Tangible Investment as an Instrument of Growth

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How EFFECTIVE is tangible investment as an instrument for economic growth? This paper surveys some recent developments in the way economists have conceived of capital and examines the implications of these ideas for productivity and growth.

THE WORLD OF HARROD AND DOMAR

One of the most important "models" of the relation of investment to growth is due to Roy F. Harrod of Oxford and Evsey D. Domar of the Massachusetts Institute of Technology. They postulated that capital and output must grow in the same proportion. Let the ratio of capital, K, to annual capacity output, Q, be denoted by the constant β. Then

$$K = \beta Q \tag{1}$$

Therefore, if we want to raise our productive capacity by one dollar we shall need β dollars' worth of additional capital. In general, an increase ΔQ in annual capacity requires a capital-stock increase ΔK equal to $\beta \cdot \Delta Q$:

$$\Delta K = \beta \cdot \Delta Q \tag{2}$$

Let us measure the increases ΔK and ΔQ from the start of the calendar year. Then ΔK is just the annual amount of investment net of replacement—or the "annual rate of net investment." We say *net* investment, for if some existing capital has to be retired during the year it will be necessary to invest (so-called replacement investment) just to keep the capital stock from decreasing. Clearly the rate at which output capacity grows each year

depends upon the annual rate of net investment. Suppose that each year the community saves and invests, net of replacement, a constant proportion, s, of its output (income). That is,

$$\Delta K = sQ, \qquad 0 \leqq s \leqq 1 \tag{3}$$

From these relationships we can derive the relative annual rate of growth of capacity output in the economy. Equations (2) and (3) tell us that $\beta \cdot \Delta Q = sQ$. Hence, dividing both sides of this equality by Q and β, we obtain the simple growth-rate formula:

$$\frac{\Delta Q}{Q} = \frac{s}{\beta} \tag{4}$$

This seemingly optimistic formula states that we can have (in perpetuity) any desired growth rate merely by choosing the appropriate fraction of our income (output) to save and invest. Suppose that $s = 9\%$ and that $\beta = 3.0$. Then the growth rate would be 3% per annum. If we wished to grow twice as fast, just multiply the target growth rate of 6% by β to obtain 18% as the required s. It suffices to double the rate of net investment.

How plausible is this? The answer depends upon the key assumption of a constant capital-output ratio. Is this assumption reasonable? Does it need to be qualified?

It is clear that if we were to interpret the ratio of output to capital as an immutable constant—one independent of the size of the labor force—this would mean that labor made no contribution to output. It would mean that capital was the only scarce factor of production. But we know that labor is scarce because it commands a positive price (wage) in the marketplace. No employer would pay for an input which was not productive. So the single-factor interpretation of the constancy of the capital-output ratio is untenable.

The Fixed Factor Proportions Assumption · The standard version of the Harrod-Domar model treats both labor and capital as necessary factors of production. How then can the capital-output ratio still be treated as constant?

Exponents of this standard version of the model suppose that capital and labor are perfectly *complementary:* every "machine" needs a fixed complement of men operating it if it is to produce, and there is only one known type of machine. A shovel is an xample; a lathe is another. Second, it is supposed that there are constant returns to scale: double employment and capital (the number of machines) and you will double capacity output.

There are clearly only so many machines that this economy can use at any point in time. As long as there are too few machines to go around, additional machines would be useful and output will grow in proportion to capital. But if there is no surplus labor to be combined with more machines, an increase in capital would not increase output: it would only lead to idle machines. *Thus the capital-output ratio is a constant only as long as there is surplus labor.*

Suppose there is surplus labor to begin with and suppose that capital is growing at 6% per annum due to a high-investment policy. Then employment and output will also grow at the rate of 6%. But suppose finally that the available supply of labor is growing at only 1% per annum. Then the economy must eventually run out of surplus labor. The growth path of output will encounter a *ceiling*—in our example, an upward-slanting ceiling. Thereafter, output can grow no faster than the labor supply, no faster than 1%. The investment rate will be reduced since there is no point to producing machines that would have to stand idle. The economy can do no better than crawl along the ceiling output path.

To give plausibility to our numerical example we have to take technical progress into account. Suppose that the output which 100 men can produce today can be performed by only 98 workers tomorrow (with the same amount of capital). Then 2 workers could be released tomorrow to tend new machines. This is as good as having 102 workers tomorrow. The increase in the efficiency of the labor force raises the amount of capital the economy can use in the same manner as an increase in the size of the labor force. We have to add the 2% increase in the efficiency of labor to the 1% increase in the supply of labor to obtain the (3%) growth rate along the ceiling output path. Harrod called this growth-rate concept the *natural* rate of growth to emphasize that it is determined, independently of investment decisions, by deep-seated technologic and demographic trends.

In the Harrod-Domar model, therefore, population and technology impose a ceiling on the capacity output which is achievable at every point in time through tangible investment. Once the labor force becomes fully equipped with machines, output cannot grow faster than the natural rate—the growth rate of the output ceiling—no matter how rapidly we might add to the stock of machines. So the Harrod-Domar model does not make investment so all-powerful after all.

THE NEOCLASSICAL RESURGENCE

The ideas of Harrod and Domar run counter to traditional economic theorizing. Neoclassical theorists like Marshall, Wicksteed and Wicksell would not have accepted the notion that capital and labor were strict complements in the productive process. And modern theorists found it difficult to swallow too. So Robert Solow of M.I.T., Trevor Swan of the Australian National University and James Tobin of Yale led a neoclassical revolt against the Harrod-Domar model.

Neoclassical theory supposes that capital and labor can be *substituted* for each other. Rather than "twenty machines, therefore twenty (or eight or fifty) jobs, and no more," neoclassical theory treats capital as an abstract substance which can be shaped to absorb any size labor force. Whereas Harrod and Domar think of capital as "machines" with rigid labor requirements, the neoclassicals think of capital as putty with which "any number can play."

Given the labor force, the larger is the amount of capital, the larger will be the level of annual output. Each worker will have more putty to work with, so he can produce more. But we have to expect diminishing returns: successive equal increments of capital will (eventually) yield successively smaller increments of output. This contrasts with the Harrod-Domar implication that at first output grows by equal increments and then, once the surplus labor is absorbed, output cannot be further increased. Where the world of Harrod-Domar is kinky and abrupt, the neoclassical domain is smooth and continuous.

This process of increasing the amount of capital per worker, in order to increase output per worker, the neoclassicals called *capital deepening*. The basic neoclassical model of the relation between capital deepening and growth can be presented quite simply.

The neoclassicals start with the notion of a *production function*,

$$Q = f(K, L), \tag{5}$$

which tells us how much output can be produced by a given combination of capital, K, and labor, L.

Second, the neoclassicals usually suppose constant returns to scale. This means, once again, that a 1% increase in both capital and labor will yield a 1% increase in capacity output.

Third, the neoclassicals suppose that pure competition prevails in every corner of the economy.

From these three assumptions it follows that the growth rate of capacity output is a kind of *average* of the growth rates of capital and labor. A "simple" average would add half the growth rate of capital and half the growth rate of labor. But generally the input growth rates must be assigned unequal weights in the averaging process: like one-third of the growth rate of capital plus two-thirds of the growth rate of labor. In symbols the result can be expressed:

$$\frac{\Delta Q}{Q} = a \cdot \frac{\Delta K}{K} + (1 - a)\,\frac{\Delta L}{L} \qquad (6)$$

What makes the result informative is that the weight attached to each input's growth rate equals the *relative share* of total income (output) received by that input. Thus a is capital's relative share and $1 - a$ is the share received in wages.[1]

1. These propositions can be derived quite easily. Any year-to-year increase in the capacity of the economy, ΔQ, must be attributable to the increase, ΔK, in its capital stock and the increase, ΔL, in its labor force. Additions to output are related to increments of input in the following way:

$$\Delta Q = \Delta K \cdot MP_K + \Delta L \cdot MP_L \qquad \text{(i)}$$

where MP_K and MP_L are the marginal productivities of capital and labor, respectively.

What is marginal productivity? Hold L constant and increase K by one unit; then $\Delta K = 1$ and the increase in output will be $\Delta Q = MP_K$. This is exactly what "marginal productivity" means: the increase in output resulting from a one-unit increase of the input, other inputs remaining unchanged.

Next, let us divide both sides of the equation by Q. Then

$$\frac{\Delta Q}{Q} = \Delta K \frac{MP_K}{Q} + \Delta L \frac{MP_L}{Q} \qquad \text{(ii)}$$

or, without really changing anything,

$$\frac{\Delta Q}{Q} = \frac{\Delta K}{K}\left(\frac{K \cdot MP_K}{Q}\right) + \frac{\Delta L}{L}\left(\frac{L \cdot MP_L}{Q}\right) \qquad \text{(iii)}$$

Suppose there are constant returns to scale and pure competition. Under the marginal productivity theory of factor pricing, each unit of input will then be paid its marginal product. Then $K \cdot MP_K$ is just the earnings of capital and $L \cdot MP_L$ the earnings of labor. Together they absorb all the output. Therefore, the weights in (iii), which are the relative shares, add up to one.

Investment Pessimism · It is easy to see that this neoclassical formula for the rate of growth paints a very different picture from the Harrod-Domar formula. For comparison, we recall that $\Delta K = sQ$ and write the neoclassical formula as follows:

$$\frac{\Delta Q}{Q} = a\,\frac{s}{K/Q} + (1 - a)\,\frac{\Delta L}{L} \qquad (7)$$

Note that capital and labor generate growth independently of one another. For that reason K/Q is no longer treated as a constant (like β). And the term $\frac{s}{K/Q}$—which we recall appeared in the guise of $\frac{s}{\beta}$ in the Harrod-Domar growth formula, equation (4)—is multiplied by the weight a.[2]

This last point is important. If a should be very small, what good is a large s, what good is investment?

Suppose, as before, that we are growing at 3%, that $K/Q = 3$ and $s = 9\%$. If we double s to 18%, what will happen to the growth rate? If $a = 1$, the growth rate will also double, reaching 6%. But a is approximately equal (we assume) to capital's share of income. This is about one-third. Thus a *doubling* of our rate of net investment, in this example, would raise the growth rate by only one percentage point, to 4%.[3]

Pretty gloomy? Yes, but less so in a sense than Harrod and Domar, who say that there is a ceiling growth path—one that may grow very slowly. At least the neoclassical world offers us the possibility of growing at almost any reasonable rate we might choose if we are sufficiently willing to tighten our belts.

The Importance of Technical Progress · Our concern with growth is not only with the increase of total output but also with the growth of output per worker or labor productivity, $\frac{Q}{L}$.

2. In this more general neoclassical world, capital growth and labor growth share the credit for growth. But the neoclassical formulation incorporates Harrod and Domar as a special case: If $a = 1$, then output and capital grow in the same proportion and labor is in surplus.

3. Matters are even worse. If $s = 18\%$ and $\frac{K}{Q} = 3.0$, capital will be growing at 6% while output only at 4%. This implies a gradual rise in the K/Q ratio which will slow down the growth rates of capital, hence output.

The relative growth rate of productivity, $\frac{\Delta\left(\frac{Q}{L}\right)}{\frac{Q}{L}}$, is $\frac{\Delta Q}{Q} - \frac{\Delta L}{L}$.[4]

From our growth-rate equation (6) we derive:

$$\frac{\Delta Q}{Q} - \frac{\Delta L}{L} = a\left(\frac{\Delta K}{K} - \frac{\Delta L}{L}\right) \tag{8}$$

This equation states that the growth of output per worker requires the growth of capital per worker; that capital's growth rate exceed labor's growth rate. Similarly, we obtain from (6) the growth rate of the capital-output ratio $\frac{K}{Q}$:

$$\frac{\Delta K}{K} - \frac{\Delta Q}{Q} = (1-a)\left(\frac{\Delta K}{K} - \frac{\Delta L}{L}\right) \tag{9}$$

Hence, if productivity is to rise, so must the capital-output ratio.

In fact, productivity has risen while the capital-output ratio has *fallen* somewhat over the past half century. What is wrong with our neoclassical model? We have omitted technical progress.

The simplest kind of technical progress to introduce is what Mrs. Joan Robinson of Cambridge calls "waving a magic wand" over the economy's inputs to make them more efficient. Suppose that this increase of efficiency yields a growth rate equal to μ independently of any increase of capital and labor. And suppose that the rate of progress μ is independent of the existing supplies of inputs. Our growth rate formula then becomes

$$\frac{\Delta Q}{Q} = \mu + a \cdot \frac{\Delta K}{K} + (1-a)\frac{\Delta L}{L} \tag{10}$$

And productivity increases at the rate:

$$\frac{\Delta Q}{Q} - \frac{\Delta L}{L} = \mu + a\left(\frac{\Delta K}{K} - \frac{\Delta L}{L}\right) \tag{11}$$

Productivity growth no longer requires that capital grow faster than labor—but this helps.[5]

4. First-year calculus students ought to prove this. Others ought to think through its reasonableness: how can Q/L rise unless Q grows faster than L?

5. Also we have:

$$\frac{\Delta K}{K} - \frac{\Delta Q}{Q} = -\mu + (1-a)\left(\frac{\Delta K}{K} - \frac{\Delta L}{L}\right) \tag{iv}$$

The capital-output ratio can fall even though capital is growing faster than labor and thus making a contribution to productivity growth.

Thus we have two sources of productivity growth: "capital deepening" and "technical progress"—which is simply a catch-all for other sources of growth. A number of economists—Solow, Abramovitz, Kendrick and others—in the mid-Fifties, posed the following fascinating historical question: what proportion of the growth of U.S. productivity is due to the increase of capital per worker?

This proportion p is defined as the *ratio* of the growth rate of productivity which would have occurred *without* technical progress to the growth rate which actually occurred as a result of both capital deepening and technical progress. In other words, p denotes that average rate of productivity growth which is attributable to the increase in capital per manhour expressed as a *ratio* to the actual average rate of growth of productivity:

$$p = \frac{a\left(\frac{\Delta K}{K} - \frac{\Delta L}{L}\right)}{\frac{\Delta Q}{Q} - \frac{\Delta L}{L}} \tag{12}$$

It is clear immediately that if $\frac{\Delta K}{K} = \frac{\Delta Q}{Q}$ then $p = a$. How large is a, capital's relative share of GNP? Only about one-third. Moreover, since 1920 or so, $\frac{\Delta K}{K}$ has been smaller on average than $\frac{\Delta Q}{Q}$. So Solow and others concluded that *less than one-third of American productivity growth in this century can be credited to the increase in capital per worker.*

But if our investment in new capital was not awfully important in raising productivity over the past few decades, does this mean that investment would be of little use in raising productivity in the future? Not at all. It may mean simply that capital has grown very slowly in this century. Does it mean that we should have sunk all our investment resources into education and research? No, for we do not know at what enormous cost our technical progress had to be purchased.

This is the crux of the matter: Is tangible investment an ineffective or expensive way to grow? Before putting all our eggs in the research and education baskets we should investigate the prospective returns on each type of investment. But before estimating the return to tangible investment we need to note another development in the theory of capital and growth.

The Improving Quality of New Capital Goods . The unexpected finding that investment was historically unimportant set economists to rethinking the role of capital in economic growth. It was soon suggested that technical progress has to be embodied in new kinds of capital goods if it is actually to raise productivity. Therefore without continual investment productivity could not grow at all. In this new view the role of investment is to *modernize* as well as *increase* the capital stock. It was concluded that investment had been underrated, that it was a more effective instrument of growth than had been thought.

Like any novel idea, this one led to exaggerations. Sometimes more value was put on modernizing the capital stock than on increasing it—as if modernization had made investment respectable.[6]

Granted that investment's new role as modernizing agent makes it *more* effective. But how effective is investment? After all, tangible investment is only one instrument of growth. Investment in research and in education are also important. Just how attractive is an additional dollar of tangible capital formation in the U.S. economy?

The traditional measure of the attractiveness of investment is its *net rate of return*. If capital goods never wore out and never obsolesced as a consequence of continual improvements in the quality of new capital goods, then the net rate of return would be easy to figure: Under pure competition it would equal the *earnings rate* on tangible capital, *i.e.*, profits as a ratio to the replacement value of the capital stock.[7]

But capital goods do depreciate and do obsolesce. So from the gross earnings (quasirents) of capital we have to subtract the replacement cost of the capital which wears out each year.

6. Actually a permanent modernization of the capital stock might well be impossible—like a dog catching its tail: a massive investment in shiny new equipment today will leave us with a massive quantity of old outmoded equipment years hence. It is not enough to accelerate the growth of capital for just a few years. A permanent decrease in the average age of capital goods requires a permanent increase in the growth rate of capital. But in the present circumstances even a temporary and short-lived modernization of the capital stock would not be unwelcome. The resulting lift to productivity—even though temporary—could be put to good advantage.

7. A word of explanation about "replacement value": it means the current investment cost of replacing existing productive capacity with equivalent new productive capacity. If two twenty-year-old tractors can do the work of one two-year-old tractor, their replacement cost is the same.

And we have to subtract the decline in the replacement value of capital which is due to the ever-improving efficiency of the new capital goods with which the economy can renew and expand its capital stock. The first subtraction is called "depreciation." The second subtraction is usually called "obsolescence." Our formula for the rate of return *net* of depreciation and obsolescence is therefore

$$r = q - \delta - \iota \qquad (13)$$

where q is the gross earnings rate, δ the rate of depreciation and ι the rate of obsolescence—all measured as ratios to the replacement value of the capital stock. The rate of obsolescence as defined here is simply the rate at which new capital goods improve in efficiency.[8]

Now we can turn to the data. We select 1954 for our calculations and we restrict our attention to the business enterprise sector of the U. S. economy.

Of course, when utilization of capacity is low—as in recessions—private investors and society get very little return from their investment. We shall be concerned here with the *potential* rate of return on investment—the return that would have been received had business been good in 1954.

The Council of Economic Advisers estimates that business output that year would have been about $300 billion had there been 4% unemployment. (This concept is called "potential output.") We suppose that under these same circumstances before-tax gross earnings in the business sector would have approached $100 billion—*i.e.*, about one-third of business output.

What *gross earning rate* on tangible business capital (valued at replacement cost) would this $100 billion have yielded? Clearly this depends upon the value of the capital employed by the business sector in 1954.

The current-dollar replacement cost of the 1954 business capital stock is usually estimated at around $650 billion. (See Row 1 in the table.) But this conventional estimate neglects the quality differential between new and old capital goods: it assumes that

8. Advanced students may challenge the appropriateness of deducting the "improvement rate" for computation of the *social* net rate of return. This deduction is appropriate, however, for it reflects the attraction to society of waiting to invest (and advancing consumption) in order to take advantage of the future cheapening of capacity (in terms of consumption).

a 1930 truck would have to be replaced by a 1954 truck if they had cost the same when new. But suppose the newer truck could do the work of two old trucks. Then the true replacement cost of a 1930 truck would be only half the cost of a new truck.

Table: *Potential Net Rate of Return on 1954 Business Investment*

Assumed improvement rate	Replacement cost of business capital K	Gross earnings rate q	Rate of depreciation δ	Rate of obsolescence ι	Net rate of return $q - \delta - \iota$
$\iota = 0\%$	$650 billion	15.4%	4%	0%	11.4%
$\iota = 2\%$	510 billion	19.6%	4%	2%	13.6%
$\iota = 3\%$	470 billion	21.3%	4%	3%	14.3%

NOTE: Potential gross business earnings in 1954 in the business sector are assumed to be $100 billion.

Row 2 of the table shows a recalculation of the true replacement cost of the capital stock on the assumption that each year there is a 2% average improvement in the efficiency of new capital goods. Of course this estimate is lower than the conventional estimate because of the existence of "old," partially obsolete, capital in the economy.

Row 3 assumes an improvement rate of 3%. This makes the replacement cost in terms of 1954 investment dollars still smaller.

The rest is arithmetic: Remembering to subtract an assumed rate of depreciation of 4% and also subtracting the appropriate assumed rate of obsolescence (improvement), we obtain three estimates of the potential net rate of return to 1954 business investment. On the plausible assumption of 2% or 3% quality improvement the net rate of return is estimated at about 14%. Tangible capital need make no apologies for this respectable rate of return.

AFTER NEOCLASSICISM

While new capital is more efficient than old capital, in the neoclassical conception all this capital is still putty: The distinction is between (old) putty and (new) super-putty. All this capital can be continuously and costlessly reshaped to accord with the price of labor. As the price of labor rises over time, old capital is supposed to be reshaped to use less labor. The labor released is then free to work with new capital.[9]

Valuable though this neoclassical conception undoubtedly is as a mental guide in many economic problems, it is also quite naïve. The typical industrial plant cannot be gradually starved of labor as neoclassical theory supposes: Instead, as the wage rate rises there must come a point where the plant must be altered and renovated if it is to be economic to produce at all. If it is not profitable to renovate, then the plant will be shut down.[10]

Economists are now developing models which capture some of these features of capital goods. A recent group of models represents a *cross* between Harrod-Domar and neoclassical ideas. Only new investments are treated as putty; once their labor requirements are decided upon, this putty turns to hard-baked clay. Thereafter this capital must be combined with labor in fixed proportions, à la Harrod-Domar.

Such models are more complex for the theorist to analyze and "ornery" for the econometrician to use in empirical studies of growth. But in time they will reward us with a better understanding of the connection between investment and growth.

9. In an efficient competitive equilibrium, labor is allocated over all "vintages" of capital in such a way that the marginal productivity of homogeneous labor will be everywhere equal.

10. Students of economics will recall that a plant will shut down if variable costs exceed revenues at the best level of production. If the plant will be economic to operate in the future, then the costs of closing down and starting up again must also be weighed in the decision to shut down temporarily.