however, disappointing. This failure could be rationalized: our estimates of barriers to trade are for the most part from the 1980s, from near the end of our sample period, and are perhaps not ideal measures of average trade policy stance over the sample period.

3.5. *What is the social rate of return to equipment investment?*

Our TFP growth regressions suggest that a 1 percentage point increase in the equipment investment share of GDP is associated with an increase of approximately 0.2 percentage point per year in the TFP growth rate. Suppose that equipment investment yields a net private rate of return of 15 percent that is a high estimate of the worldwide average return on private business investments, and an associated gross rate of return on the order of 25 percent per year. What then is the social rate of return to equipment investment?

The calculation of the social rate of return hinges on whether it is correct to view the association of equipment investment and TFP growth as reflecting a causal relationship, and on the timing of whatever external rise in TFP might be induced by equipment investment. If the relationship is causal and if the extra rise in TFP happens immediately – at the moment of installation, as new equipment is brought on line and workers and organizations learn the skills necessary to use it efficiently – then the net social rate of return to equipment investment could be as high as 35 percent per year: 15 percent in extra privately-appropriable value created through capital deepening and approximately 20 percent through the external effects induced. Models like that of Aghion and Howitt (1992) in which private investments in new types of equipment raise productivity at the moment of such investments suggest such a front-loading of the TFP boost.

If the cross-section regressions will bear a causal interpretation, *net* social rates of return from equipment investment in the range of 25 percent per year or more are defensible under the maintained hypothesis that the large coefficient on equipment investment arises because equipment investment is a trigger of learning-by-doing and thus of substantial total factor productivity growth. To the extent that causality flows in the other direction as well, the social rate of return will be somewhat lower. To be more precise would require a much sharper vision of the process of productivity growth and on-the-job-training than we possess, and more confidence that the growth–equipment nexus is in fact a causal one.

4. Implications and conclusions

We have documented that a strong connection between equipment investment and productivity growth holds for developing countries. We have also

reported instrumental variables regressions that produce the same association between growth and machinery. Our instruments – savings rates, trade barriers, and the relative price of equipment – are variables that are in large part determined by economic policy, and only very indirectly affected by output per worker growth. Thus our evidence suggests that a large portion of the growth–machinery investment relationship arises from a causal nexus between equipment and growth.

If this argument is correct, our conclusions have clear implications for development policy. Policies that make it difficult for developing economies to import and install machinery and equipment are likely to be disastrous. Moreover, there is a case that the social returns from investments in equipment are greater than the private profits obtained: if so, then 'getting relative prices right' in the sense of attaining a relative price structure most conducive to rapid growth and long-run welfare would involve pushing the real relative price of equipment below what might be thought of as its *laissez faire* value.

However, it is important to note that the possibility that some activist policies to shape relative price structures could promote growth does not imply that a typical government would be well-advised to seek to put such policies into effect. Westphal (1990), for example, a strong believer that Korea's government has significantly accelerated growth, believes that governments that attempt to promote growth by means of industrial policies usually fail – for reasons familiar to theorists of the rent-seeking society. Reflection on the broad range of attempts to supplement the invisible hand by the visible hand of industrial policy in countries like India, Argentina, and Ghana as well as Korea and Japan adds force to his argument.

If we have correctly identified the growth–equipment nexus as a powerful source of economic growth, than those who wish to argue that East Asian 'developmental states' have generated extraordinary benefits because the *microeconomic* management exercised by their activist governments do a better job of allocating resources for growth than market forces face a roadblock at the beginning of their argument. In our regressions, growth in East Asia has not been extraordinarily high, in the sense of diverging from the general pattern given the macroeconomic fundamentals. Growth has been rapid, yes: but we would have expected growth to be rapid because fundamentals – especially rates of equipment accumulation – have been very favorable. Hong Kong is the sole outstanding positive outlier in our regressions among East Asian economies.

We are tempted to argue that to the extent that interventionist governments have aided development, they have done so because a byproduct of their concentration on export promotion established a relative price structure that made machinery and equipment disproportionately cheap. This does not mean that good economic policies have not been very important in economic growth. In the Korean case, for example, government policies are the source of Korea's effective educational system, of its relatively unbloated government, of its relatively low equipment prices, and of its relatively high rates of equipment investment. The relative stagnation of the Korean economy in the 1950s under the Rhee régime, and subsequent rapid growth beginning soon after the initial reforms of the Park régime, point strongly to a key role played by government policies in creating the fundamental foundations for growth.

But a focus on government 'guidance' and on the directive bureaucracy–firm relationship draws attention away from what are perhaps the true sources of rapid growth. Argentina, India, and many others have all used similar rhetoric to justify 'interventionist' policies: all the programs are rationalized by similar appeals to 'Schumpeterian' rather than 'Ricardian' advantage and to the crucial role of industry in economic development [see Johnson (1982) and Srinivasan (1989)]. But in only a few East Asian cases does anyone even try to claim that such policies have succeeded.

Note also that we are far from being the first to stress the association between equipment investment and economic growth. Not even a quarter of a century after World War II Díaz Alejandro (1970) argued that Argentina's extraordinarily poor economic performance in the post-World War II period was due to a very low rate of investment in machinery and equipment generated by counterproductive policies. Jones (1991) has found that a distorted relative price structure that makes investment in equipment difficult and expensive can cripple economic growth.

In addition, economic historians like Rostow (1960) and Gerschenkron (1962) have also interpreted successful and unsuccessful growth largely as the results of rapid or slow acquisition and installation of machinery and equipment. A low price of machines – the ability to make or acquire industrial capital goods cheaply – and a high quantity of savings devoted to the purchase of machinery and equipment have always featured prominently in economic historians' discussions of the sources of modern economic growth. The reference to an industrial revolution, rather than to a productivity-growth revolution or to a standard-of-living revolution, is shorthand for the key role that economic historians have attributed to mechanization and machinery in driving the tremendous explosion of wealth over the past two centuries.

Moreover, an old development economics tradition dating from the early post-World War II years [for example Hirschman (1958)] and the modern 'new growth theory' tradition dating from the late 1980s [for example, Romer (1986)] point in the same direction. Both traditions of analysis stress the importance of external economies or 'linkages' as fundamental sources of growth. And on the microeconomic side authors like Mowery and Rosenberg (1989) have argued that learning-by-doing plays a key role not only in using existing capital goods efficiently and productively but also in generating technological change and total factor productivity growth. They suggest that a necessary prerequisite to productivity growth is a wide range of experience using existing technologies. In such a case, equipment investment might well be a necessary prerequisite for rapid growth.

Thus our central argument is far from a novelty.

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