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FROM PLEIOSCENE TO PLASTICINE
The Age of Capital Measurement

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Table of Contents

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1. Introduction

In economics, from the time of the classical writers like Smith, Marx and Schumpeter to more modern theorists such as Swann, Solow, Dennison, Griliches and Romer, the central role of labor and capital in explaining the process of economic growth and development has never been in doubt. The essential dispute has only been how labor and capital, in combination and in their various aspects, make their separate respective contributions to production and growth. The topic continues to be the subject of prolonged debate as policymakers search for the appropriate formula that can identify the relative significance of each factor to output and productivity. The debate has not been helped by the absence of satisfactory measures of labor and capital and by a vagueness about the more amorphous process of how the basic factors of production are pieced together and managed to produce output. The following paper looks, first, at traditional approaches to capital measurement and then, secondly, how these have been modified to incorporate notions of quality and productivity. It then examines some alternative approaches to the notion of capital (as a stock) in economics before looking at some extensions to embrace concepts of sustainability and the need for international comparability and (hence) aggregation.

2. Traditional Approaches

2.1 What is Capital?

The term "capital" has different meaning when applied in various contexts depending on whether it relates to financial assets and portfolio investment as reported on balance sheets, or stocks of wealth or productive capital. This is also linked to how history has influenced public understanding of the term (see 4. below).

a) Capital and Other Inputs

Despite recent developments in theory, and the crucial significance economists traditionally attach to the role played by capital in explaining growth, little progress has been made in measuring what it is that economists perceive (not always unambiguously) as "capital". Like money, capital is effectively what capital does, and the importance of capital probably lies more in the economic services it delivers rather than what is represented as its value as a "stock" by what it costs (see later). The imprecision surrounding how capital should be identified and quantified is directly associated with the "fuzziness" of the concept itself and how it is related to production. But, the related concepts of true (net) production or value-added, (gross) output and total basic inputs, are also themselves rather "fuzzy", making comprehension of the linkages between capital and all these other variables vague if not confusing. Output (gross) is some combined measure of quantity and quality; the automobile of 1997 is clearly superior in terms of performance and reliability than one built 30 or 40 years ago but, like for like in physical terms, it is lighter and contains fewer resource based materials.[1] The examples of computers and telephones, which in their external physical appearance have changed very little over the past 10-15 years are, perhaps, even more dramatic illustrations of the increasing "quality" component of output. As providers of a level of service, they have improved their delivery capacity more than ten-fold.

The same applies to the physical and technical aspects of individual inputs. In this case, however, the way the inputs are initially processed, brought together to the place of production and organized at the plant level has also changed significantly. Many production processes are virtually fully automated reflecting how "imbued" technical progress in machine technology and intellectual capital have progressively eliminated the need for direct manual labor. (Indeed, unskilled labor generally has been able to capture some of the economic rent that has accrued from such "invention").

A component of production that, as a direct input, has not changed, however, is energy. Electricity, coal, gas remain the same as commodities, but how they are generated and incorporated into the production process clearly has undergone considerable development and efficiency improvement. Direct inputs like fuel and energy, however, are not in a sense identifiable in some definable physical meaning in the final product. Nor indeed are those inputs connected with communications, storage, insurance, etc. services very visible. Yet here, too, progress has been dramatic. In assessing the true addition to the stock of goods and services available to satisfy customers' welfare, therefore, social scientists have conveniently resorted to more simplified monetary measures that estimate the residual between inputs and outputs, viz. "value-added". Such an aggregate, unfortunately, cannot readily reflect the complex interactions between the whole range and combination of economic activities that have been undertaken to generate this net product outcome.

b) Capital and the Quality of Inputs

Although labor and capital (in external, physical terms that is) can usually be readily identified (and, in principle measured in some sense), they are both in reality highly complex, heterogeneous variables. Not until the post-war period is there any real recognition that factors of production comprise not only a quantity but also an important and crucial quality element. Thus, what in the past had been mainly attributed in traditional production function analysis to "entrepreneurial skill" or to an ill-defined component labeled "technical progress", has turned out to be -- to a very significant extent -- improvements in human capital and technical invention, rather than "autonomous innovation". The latest machinery and equipment usually

[1] Some might argue, however, that an American car of the '40s and '50s -- because it was solid and could potentially last longer - was superior to a modern vehicle, or that the overall quality in terms of durability and reliability of a VW "Beetle" of the 1960s has never been bettered in a small car.

automatically incorporate or ("embody") productivity enhancements in the respective elements of labor (design) and capital contributing to the production process. These inherent qualities reflect continuing investments in social capital such as education, health and vocational experience as well as the acquisition of external knowledge. It is difficult to determine, however, precisely when such "inputs" kick into the productivity process when trying to assess their impact on growth.

To help understand how these newly perceived elements in the growth equation interact, researchers -- who have long drawn an essential difference between the "widening" and "deepening" of capital (in its broadest sense) -- have attempted a more refined distinction between the conventionally acknowledged contribution of exogenous, "quantum" amounts of labor and capital (more people, and more equipment of the same type) and the more elusive endogenous 'quality' components that enhance the efficacy and value of these factors (see Annex I). Indeed, it could even be argued that the "quantum" components represent the static stocks", while the "quantity" elements (which are more variable) reflect the dynamic "flow" inputs to production.

In the case of labor, these "quality" components relate to better education, training and skills learned on the job and work-related "experience". For capital, it is the research and development and technical improvements that are incorporated into the machine, much of which is attributable to more focused inputs of "intellectual capital," research and development, and invention (whether foreign or domestic). The case of computers and their associated software is an excellent and often quoted example. The capacity of today's computer, virtually indistinguishable in outside appearance from one in use a decade ago, is many times greater than its antecedent; and yet the price has even fallen. Not to take these endogenous technological changes and their associated educational developments into account, therefore, could lead to enormous misunderstandings of the estimated contributions of capital and labor to growth in traditional production function analysis.

2.2 Why Measure Capital?

Before deciding what to measure and how to find appropriate data, it is useful to ask why is it necessary to measure capital in the first place? Since the beginning of time when the Ancient Egyptians and then the Roman Empire ruled the World, people and princes have been interested in capital. Initially, capital was regarded as a measure of wealth and status. It represented also, perhaps, a bargaining asset. The first comprehensive quantitative studies like the Doomesday Book that came much later recorded capital holdings of land, buildings and livestock because the authorities recognized that capital not only represented power (to raise armies) and wealth (to entertain the monarch) but could also be a source of income and, therefore, taxation.[2] By the time of Quesnay' s "Tableau Economique" and Adam Smith' s "Wealth of Nations" (an Enquiry into the Nature and Causes of ...), the role of capital not simply as a stock of wealth but as generator of future wealth was

[2] Taxes were levied on the capital directly because it was clearly identifiable and could not be easily shifted or readily translated into something else.

pretty much understood. Later, by the end of the 19th Century, Alfred Marshall was able to draw together the threads of Austrian thinking about "scarcity" and British views on "value" to fuse them into a coherent theory that explained the role of capital in the production process (a perspective, however, that was interpreted differently by Marx in linking capital with capitalism).

2.3 What Should be Measured in this Context?

Economists have long been taxed, therefore, about what is "capital", and so statisticians have been equally exercised and pre-occupied about what it is they should measure. As a first -- and not so bad -- proxy, statisticians decided to calculate as "capital" the value of gross fixed capital stocks (GFCF). Being a value measure, GFCF embraces both quantity and price and over time an indirectly derived (V/Q or V/P) series will embody quality improvements. Unlike labor, there is no identifiable physical aggregate of capital, as the units are all different and can only be aggregated across type. The role of capital in explaining growth and the value of benefits accruing to the community resulting from the use of capital, therefore cannot be easily determined by inspection: without first deciding on what units are to be measured, the assumptions underlying new ideas about economic growth, plus the theories upon which they rest, are hard to test. The relevant data to support them are also difficult to find.

3. From Convention to Complexity

3.1 What are the Dimensions of Capital?

It is important in the first instance, consequently, to decide what are the different dimensions of capital to be identified. Ideas on this have changed with time. Through the "twenties and 'thirties, the importance of capital began to assume a wider dimension with even the popular press and the cinema ("Modern Times", "Metropolis") looking to machines and automated processes to take over all the physical toil associated with work. They saw the role of labor being increasingly confined to operating switches and watching dials. While the West was becoming concerned with how capital could raise levels of productivity and, by making things more efficiently and cheaply, satisfy a growing consumption demand, the newly formed socialist republics of the Soviet Union were focusing primarily on the aspects of technology and economies of scale that could create more capital. By creating more capital at an increasingly faster rate, the Soviet leaders believed this would enable them to catch up and overtake the Capitalist West in an ever shorter space of time.

As the academic literature clearly recognized, all these different aspects of capital -- technical efficiency change, allocative efficiency, relative factor costs and factor contributions, economies of scale, productivity and invention -- are of interest to policymakers. The problem is one of separating them out and explaining their relative importance. This implies determining how technology is imbedded in particular types of capital and how this affects the way such pieces are all fitted together.

As described above, capital, (like labor), possesses both quantity and quality components and, in the production of commodities by means of commodities, it thereby contains hidden efficiency and productivity elements. Indeed, to the most fundamental Marxist -- because of the importance of human invention and "intellectual capital" in creating physical stocks of capital that can be traced (virtually reductio ad absurdum) down a long trail back through the incorporation of labor in the production of all goods used to manufacture other goods - capital itself could be regarded simply as cumulative labor. This does little to help the statistician. Unfortunately, not much additional guidance can be gained from the neo-classical view of capital (Walras, Cassel) because this was never uniform nor especially well defined. The perception of the traditionalists (Smith, Ricardo, Bohm-Bawerk and the like), though clear, remains perhaps rather too simplistic to satisfy the modern economist who is concerned not just with production equilibrium but total factor productivity assessment. Indeed, latter day economists such as Dennison, Maddison and others have clearly demonstrated that the pursuit of this route can yield rather ambiguous interpretations concerning the respective contributions of different factors to growth.[3]

3.2 What Dimensions are of Interest and How Should They be Measured?

Statisticians have resorted to various techniques, therefore, to try to measure the different dimensions of capital that they interpret as being the main interests of economists when the latter want to determine the relationship between factor inputs and their respective contributions to output. In this connection, Ray and Mukherjee (1996) propose a non-parametric method of decomposing the Fisher Ideal Index of productivity into individual factors measuring: --

(i) technical efficiency change

(ii) allocative efficiency change

(iii) shifts in the cost function

(iv) scale economies due to output change

(v) an adjustment factor reflecting change in the output attributes.

In theory, but not always in practice, in a satisfactory way, the concept of total factor productivity can be applied at the sectoral, overall manufacturing and general economic level. Total factor productivity (TFP) as opposed to multi-factor productivity (MFP) growth is customarily calculated as the change in the ratio of output to the weighted average of factor inputs classified into their separate capital and labor components (see OECD method in Annex II).

[3] It is also perhaps necessary to add that other economists have been equally concerned with whether it is aggregate savings or the income distribution itself that determines the amount of capital and hence growth.

The rate of multi-factor productivity growth (MFPG) over time, in the simple, single output -- multiple input case can be measured by the difference in the ratios of growth in the quantity of output and the Divisia index of input quantity. When no technical inefficiency exists, this rate of MFPG can be decomposed into two additive components:-

a) the rate of technical change measuring the rate of change in the volume of output, while holding the input bundle unchanged;

b) a returns to scale effect showing change in productivity with changes in the input quantities without technical change.

When technical efficiency varies over time, a part of the measured rate of MFPG could be due to efficiency change (i.e. there is a separation between technical progress and efficiency in measured productivity growth). Under competitive cost conditions, Ray and Mukherjee assert the autonomous shift in the dual cost function over time can be allocated to the returns to scale effect and the rate of technical change.

In measuring MFPG parametrically, the explicit functional form of a production cost, or profit function, must be pre-specified and the model estimated econometrically to compute the rate of productivity change and its various components. Generally quantity input and output data are required as well as information on respective prices. In a non-parametric approach using a Fisher index, however, the authors show that specific benchmark information concerning prices, quantities or technologies is not needed, although the computed productivity index then does not reveal anything about the sources of change in productivity. But if competitive cost minimization is seen as the standard, then changes can be apportioned to the different elements defined above.

3.3 Multi-Dimensional Capital Measurement in Economic Analysis

Over the past few decades, analytical interest in capital has for the most part focused on the relationship to human capital and growth and only more recently have economists begun to study, in the elaboration of "endogenous growth" models, the importance of the contribution of R&D and the "technology spillover" effects arising from trade in capital goods. Recent empirical findings (Coe and Helpmann; 1995) demonstrate a clear relationship between spillovers and trade using a total factor productivity framework, i.e. there are significant foreign R&D elasticites (rent spillovers) embodied in imported capital. The results have been implicitly disputed, or at least nuanced, by Mohnen (1995) and Verspagen (1996), who (with others) point out that questions of production structure, size of enterprises, their sectoral and technological nature and their form of ownership (and especially their links to government funded research) have a lot to do with whether the "quality of capital" elements are generated by local R&D, foreign knowledge or imported "embodied" R&D. The competitive nature of the domestic market also has an important influence on whether domestically generated technology improvements are readily transferable to smaller or less research oriented firms within the same or technologically related sectors, and whether it is easier for them to buy such technology from abroad.

R & D spillovers, given that technology is seen as the main source of long-run economic growth, provide a crucial part of the explanation of why growth rates differ. But the links are not self-evident; many "low tech" countries have grown faster (and for longer periods) than some high tech countries[4], and the long term growth rates in most advanced industrial countries have remained remarkably stable over the past half-century.

In many, these rates have rarely risen much above of 4 to 5% p.a. for any period of time unless associated with "windfall" resource depletion. This does seem to raise the more fundamental question of whether there is any single factor such as the quality of human capital (for which it is difficult to determine exactly where it links in to the growth process and have any significant impact), local R&D, trade "spillovers", enhanced repairs and maintenance, etc. that can really make a major difference to long term growth and future development potential.

In the most comprehensive study of its kind covering 22 sectors and 14 OECD countries, Verspagen (1996) shows that own direct R&D (including intra-sectoral diagonal "spillovers") yields the most important effects on output with domestic indirect R&D (i.e. technology transferred to non-leading firms) having a much smaller elasticity. Foreign indirect R&D (through imported capital) has the lowest impact of all. When a time dimension is introduced, however, foreign indirect R&D assumes greatest importance, perhaps implying that -- in the cross-country case -- some individual countries experience difficulties in assimilating foreign R&D. Clearly, too, there are differences between industries in terms of their production structures and in the levels and types of technology they employ which may account for significant differences in rates of assimilation.

Distinguishing between high-tech, medium-tech and low-tech sectors (not enterprises), Verspagen comes up with the not surprising finding that direct R&D is most significant in the high-tech sectors and lowest in the low-tech sectors (where there may be little R&D in general). For the low-tech sectors, domestic indirect R&D spillovers and trade spillovers share a similar importance.

These findings can be used to obtain a more refined understanding of the sources of national total factor productivity (TFP) growth defined in terms of a logarithmic transformation of a traditional Cobb-Douglas production function. This equation links output to capital stock, labor, own R&D, indirect domestic R&D and foreign technology spillover effects, all measured as stocks. With cross-sectional analysis related to growth rates over a given time period (Verspagen takes 1980-88), it is also possible to distinguish between R&D/TFP generating countries and R&D/TFP receiving countries. Verspagen's results show clearly that, as

[4] This is mostly because they start from a lower GDP and capital base and their rate of capital accumulation is faster (see discussion under "International Comparisons of Capital").

expected, Germany, Japan and USA (in order of importance) have a significant impact on other countries TFP growth and that the Netherlands, Norway and UK are countries (notably with a high trade ratio) which have assimilated large foreign contributions to domestic TFP. Again, it is necessary to examine such general conclusions in more micro detail at both the sector and enterprise level, and to look further into the relative contributions of" pure knowledge" acquisition (patents, technical articles etc.) and imported technology gains obtained through imported equipment purchases when determining the importance of foreign knowledge spillovers.

The results do seem to suggest, nevertheless, that countries that are more open to trade are also more absorbent of foreign knowledge in general as well as acquiring that embodied in purchased capital inputs. What is indisputable is the importance of both international and domestic R&D spillovers to productivity growth in major OECD countries. Other recent studies (Bosca, Fuente and Domenech, 1996) also point out the strong positive complementarity between human capital stock and R&D investment showing both to be important and self-reinforcing determinants of the rate of productivity growth.

4. Rethinking the Perspective on Capital

4.1 The Link Between Output and Factor Inputs

Value added is a flow concept while labor and capital are basic stocks. Furthermore, while value added is notionally an output, it is approached essentially by measuring inputs. Many economists have long felt uncomfortable with the use of" net" figures in the national accounts, partly because many other variables of interest correlate with gross measures, and partly because of suspicions regarding the soundness of the estimates of depreciation and the fact that such capital consumption relates only to produced capital. In addition the recurring 'heavy' weight of construction capital, buildings, etc. in the capital stock (in part because of actual cost, in part because of their length of life) exerts a dampening effect on the real value of new additions to capital to total output growth.

4.2 Capital Consumption as Capital Service Value

Value added, as an output concept, is measured as the sum of its respective factor inputs, i.e. the value of the application, over a given period, of capital, land and labor to the raw materials inputs that go in to producing a certain production level. In principle, such measures should be in quantum terms but, given the impossibility of aggregating resources denominated in different units, the contribution of each component in these equations is assessed in terms of value in constant prices. What is clear is that there is a specific time bound to this assessment and that when labor and capital operate on a collection of inputs in a production process, they effectively provide productive services to a set of inanimate objects.

To explain clearly the contribution of labor and capital to economic "development", the latter being more specifically defined as growth in GDP, it is necessary to place the valuation of both factors on an equal footing. If labor is rewarded by the value of its marginal product it is then, by definition, a "service flow" concept. This is consistent with the idea of both value added itself and annual additions to that net output (growth). In early discussion (Ward, 1976), it was suggested that capital, measured as gross fixed capital stocks, did not fall into this category and, indeed, that net capital stocks was no better, therefore, as a measure. In the absence of a valid capital "flow" measure to quantify the real value of the services that capital renders to yearly output, it was suggested than an "annualized" capital measure would be more appropriate. Since the value of capital in theory in a well functioning economic system is equivalent to the total present value of the discounted future annual returns to capital over whatever the respective asset lifetime is thought to be, i.e. the aggregate net income stream discounted to the present, the annual contribution of a piece of capital can be approximated by taking the present value of that capital stock item divided by its expected durability in years. In other words, the resulting statistic can be taken as a proxy to represent the combined "service" inputs of capital to output. It would be effectively equivalent to the consumption of capital in the year in question.

How much capital contributes to production in any year, of course, depends on a variety of factors but, given the law of large numbers covering all types of capital when they are aggregated, and assuming good repair and maintenance activities are continued throughout their use, the value of a piece of equipment (like an hydraulic press) at the beginning of its lifetime will be similar to that at its end. When the technology is new, there are usually some "teething problems" and operational lessons to be learned at the start of its use; and it is probably equally reasonable to assume that as a machine nears the end of its life (even when it is beginning to wear out and become obsolescent, i.e. too expensive to operate), it will have a similar value if its physical production characteristics remain the same. If this is the case, then the "contribution of capital" can be approximated by a simple straight-line depreciation function. The only problem here is that the value of each piece of capital is related to its vintage because, implicitly, its value is defined in terms of the prices prevailing in the year in which it is installed or comes on stream. In other words, such a valuation is in "historical prices", when it is "replacement value" that matters. The age of capital related to the specific "vintage" of a piece of equipment is significant, not only for this reason but also because it has an important bearing on its state of technology and, hence, on its subsequent obsolescence and economic lifetime.

4.3 Energy as a Proxy for Capital Use

Another way to approach this same question of service value may be to assume a set of given power: to output ratios in different sectors and use energy inputs as a proxy for the real contribution of capital. In so far as in the short run there are probably fixed technological coefficients relating energy requirements to power needs for a given stock of capital, changes in the flow of energy through the production work place will reflect capacity utilization and can serve as a proxy for when and where and how much capital is actually being used in the process. But, there are problems; energy is ubiquitous and it can't reflect the operating improvements in capital and gains in efficiency that are constantly taking place. Also the amount of energy used in a plant reflects factors other than on-line production, e.g. changes in the weather, or switches in the pattern and composition of the basic energy supply itself. As earlier indicated, improvements in the way energy is generated and applied has an impact on overall value added in a way that is independent of the use and utilization of capital. This approach is limited, however, mainly because it is restricted to "operating" productive capital (and often only in combination or "gross" for a plant).

Capital items that do not rely on energy inputs for their effective functioning, cannot be covered in this way. Public infrastructure capital like roads and buildings, characteristically not only do not have this link to energy use -- or any link that is related directly to output -- but they also represent goods and services that are not generally marketed. The production of goods and services to which public capital has contributed and that are provided collectively to the community may not be valued; or they may be valued differently to the market.

The traditional means of evaluating fixed assets may thus prove less than satisfactory as measures of capital in certain contexts. In many advanced industrial countries where the more conventional yardsticks have fallen short in providing relevant signals for policy action, the combination of narrow short term financial perspectives and limited traditional accounting practices have contributed to arbitrary measures of the real value of capital. Often, this is simply on practical costing grounds. Such accounting practices could lead to inappropriate assessments of the rate of depreciation and to inadequate measures of the loss of value of physical capital during use, even when assessed in financial terms. At the extreme, in many developing countries, it is evident that key public infrastructure facilities through lack of funds for upkeep have been allowed to deteriorate. This is partly because much of the state owned and maintained capital cannot be readily connected to a market and thus to pecuniary returns, and to the output it generates. In some sectors and countries, the present conventional procedures for measuring capital as gross fixed stocks, therefore, would show a capital "value" where, in reality, little value exists because the capital concerned does not provide a satisfactory or adequate service related to its design capacity. The conventional measurement method adopted offers little scope or guidance for placing a value on the need to maintain such capital.[5]

[5] A parallel can be found in the degradation of natural environmental assets, where present generations use up scarce, non-renewable resources because they are not required to pay the costs of resource depletion, and their replacement. They are only concerned to benefit from their extraction.

5. Capital as a Flow of Physical Services

5.1. Why an Alternative Approach?

Much capital, and particularly public capital, that is put in place is designed from the outset to provide a specified level of service. The quantity, quality and reliability of the flow of services, and the actual carrying capacity of installed assets, are critical when it comes to measuring the real contribution of that capital to an economy. To carry out capital service flow assessments properly, therefore, it seems necessary first to identify relevant output and impact "performance" indicators. The need to resolve some equally complex questions of aggregation, scale ordering and weights for such measures has also to be faced.

Investment in capital assets and their maintenance can be viewed as decisions which are based on the value that decision-makers place on existing assets. In turn, of course, this is related to their expected profitability. Investment decisions, however, are mostly "partial" or combined additions to GFCF and estimates of rates of return need to be evaluated in the context of how the additional assets harmonize with the existing stock of capital, and how they balance with other factors already in place.[6] As investment accumulates and the stock of capital expands, the introduction of new assets will tend to represent a progressively smaller component of the total capital stock. The ability of this new investment to provide future services will depend on how well it can be integrated effectivelyinto the existing stock of capital and how satisfactorily it will blend in with the pattern of service this capital already delivers, since the latter will comprise the dominant characteristic of the level of service provided. This can only be assessed in terms of the service performance of the aggregate stock.

5.2. The Measurement of Capital Services

As has been seen, in theory, if product and factor markets are functioning effectively, the price of an asset will be its present value which is related directly to its expected contribution to profits and turnover. But, reflecting the conflicting arguments that have raged over the meaning of capital, policymakers are confronted by a choice between monetary or physical indicators to measure output streams. Since capital forms an important component of the production function, as a concept, it appears to sit firmly on the supply side of the equation. But, as has been evident over successive business

[6] This underlines the difficulty, in practice, of distinguishing between "fundist capital" and : materialist capital"; see Hicks (1974).

cycles, the capacity to produce is not the same as the actual contribution to production. The length of life of a piece of capital, for example, is linked to the enterprise as a going economic concern. Both physical and financial factors may cut that life short -- or, indeed, prolong it. In the case of installed productive capital and social overhead capital, the availability of supply factors available to generate output determines neither their use, their usefulness, nor their utilization. Thus, the traditional practice of using the cost of capital to best represent the value of capital in productive activity may be again misleading.

5.3 The Real Demand for Capital

A more meaningful approach, at least for some types of capital, thus may be to consider the importance of capital from the standpoint of the demand for its real services. This is particularly relevant in the case of estimating the value of infrastructural facilities and social overhead capital where the direct link to production performance is unclear and non-market situations often apply. A procedure that focuses on the value of services received by users and, therefore, on measures of demand, clearly has considerable merit. The real output, represented by the actual level of services delivered, is often measurable and comparable using physical indicators. Early social cost benefit analysis strove to quantify this when appraising large projects. The distinction between the two approaches, however, rests more with the financial marketability of output and the perception that certain forms of capital constitute direct rather than indirect components of final output value. Roads, vehicles, railways, ships, aircraft, telephones, water supply and even street lighting, for example, all have an identifiable (if not always easily measurable) end-use and their output can be quantified. Such capital serves both intermediate and final demand. Plant and machinery and factory buildings, on the other hand, only provide an indirect contribution to output. As factor inputs, used in combination with other factors, their individual contributions to final output are often less evidently quantifiable, even if their specific machine output can usually be physically determined.

6. International Comparisons of Capital

When making comparisons across countries, determining consistent and standardized measures for a concept like capital poses a number of methodological questions. Their satisfactory resolution, however, can assist analysts in making economic policy formulation more meaningful and operationally relevant. The World Bank, for example, globally finances from its capital fund investment projects designed to support sustainable socio-economic development in its member countries. Such investments are intended to help borrowers make the best use of their natural, financial, physical and human resources to achieve development. But allocations are made on a country by country basis and the use of capital is not necessarily optimized in a truly global economic sense.

Existing international comparisons of capital are less than satisfactory. This is not just because they are locked into the conventional methods of statistical evaluation. Across countries, there is no common measure of capital available (even assuming the concept and definition are the same) that can provide a consistent assessment of the economic value of productive assets in different geographic situations. Historically, therefore, comparisons of relative growth and productivity performance between countries have been carried out mostly using "within country" variables to explain differences. The approach has been to link output in a given country to domestic capital and internal labor factors to describe variations in that country's economic activity. Since the end results of such exercises are apparently "value free" if not "value neutral" (expressed in terms of growth, percentage changes in net output per capita, etc.) they are deemed to be directly comparable across countries. Few seek to question the intrinsic validity of inter-country comparisons (are the deflators relevant and comparable?) and whether the explanatory "input" variables-- if measured on a cross-sectional basis -- are truly comparable. From an analytical perspective, these studies do not allow policymakers to conclude very much about the actual size and importance of the contribution of capital to the process of development in different countries. Where a broader international perspective of resource allocation is needed, the results fail to help those charged with disbursing funds to identify where investment is most effective in raising output and income levels.

There have been one or two small "regional" based studies covering a handful of countries, and the University of Pennsylvania's Penn World Tables" contain more extensive country series but there has been no comprehensive international comparison until a few years ago when the World Bank carried out a quick and dirty study of Capital Stock Estimates for ninety-six (96) countries. Comparable capital measures for developing countries were few and far between and the Bank simply applied the standard perpetual inventory model (PIM) to the reported country specific gross fixed capital formation series (GFCF). It did this in constant 1987 US dollars over the period 1950 to 1990 to generate comparable capital stock estimates for a ten year period, 1980-1990. The study, being the first comprehensive one of its kind possessed, however, some important limitations. It adopted some highly restrictive and unsuitable statistical assumptions that included the application of uniform across the board service lives for the different classes of physical assets in all the countries studied. In all cases, lifetimes of thirty-five (35) years were applied for buildings and construction and fifteen (15) years for machinery, transport and other equipment. The model also used a simple standard rectangular or single exit distribution for capital retirements for both categories of assets. The service lives were allegedly based on the respective unweighted average of asset lifetimes in a sample of countries (thought to belong to the OECD). These service lives were deemed also to remain constant over the whole forty (40) year period of the calculations. The constituent country specific investment series were initially converted into constant 1987 US dollars at the prevailing nominal exchange rate (IMF 'rf" series) to provide a standard (but not equivalent, nor uniform) valuation basis.

The exercise was designed primarily to facilitate a standardized "transparent" calculation. It could perhaps be justified on the grounds that, in most developing countries, at least in the case of imported machinery and equipment, much of the capital would be imported, similar and substitutable. Furthermore, most equipment in these countries would originate from the same basic source, i.e. the G-7 or OECD industrial countries, and would be competitively priced.

Surprisingly, the results were meaningful, analytically interesting and far from counter intuitive. They showed that the rate of capital accumulation in East Asia was much faster than in other regions and that the growth in assets in that region had been particularly impressive in the area of machinery, transport and other equipment. This strongly supported the belief that embodied technical progress incorporated within new equipment, in particular through imported machinery, had been rapidly absorbed in East Asia (through trade especially) and that this, in turn, had contributed significantly to income growth in the region. The results also revealed that, by comparison in the case of Europe, Sub-Saharan Africa, Latin America and the Middle East and North Africa, the relative share of plant, machinery and equipment in the capital stock declined over the decade of the 1980s. Only in the OECD countries did the share of machinery also rise. Furthermore, the absolute share of machinery in the capital stock was highest for East Asia and lowest for the Middle East and North Africa. Calculated on a per capita basis, the differences appeared even more significant.

Such analytically interesting measures, however, need to be placed on to a sounder conceptual basis. Most importantly, in comparing capital across countries, it is necessary to move away from exchange rate valuations and shift to a purchasing power parity basis for compiling the fundamental individual country level GFCF series used in the perpetual inventory model. The PPP adopted should also relate to its respective sector or expenditure category level rather than to the overall GDP purchasing power parities (PPPs). In this way, more comparable estimates of investment on the basis of a common currency denominator that eliminates the differences between countries in relative national and sector price levels will be obtained. The value of investment and the associated rate of return on capital in different situations can be thus better compared in a relatively uniform and equivalent manner across countries. Depending on the specific aims of the study and whether comparable estimates of real change over time are required, the decision will still need to be made as to whether to apply a single year's PPP (such as the latest "replacement cost" year) or use a sequence of annual PPPs. Given that PPPs are more stable than exchange rates over time and are linked more closely to relative trends in domestic inflation (although perhaps less so in the case of imported machinery and equipment), it may not be so materially important to select any particular base reference year to effect this transformation process. Indeed, whatever the choice, it is unlikely all countries will be able to conform to the same view as to a base reference year's "normality".

Because of variations in capital use and in climatic and other conditions, it would be desirable to dispense with the "consistency"assumptions about uniform lengths of life and a standard single exit retirement function across all countries. If good information exists about the actual lifetimes of different classes of assets, these would have more meaning. Though country specific lifetime estimates merely represent historical experience with already retired capital, they tend more closely to reflect the reality of existing practice (and the actual assumptions of entrepreneurs). In the absence of anything better, they can serve as an appropriate proxy.[7] Modifying the length of life assumptions over time to take account of faster rates of technical progress and more rapid scrapping patterns would yield some improvement. If analytical interest is mainly in the relationship between production capacity and development potential, it would not be necessary to introduce additional capital utilization coefficients. These are interesting, however, in adjusting the derived capital stock estimates to reflect the real operational productive contribution of such assets. Such a modification would possibly help explain better actual growth performance.

7. Extended Notions of Capital

7.1 Sustainability and Wealth

The method of estimation of capital stock and depreciation has wide-ranging implications for countries, not least in looking at more recent concerns about genuine saving and the wealth of nations. These broader concerns take a more extensive view of the concept of capital and expands it to embrace the contribution of "nature", and particularly the natural resource environment -- perhaps what some former economists traditionally might have referred to more vaguely as "land." But much natural capital is non-reproducible (which makes it nonetheless important) and, as such, it cannot be seen in the same way as physical capital which has, as one of its more important characteristics, the capacity to be replicated. Capital must also be able to provide a continuing and regularly reproducible contribution to production.

7.2. True Savings and Capital

Now that sustainable development is an explicit strategic goal of most policy makers, however, net product, net income, net savings and net investment have assumed a more important role as principal indicators of economic progress. The Bank, through its recent work on "Sustainable Economic Development" carried out under the auspices of its Environment Department, has been conducting research on the measurement of "genuine saving" that take account of broader concepts of wealth. This is because some natural wealth has been considered usable capital and, through its disposal and sale, it has generated income flows that have reduced its value as a stock of capital because such income has been channelled into private and public consumption rather than being converted into other productive capital assets that can continue to generate future income. With the decline in real wealth, there has been a corresponding decline in sustainable income and its mirror economic counterpart, genuine or true savings. Although net savings figures are useful economically, they are only the necessary first step in measuring genuine saving which, in turn, is an indication of the potential for the capital base to grow. In many countries, traditional net saving appears to be near zero,which should set off an alarm signal of trouble for any policy economist. Aggregate real savings, therefore, can easily become negative if the depletion of resources (natural wealth) and degradation of the environment are taken into account as measures of total capital available.

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[7] Most assets are, physically, more durable than their actual economic lifetimes. But, in recent years, the more rapid advancement of technology often renders them obsolescent much sooner.

Annex I

Structure of Net Output Value

Gross Output = Factor Inputs + Intermediate (Basic) Inputs
Value Added = Gross Output Value - Basic Input Value
= Returns to factor inputs
(broadly, the value of contributions of labor and capital)

= $L.\bar{w} + K.\bar{r}$ (respective factor "stocks x their average "reward")

where L = Labor Quantity + Labor Quality

= Basic numbers by sex + education, skills, work experience, etc.
(and possibly age)

and K = Physical Units of Machinery, etc. + Quality of that Capital
(to be defined) (technology, patents, invention)

$\bar{w}$ = average wage rate

$\bar{r}$ = average rate of return on capital

In reality, $L.\bar{w}$ = $\sum L_i w_i$ for different grades of labor,
or $Q_L.P_L$

and $K.\bar{r}$ = $\sum K_i, r_i$, for different types of capital

But this is = $Q_k P_k r_k$
where r_k is a value free vector obtained from
"returns($)/capital value ($)" for different pieces
of equipment

Thus, $\sum K_i.r_i = Q.p.\frac{R}{Qp}$ (for all i) where R = actual ($) returns to capital

= Gross operating surplus (for all sectors), a "fundist
capital" rather than "materialist capital" concept.

In other words, the real elements of labor and capital are quite different and they are applied to net output value in a separate disaggregated form that is not consistent.

Total Factor Productivity

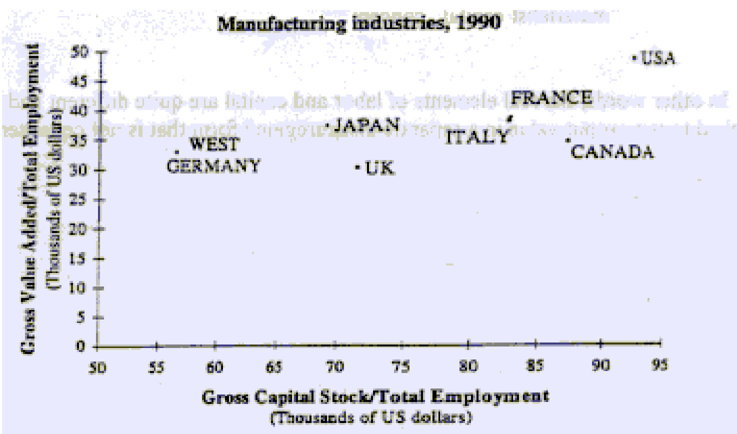
The concept of total factor productivity (TFP) has been the focus of interest in a number of recent studies, notably at the level of aggregate manufacturing industry and the business sector. The ISDB permits an extension of a similar approach to a number of individual sectors of the economy. Essentially, total factor productivity growth is calculated as growth in the ratio of output and the weighted average of factor inputs, in this case capital and labour inputs.

$$TFP = \left[\frac{VA}{ET^{(w)} * GCS^{(1-w)}} \right] / TFP_0$$

TFP	= Total factor productivity index
GCS	= Gross Capital Stock
VA	= Value added
ET	= Total employment
w	= Standardised labour share weights
TFP_0	= Total factor productivity, 1985 value

Capital-output ratio

The graph below shows the relationships in 1990 between employment and each of gross capital stock and gross value added for countries of the 67. Gross stock of fixed capital and gross value added are expressed at 1985 prices. (Source: ISDB 95).



Bibliography

Barna, Tibor (1961), "On Measuring Capital in The Theory of Capital by F. A. Lutz and D.C. Hague, MacMillan, New York.

Bliss, Christopher (1996), A review of "Theory of Production: A Long Period Analysis," by Heinz Kurz and Neri Salvadori, Economic Journal, Vol. 106, No. 439.

Bosca, Jose; Angel de la Fuente and Rafael Domenech (1996), "Human Capital and Growth: Theory ahead of Measurement," 24th General Conference of the International Association for Research in Income and Wealth (IARIW), Lillehammer, Norway.

Coe, D. T. and E. Helpman (1995), "International R & D Spillovers," European Economics Review, Vol. 39.

Denison, E. F. (1967), "Why Growth Rates Differ: Postwar Experience in Nine Western Countries," The Brookings Institute, Washington D.C.

Farrell, M. (1957) "The Measurement of Productive Efficiency," Journal of the Royal Statistical Society, Series A, Vol. 120.

Goldsmith, Raymond and Christopher Saunders (1959), "The Measurement of National Wealth," Income and Wealth Series VIII; Bowes & Bowes, London.

Griliches, Z. (1979); "Issues in Assessing the Contribution of Research and Development to Productivity Growth; The Bell Journal of Economics, Vol. 10.

Hee, Michael and Raquel Fok (1993), "Physical Capital Stock: Estimates for Developing Economies," Socio-Economic Data Division Working Paper, The World Bank, Washington D.C.

Hicks, J. R. (1946), "Value and Capital" (2nd edition), Oxford University, Clarendon Press.

Hicks, J. R. (1974), "Capital Controversies: Ancient and Modern," American Economic Review, May.

Kendrick, John (1967), "The Formation and Stocks of Fixed Capital," NBER, Columbia University Press, New York.

Mohnen, P. (1995), "Some Estimates of International R&D Spillovers" Paper presented to the productivity conference, "The Emerging Knowledge-based Society," Vienna.

Nehru, V., E. Swanson and A. Dubey, (1995), A New Database on Human Capital Stocks in Developing and Industrial Countries: Sources, Methods and Results," Journal of Development Economics, 46.

OECD (1993), "Methods Used by OECD Countries to Measure Stocks of Fixed Capital," National Accounts: Sources and Methods, Paris.

Ray, S.C. and K. Mukherjee (1996), "Decomposition of the Fisher Ideal Index of Productivity: A Non-parametric Dual Analysis of US Airlines Data," Economic Journal, Vol. 106, No. 439.

Romer, P.M. (1990) "Endogenous Technological Change," Journal of Political Economy, Vol. 98.

Summers, R. and Alan Heston (1991), "The Penn World Tables (Mark 5): An Expanded Set of International Comparisons, 1950-1988," Quarterly Journal of Economics CVl(2).

Verspagen, Bart (1996), "Technology Spillovers and Growth, A Reassessment of the Empirical Evidence," 241h General Conference of the IARIW, Lillehammer, Norway (Maastricht Economic Research Institute on Innovation and Technology).

Ward, Michael (1976), "The Measurement of Capital," OECD, Paris.

Ward, Michael (1996), "A Perspective on International Comparisons of Capital," in "International Comparisons of Prices, Output and Productivity," by D. S. Prasada Rao and J. Salazar-Carrillo, Elsvier, North Holland, Amsterdam.