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CAPITAL AND ITS PRODUCTIVITY IN FINLAND, 1975-2001*

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AULIN-AHMAVAARA, PIRKKO – JALAVA, JUKKA: CAPITAL AND ITS PRODUCTIVITY IN FINLAND, 1975-2001.

Abstract: The fundamental role of capital in economic growth has been long known. How capital should be defined and measured has been the subject of much discussion. The starting point of this study is methodological as we define starting from a neoclassical production function the indicators for capital input and compare these with the traditional capital stocks of national accounts. The origin of Finnish capital measurement is also traced. In the empirical part of the paper we apply the different capital measures to Finnish data in 1975-2001. This period is interesting as the early 1990s was a turbulent period for Finland with GDP declining by 11 per cent. We find as a result of our number-crunching effort that there was a spectacular increase in capital productivity growth after the recession. Finally, we observe how our new estimates accord with the previous view on how capital has influenced recent Finnish historical economic development. Our main result is a resolution of the Artto-Pohjola paradox, as we show that a high rate of return was combined with a low capital productivity growth in 1975-1990.

Introduction

The fundamental role of capital in economic growth has been known at least since the writings of the physiocrat Anne-Robert-Jacques Turgot and Adam Smith in the 18th century. Since Karl Marx and the Cambridge controversies there has been constant dissension on how to define capital and what for instance is meant by the quantity of capital. Separate views even exist on the question whether heterogeneous capital can be aggregated into a single measure of capital at all. The practical measurement of capital is also subject to opposing views. Therefore the economic historian doing research on matters pertaining to capital should be prepared to meet criticism. However, as Hicks has it:

> *"Capital (I am not the first to discover) is a very large subject, with many aspects; wherever one starts it is hard to bring more than a few of them into view. It is just as if one were making pictures of a building; though it is the same building it looks quite different from different angles."* [1]

While the recent discussion in the historical economics literature has focused on alternative models explaining economic growth[2], i.e. exogenous or endogenous growth[3], institutions[4] and catching-up[5], the problems relating to capital measurement are many times ignored altogether, and often K is casually written to denote both the value of capital and the input into production it provides, both of which are then assumed to decline uniformly by the same rate δ, which is called the depreciation rate.

In the national accounts (SNA93[6] and ESA95[7]) on the other hand, there are two measures of capital stocks: the gross capital stock and the net capital stock. The traditional capital stock measures have been developed since the 1950s and due to their easy availability they have been widely used in productivity calculations. However, neither national accounts capital stock measure is appropriate for use in productivity or growth accounting computations. The gross capital stock does not

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[1] Hicks, John, *Capital and Time*, Clarendon Press, Oxford, 1973.

[2] For an overview of the models, see: Crafts, Nicholas, Productivity Growth Reconsidered, *Economic Policy,* Vol. 15, October 1992, 388-426.

[3] Crafts, Nicholas, Exogenous or Endogenous Growth? The Industrial Revolution Reconsidered, *Journal of Economic History,* Vol. 55, December 1995, 745-772. Greasley, David and Oxley, Les, Endogenous Growth or "Big Bang": Two Views of the First Industrial Revolution, *Journal of Economic History,* Vol. 57, December 1997, 935-949.

[4] Booth, Alan, Melling, Joseph and Dartmann, Christoph, Institutions and Economic Growth: The Politics of Productivity in West Germany, Sweden, and the United Kingdom, 1945-1955, *Journal of Economic History,* Vol. 57, June 1997, 416-444.

[5] Abramovitz, Moses, Catching Up, Forging Ahead, and Falling Behind, *Journal of Economic History,* Vol. 46, June 1986, 385-406.

[6] SNA93, *System of National Accounts 1993*, UN, OECD, EU, IMF, World Bank, 1993.

[7] ESA95, *European System of Accounts*, Eurostat, 1996.

take into account the possible decline in the capital good's productive capacity as it ages. The net capital stock depicts the market value of capital and not its productive capacity.

In growth accounting based on neoclassical theory (and the productivity research associated with it), the measure of capital input to be used (instead of gross or net stocks) is widely accepted to be the Jorgenson and Griliches[8] measure of capital services based on the concept of productive capital. The productive capital stocks of homogeneous capital goods are aggregated using their rental prices. Complete consensus has not been reached on the empirical side either, though there has been a vivid recent discussion, especially under the auspices of the OECD.[9] The differences in opinion mainly focus on the definition and quantification of depreciation.[10] There is no consensus on what the measure of capital should encompass either. In productivity research produced fixed assets, land and inventories are often included in capital input. In addition to these, human capital and natural resources are needed in production. Research and development expenditure can also be seen as capital formation. In some cases even the inclusion of financial capital into the measure of capital input has been suggested.[11]

The purpose of this paper is twofold. Firstly, we introduce state-of-the-art tools of economic analysis to Finnish data and extensively discuss what kind of theoretical and empirical choices have to be made in quantifying capital and its contribution to growth and productivity in the period 1975 to 2001.[12] The origin of Finnish capital

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[8] Jorgenson, Dale W. and Griliches, Zvi, The Explanation of Productivity Change, *Review of Economic Studies*, Vol. 34, July 1967, 249-283.

[9] OECD, *Methods Used by OECD Countries to Measure Stocks of Fixed Capital*, National Accounts: Sources and Methods, No. 2, Paris: OECD 1993. OECD, *Measuring Capital - OECD Manual: Measurement of Capital Stocks, Consumption of Fixed Capital and Capital Services*, Paris: OECD 2001. OECD, *Measuring Productivity - OECD Manual: Measurement of Aggregate and Industry-level Productivity Growth*. Paris: OECD 2001. Aulin-Ahmavaara, Pirkko, The SNA93 Values as a Consistent Framework for Productivity Measurement: Unsolved Issues, *Review of Income and Wealth*, Volume 49, March 2003, 117-133.

[10] Hill, Robert J. and Hill, T. Peter, *A New Conceptual Approach to the Measurement of Capital Gains, Depletion and Net National Product*, School of Economics, University of South Wales, Discussion Paper 99/9.

[11] Keuning, Stephen, The Role of Financial Capital in Production, *Review of Income and Wealth*, Volume 45, December 1999, 419-434.

[12] The reason we start our periodization from the year 1975 is that the share of secondary production in GDP only peaked as late as 1974. Thus the pattern of development thus far had differed in Finland from other developed countries, where usually the main contribution to economic growth first shifted from primary production to secondary production during the process of industrialization, and subsequently from secondary production to tertiary production as countries entered the post-industrial stage. Although the absolute contribution of services to GDP in Finland surpassed that of secondary production already in 1956, both continued by and large to increase their relative shares at the expense of primary production until 1974. Hjerppe, Riitta, *Suomen talous 1860-1985, kasvu ja rakennemuutos*, Studies on Finland's Economic Growth XIII, Bank of Finland Publications, Helsinki, 1988.

measurement is also traced. We observe how the different capital measures perform in a turbulent period in Finnish economic history. This period is interesting because the Finnish economic recession in the early 1990s was very severe; with GDP declining by 11 per cent from 1990 to 1993 (the 1930s recession was much less severe in comparison as GDP declined by only 3.5 per cent 1929-1931). We define capital as produced tangible fixed assets such as machinery, equipment, and produced intangible fixed assets such as computer software, and construct in the neoclassical tradition the indicators for capital input and compare these with the traditional capital stocks of national accounts in Finland. We show how the rental prices are used in the aggregation of heterogeneous productive capital stocks into a volume index of capital services for the whole economy, and discuss the alternative rates of return on capital. A sensitivity analysis on the impacts of the different capital measures on growth, capital productivity and multi-factor productivity (MFP) is also performed, which to our knowledge has not been done for Finland before. The most significant result of our number-crunching effort is an observation of a spectacular increase in capital productivity growth in the latter part of the 1990s. Secondly, we observe how our new estimates accord with the previous view on how capital has influenced recent Finnish historical economic development. Olli Haltia and Mikko Leppämäki coined the term Artto-Pohjola paradox, to describe the seemingly conflicting observations of Matti Pohjola and Eero Artto.[13] Pohjola observed that in 1960-90 a high investment ratio resulted in low capital productivity growth and concluded that capital was inefficiently used in Finland. Pohjola acknowledged that capital fundamentalism, the view that economic growth would be attained by massive fixed investments, did result in growth. His point was that the high social cost paid by Finland due to high investment ratios could have been lower with a more efficient use of capital. Artto countered with his findings of reasonable returns on capital especially in the paper industry. We offer an empirical resolution (as Haltia and Leppämäki already presented a theoretical one) to the Artto-Pohjola paradox by observing how capital productivity and the return on capital have evolved. In our results we show that a high rate of return was combined with a low capital productivity growth in 1975-1990.

This paper is organized in the following way. First the stage is set by going through the genealogy of capital measurement in Finland until their incorporation in the national accounts. We continue by showing how capital is defined in the national accounts and how these definitions are related to the productive capital stocks and their rental prices. The penultimate section contains our empirical results and the ultimate section concludes.

[13] Haltia, Olli and Leppämäki, Mikko, Do Shareholders Care About Corporate Investment Returns?, *Finnish Economic Papers,* Spring 2000, 19-27. Pohjola, Matti, *Tehoton pääoma. Uusi näkökulma taloutemme ongelmiin,*WSOY, Helsinki, 1996. Artto, Eero W., *Performance and International Competitiveness of Listed Paper Industry Groups 1982-1996 – Finland vs Sweden, Canada and USA*, Helsinki School of Economics, Working Papers W-182, 1997.

Previous research

Both in productivity analysis and growth accounting capital input is often measured by using either gross[14] or net[15] capital stocks (or both[16]). The stocks are constructed using the perpetual inventory method (PIM) pioneered by Raymond Goldsmith in 1951.[17] Neither of these stock measures, however, depicts the productive capacity of capital. In the GCS the capital good is assumed to retain its full productive capacity until retirement. The NCS is a measure of wealth; it describes the market value of the capital stock. The market value is of course dependent on the expected evolution of the productive capacity, but does not reflect the productive capacity at a certain point in time. The value of the asset declines as its service life draws to an end (with less future revenues accruing) even though no physical deterioration in the capital good's productive capacity necessarily takes place. In growth accounting based on neoclassical theory, the measure of capital input to be used is widely accepted to be the Jorgenson and Griliches[18] measure of capital services based on the concept of productive capital. The productive capital stocks for homogeneous capital goods are aggregated using their rental prices. Intuitively, when adding up e.g. the stocks of non-residential buildings and computer software, we must in the production function take notice of the fact that their respective service lives and price changes are very different (computer software must generate revenue in a much shorter period than buildings, since capital theory[19] tells us that the capital assets value equals the discounted flow of future rental payments that the good is expected to accrue).

Olavi Niitamo[20] distinguished the difference between the capital in place (stock)

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[14]Denison, Edward F., United States Economic Growth, *Journal of Business,* Vol. XXXV, April 1962, 109-121. Maddison, Angus, Growth and Slowdown in Advanced Capitalist Economies, *Journal of Economic Literature*, Vol. XXV, No. 2, 1987, 649-698. Kendrick, John W., How Much Does Capital Explain?, in Szirmai Adam, van Ark, Bart and Pilat, Dirk, (eds.), *Explaining Economic Growth, Essays in Honour of Angus Maddison,* Contributions to Economic Analysis, North Holland, 1993, 129-145. Maddison, Angus, Macroeconomic Accounts for European Countries, in van Ark, Bart and Crafts, Nicholas, (eds.), *Quantitative Aspects of Post-war European Economic Growth,* CEPR, Cambridge University Press, 1996, 27-83. O'Mahony, Mary, Measures of Fixed Capital Stocks in the Post-war Period: A Five Country Study, in van Ark, Bart and Crafts, Nicholas, (eds.), *Quantitative Aspects of Post-war European Economic Growth,* 1996, 165-214.

[15]Kendrick, John W., *Productivity Trends in the United States,* Princeton, 1961. Nordhaus, William D., The Recent Productivity Slowdown, *Brookings Papers on Economic Activity,* Vol. 1972, No. 3, 1972, 493-545.

[16]Denison, Edward F., The Interruption of Productivity Growth in the United States, *Economic Journal,* Vol. 93, March 1983, 56-77.

[17]Goldsmith, Raymond W., A Perpetual Inventory of National Wealth, *Studies in Income and Wealth*, XIV, New York: NBER, 1951.

[18] Jorgenson and Griliches, The Explanation of Productivity Change.

[19] Diewert, W. Erwin, *Measuring the Price and Quantity as Capital Services Under Alternative Assumptions*, Discussion Paper No. 01-24, Department of Economics, The University of British Columbia, 2001.

[20] In his earlier work Niitamo alternatively used consumption of electricity in industry and power directly

and the capital in use (services) in an early MFP calculation for the Finnish manufacturing industry. As capital input he quite elegantly used the volume index of the electricity used in manufacturing. An early attempt to construct actual capital stocks for Finland was done by Kalevi Koljonen.[21] He was well versed in state-of-the-art capital measurement, but decided not to use the PIM method when constructing residential and non-residential capital stocks due to data availability and reliability issues. Instead Koljonen used data on building stocks in the 1950 and 1960 censuses as bench-marks. He estimated the flows in the interim years using construction statistics as proxies for investments and the volume changes by type of building as basis for estimates of retirements. In an other study done the same year Eino Laurila did not even attempt to measure capital stocks, he simply defined ΔK (the change in capital) as investments and calculated capital-output ratios at constant 1954 prices.[22] These ratios he compared with those of other advanced European economies, respectively at different stages in the business cycle and by industry. In the mid-1970s Reino Hjerppe and Pertti Kohi calculated gross capital stocks for the years 1960, 1965 and 1967 at fixed 1963 prices.[23] In addition to buildings they also incorporated measures for civil engineering construction and machinery and equipment. The methodology used was a combination of the PIM, bench-marks plus investments less retirements and physical quantities times their unit prices. Seppo Suokko and Pirkko Valppu used the perpetual inventory method consistently to estimate gross capital stocks at constant 1975 prices for the years 1960-1975.[24] Their work laid the foundations for a joint venture three years later when Statistics Finland as a part of implementing SNA68 also started to compile capital stock statistics.[25] Both gross and net stocks, as well as retirements and consumption of fixed capital, in current and constant 1975 prices were included in the measures of the stocks and flows of fixed capital. As the investment series were (and are) the main inputs into the Finnish national account's capital stock calculations, the stock series were rebased to a new base year whenever the capital formation (and production) series were rebased. The base years have been 1975, 1980, 1985, 1990, and 1995. The switch to 1995 also entailed an enlargement of the asset classification as the intangible fixed assets

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installed for driving machines, and in his later work only electricity as proxies for capital services. Niitamo, Olavi, *Tuottavuuden kehitys Suomen teollisuudessa vuosina 1925–1952 [The Development of Productivity in Finnish Industry 1925-1952],* Kansantaloudellisia tutkimuksia, XX, 1958. Niitamo, Olavi, *Tuotantofunktio, sen jäännöstermi ja teknillinen kehitys,* Monistettuja tutkimuksia n:o 9, Tilastollinen Päätoimisto, 1969.

[21] Koljonen, Kalevi, *Pääomakannan käsite ja mittaaminen sekä sovellutus Suomen rakennuskantaan vuosina 1950–60,* Monistettuja tutkimuksia n:o 8, Tilastollinen Päätoimisto, 1968.

[22] Laurila, Eino H., Kapitalbildningen och kapitalets produktivitet i Finland åren 1948–1967, *Ekonomiska Samfundets Tidskrift,* 1968:3, 160–167.

[23] Hjerppe, Reino and Kohi, Pertti, Pääomakantalaskelmien ongelmista, in *Kokonaistaloudellisia ongelmia II,* Tilastokeskus tutkimuksia nro. 34, 1975, 67–76.

[24] Suokko, Seppo and Valppu, Pirkko, *Pääomakanta vuosina 1960–1975,* Taloudellinen suunnittelukeskus, 1977.

[25] Vihavainen, Hilkka, Valppu, Pirkko, Suokko, Seppo, and Björk, Bo-Christer, *Pääomakanta vuosina 1965–1977,* Tilastokeskus tutkimuksia nro. 58, 1980.

as defined by SNA93/ESA95 were introduced.

Capital in the national accounts

In the most recent worldwide national accounting recommendation SNA93 the passages on capital stocks are rather dispersed. Paragraph 15.101 states that the perpetual inventory method is usually used to obtain measures for gross and net capital stocks. According to SNA93 stock measures are needed for analyzing production and productivity and for balance sheets. Based on SNA93 also the European system of national accounts has been revised. Also ESA95 deals with capital stocks briefly and fragmentarily. In paragraph 6.04 the PIM is recommended whenever direct information on capital stocks is missing. The net capital stock is the stock measure in both SNA93 and ESA95. It is used in balance sheets, input-output analysis and use tables.[26]

Gross capital stock (GCS) is the value of the capital used in production, valued at "as new" prices, i.e. regardless of age or actual condition, at a certain point of time. GCS consists of the value of the cumulated past investments less the cumulated retirements of fixed assets. A capital good is retired from the capital stock when its service life expires. Gross capital stock K_t^G at the end of year t is estimated using the perpetual inventory method:

$$K_t^G = \sum_{s=0}^{S-1} d_s^G I_{t-s} \,, \tag{1}$$

where d_s^G is the surviving share of the cohort of capital goods that are s years old in year t and S is the maximum service life of the asset type.[27] The relative share of survivors is declining and eventually goes to zero. The GCS of the whole economy is calculated as the sum of the gross capital stocks by asset type, industry and type of producer.

The gross capital stock as such is not needed in the SNA93/ESA95 accounting framework. Previously the GCS was thought of as a kind of production potential. However, since the gross capital stock does not take into account the physical deterioration of assets, it is only used as an intermediate step in calculating productive and net capital stocks, and not always even for that. For instance the U.S. Bureau of Economic Analysis now directly calculates net capital stocks for all capital assets.[28]

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[26] The use table describes the use of goods and services by product and type of use, i.e. intermediate consumption, final consumption, capital formation or export. ESA95, *European System of Accounts*, paragraph 9.04.

[27] SNA93 and ESA95 do not present formulas. The equation shown here is the authors' interpretation of the SNA93 and ESA95 verbal definitions.

[28] Katz, Arnold J. and Herman, Shelby, W., Improved Estimates of Fixed Reproducible Tangible Wealth, 1929-95, *Survey of Current Business,* May 1997, 69-92. Fraumeni, Barbara M., The Measurement of De-

Net capital stock (NCS) is the market value of the capital in use. The net value of the capital good is defined as the current purchaser's price of a new asset of the same type less the cumulated consumption of fixed capital.[29] The national accounts term consumption of fixed capital broadly equals the term depreciation, which is more widely used in economics and economic history.[30] According to the SNA93 consumption of fixed capital is calculated for all capital goods in the GCS using either the linear or geometric depreciation formula. Consumption of fixed capital is the decline in the value of capital during the accounting period due to physical deterioration, normal obsolescence, normal accidental damage and aging.[31]

preciation in the U.S. National Income and Product Accounts, *Survey of Current Business,* July 1997, 7-23.

[29] SNA93, *System of National Accounts 1993*, paragraph 6.199.

[30] By depreciation is in the productivity literature usually meant the difference in price at the same time point in time between two otherwise identical capital goods of successive vintages. This is the loss in value due to aging, which is often called cross-section depreciation. Diewert, W. Erwin, *Measuring the Price and Quantity as Capital Services Under Alternative Assumptions*. Hill, T. Peter, *The Productive Capital Stock and the Quantity Index for Flows of Capital Services,* paper presented at the meeting of the Canberra-group in Washington, D. C., November 1999.

[31] SNA93, *System of National Accounts 1993*, paragraph 6.179. ESA95, *European System of Accounts,* paragraph 6.02. Katz & Herman, Improved Estimates of Fixed Reproducible Tangible Wealth, 1929–95.

Productive capital stocks and rental prices

Capital performs capital services, being a factor of production along with labour and intermediate goods. The quantity of services a capital asset produces is usually dependent on its age. Assuming that the capital service a new homogeneous asset performs is one, and that the flow of relative services is declining:

(2) $$d_0^P = 1 \text{ and } d_s^P - d_{s-1}^P \leq 0 \qquad (s = 0,1,...).$$

Assuming that all capital assets eventually are discarded or retired, so that the capital service diminishes to zero:

(3) $$\lim_{s\to\infty} d_s^P = 0.$$

The capital service of a new, year t acquired, capital good is I_t. The capital service of the capital good acquired the previous year, $t-1$, is then $d_1^P I_{t-1}$ and $d_s^P I_{t-s}$ for the assets invested in year $t-s$. When the flow of capital services of a new asset is thought to be proportional to the capital asset, d_s^P can also be said to represent the relative efficiency of the capital goods acquired in year $t-s$.

The flow of capital services can be perceived as representing the services of fixed capital analogously to labour representing the services of human capital in the production function. Furthermore, assuming that the different vintages of capital services are completely substitutable and that there is only one kind of capital (and no intermediate goods), the production function can be written as:

(4) $$Q = A_t F(L_t, K_t) = AF(L_t, \left[d_0^P I_t + d_1^P I_{t-1} + \cdots + d_{S-1}^P I_{t-S+1}\right]).$$

The sum within brackets can also be expressed as:

(5) $$K_t^P = \sum_{s=0}^{S-1} d_s^P I_{t-s},$$

which is often called the productive capital stock (PCS) .[32] Equation (5) is meant to be used directly on the investment vintages.

A first step in calculating productive capital stocks is to choose the profile of efficiency decline. Commonly used assumptions are the hyperbolic and the geometric age-efficiency profile.[33] In this paper we will only deal with geometric decline in

[32] OECD, *Measuring Capital.* OECD, *Measuring Productivity.*

[33] For an extensive coverage of the subject, see: Jorgenson, Dale. W., Gollop, Frank, and Fraumeni, Barbara, *Productivity and US Economic Growth*, Harvard University Press, Cambridge, Massachusetts, 1987.

efficiency[34], thus

(6) $$d_s^P = (1-\delta)^s \ .$$

As point of departure in a growth accounting exercise is often a standard neoclassical production function, where the change in MFP is calculated using the Törnqvist-index. The Törnqvist-index is also used in aggregating heterogeneous capital input. Different types of capital are aggregated using their respective rental prices, which takes into account the contributions of different types of capital to production. A substitution towards capital assets with higher marginal products implies a change in capital quality. As rental price the Hall-Jorgenson[35] rental price is used:

(7) $$P_{t,0}^K = rP_{t,0}^I + \delta_{t,0}P_{t,0}^I - \rho_{t,0}P_{t,0}^I \ .$$

In equation 7 the depreciation rate δ can be estimated from the expected age-efficiency profile. Holding gain/loss ρ can be obtained from the price index of new capital assets. The remaining unknown term is the net rate of return on capital r. In the *ex-ante* approach some interest rate can be used as return on capital, e.g. the base rate of the central bank. In the *ex-post* approach the internal return on capital is estimated. That is, it is assumed that the industry's capital income Ψ_t is equivalent to the imputed rents it receives each period t:

(8) $$\Psi_t = \sum_j P_{j,t,0}^K K_{j,t}^P \ .$$

The rate of return can be solved by placing equation (7) into equation (8):

(9) $$r_t = \frac{\Psi_t - \sum_j (\delta_{j,t,0} - \rho_{j,t,0}) P_{j,t,0}^I K_{j,t}^P}{\sum_j P_{j,t,0}^I K_{j,t}^P} \ .$$

In empirical work nominal value added less labour income[36] is mostly used as

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OECD, *Measuring Capital*.

[34] Empirical research performed in the U.S. has supported the use of geometric depreciation applied directly on the investment vintages. Hulten Charles R. and Wykoff, Frank C., The Measurement of Economic Depreciation, in Hulten, C. R. (ed.): *Depreciation, Inflation and Taxation of Income from Capital*, The Urban Institute Press, Washington, D. C., 1981. Hulten, Charles R. and Wykoff, Frank C., Issues in the Measurement of Economic Depreciation: Introductory Remarks, *Economic Inquiry*, Vol. XXXIV, January 1996. Jorgenson, Dale W., Empirical Studies of Depreciation, *Economic Inquiry*, Vol. XXXIV, January 1996. Fraumeni, The Measurement of Depreciation.

[35] Hall, Robert E. and Jorgenson, Dale W., Tax Policy and Investment Behavior, *American Economic Review*, Vol. 57, June 1967, 391-414.

[36] This equals the national accounts compensation of employees plus the imputed labour income of the self-employed. The imputed labour income is usually estimated by multiplying the self-employed's hours worked by wage earners average hourly earnings.

capital income.

The rental prices are used to aggregate productive capital stocks by asset type into a measure of capital services by industry. If the capital input is a translogarithmic function of its components, then the capital service of industry i, that is, the volume index of its capital input can be expressed as[37]

$$(10) \qquad c_{it} = \frac{K^P_{i,t}}{K^P_{i,t-1}} = \prod_j \left(\frac{K^P_{ij,t}}{K^P_{i,t-1}} \right)^{v_{ijt}},$$

where the weights ν are defined as:

$$(11) \qquad v_{i,t} = \left(\frac{P^K_{ij,t} K^P_{ij,t}}{\sum_i P^K_{ij,t} K^P_{ij,t}} + \frac{P^K_{ij,t-1} K^P_{ij,t-1}}{\sum_i P^K_{ij,t-1} K^P_{ij,t-1}} \right) / 2 \ .$$

[37] Jorgenson, Gollop, and Fraumeni, *Productivity and US Economic Growth.*

Capital in Finland: Resolution of a Debate

Our focus shifts from theory to application as we turn our attention to how different capital measures perform in quantifying a turbulent period in recent Finnish economic history. This period is interesting because the Finnish economic recession in the early 1990s was very severe; with GDP declining by 11 per cent from 1990 to 1993 (the 1930s recession was much less severe in comparison as GDP declined by only 3.5 per cent 1929-1931). Our results also enable us to compare capital productivity growth and the rate of return on capital prior to the 1990s recession, the indicators which are the main ingredients of the Artto-Pohjola paradox.

We used a geometric age-efficiency profile in calculating productive capital stocks for Finland. The productive capital stock in year *t* for a homogeneous capital asset type is defined as[38]:

$$K_t = K_{t-1}(1-d) + I_t = \sum_{\tau=0}^{\infty}(1-d)^{\tau} I_{t-\tau}\,, \tag{12}$$

where *I* is gross fixed capital formation and *d* is rate of depreciation. The symbols for industry and asset type (*i* and *j*) have been suppressed for notational simplicity. In the ex-ante method we used the central bank's base rate as rate of return and used equation (7) to calculate the rental prices. In the ex-post method we used equation (9) to calculate the internal rate of return and equation (7) to calculate the rental prices. These rental prices were used to aggregate the eight different capital asset types into a volume index of capital services (see Table 1 for the asset type classification and the average service lives).[39] The capital goods are also classified by type of producer and industry, which accounts for the variation in service lives. Consumer durable goods, inventories and land are not included in the capital stocks.

[38] For recent applications see: Jorgenson, Dale W. and Stiroh, Kevin, J., Raising the Speed Limit: US Economic Growth in the Information Age, *Brookings Papers on Economic Activity* 1, 2000, 125-211. Timmer, Marcel, Ypma, Gerard and van Ark, Bart, *IT in the European Union: Driving Productivity Divergence?,* Research Memorandum GD-67, Groningen Growth and Development Centre, University of Groningen, October 2003.

[39] When the fixed price productive capital stocks are aggregated using the prices of new investment goods as weights the result is capital quantity, and when they are aggregated using rental prices as weights the result is capital services.

Table 1 Asset types and average service lives of fixed assets

Asset type	Average service life in years
Non-residential buildings	20–50
Civil engineering and other structures	20–70
Transport equipment	7–25
Other machinery and equipment	5–32
Mineral exploration	10
Computer software	5
Entertainment, literary or artistic originals	10
Improvement of land	30–50

Since residential buildings are a significant part of the capital stock (39% of the nominal productive stock in 2001), but are not actually a production factor we decided to omit residential investments from our definition of capital and symmetrically also the value added of industry operating and letting of dwellings from GDP at basic prices.

In Table 2 can be seen the shares of the PCS by asset type. The share of non-residential buildings has grown nearly 10 percentage points and constitutes close to half of the capital stock, while the share of civil engineering has declined to 22 per cent. Together non-residential buildings and civil engineering structures are more than two thirds of the capital stock in 2001. The share of transport and other machinery and equipment was one third of the stock in 1975 but their share has declined to slightly more than a quarter in 2001. The share of intangible produced assets (mineral exploration, software and originals) was less than 3 per cent of the PCS and improvement of land 2 per cent in the year 2001. The investment ratio less residential gross fixed capital formation (i.e., nominal investments divided by nominal value added) changed from 23.2 per cent in 1975–1990, via the early 1990s 18.5 per cent to 17.7 per cent in the years 1995–2001. There was a shift regarding capital after the early 1990s recession to more intensive growth – that is, economic growth was achieved with less investments and greater capital productivity than previously.[40]

The lower investment ratio in the 1990s resulted in a deceleration of the growth rates of the different kinds of capital[41] as can be seen in Table 3 and in Figure 1[42] where the volume indexes are shown graphically with year 1975 normalized as 100.

[40] Jalava, Jukka, Accounting for Growth and Productivity: Finnish Multi-factor Productivity 1975–99, *Finnish Economic Papers* 15, Autumn 2002, 76-86.

[41] On the definition of GCS and NCS in Finnish national accounts, see Statistics Finland, *Capital Stock Data 1975–1998, Time series, ESA95 revision,* National Accounts 2000: 7.

[42] See the appendix for the series. The early 1990s economic recession is clearly visible in the graph and is the reason behind the periodization of time in the subsequent tables.

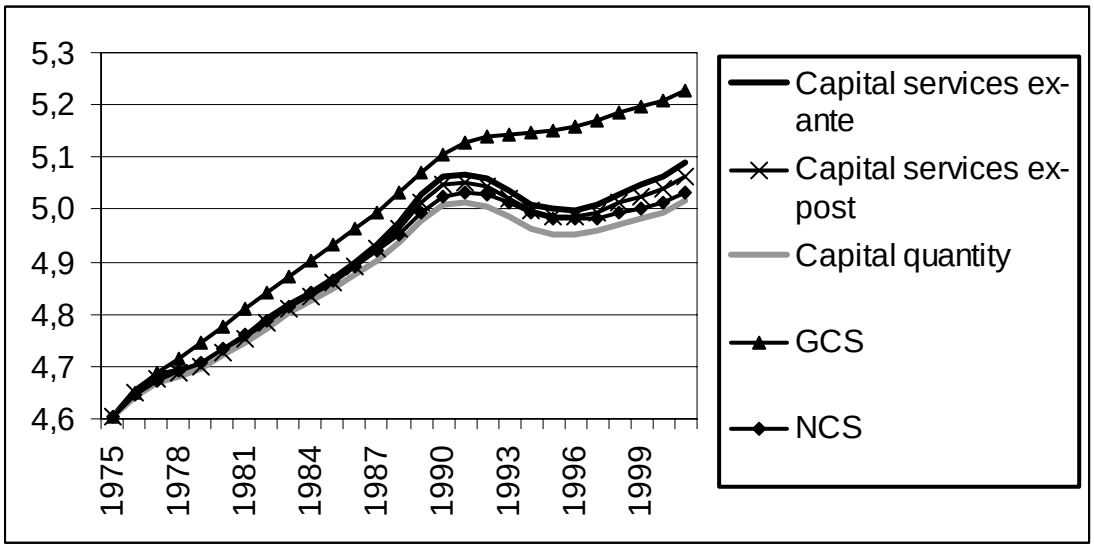
The GCS has consistently grown faster than the other kinds of capital throughout the observation period. The other capital measures grew in 1975–1990 on average by 2.6–2.9 per cent per year, but the picture changes during the recession. By 1995 the NCS is nearly at the pre-recession level, as the average growth rate in 1990–1995 is close to zero. At the same time the growth rates of the capital services were the weakest: -0.5 per cent. In the years 1995–2001 the ex-ante capital services grew 1.1 per cent per year, the ex-post capital services by 0.9 per cent per year, the net stock by half a per cent and capital quantity by 0.7 per cent. The main differences between NCS, capital quantity and capital services are due to different assumptions regarding retirements/depreciation. In the case of capital services a compositional shift towards intangible capital has also taken place (Table 4). After the recession the growth rate of the gross stock is closer to that of the capital services than the NCS. The growth rates of the stocks are also influenced by the depreciation rates, which have increased since there has been a shift to capital goods with shorter service lives (Table 5).

Table 2 Shares of nominal productive capital stock by asset type, 1975–2001, %

	1975	**1980**	**1985**	**1990**	**1995**	**2001**
Non-resid. buildings	36.8	39.6	42.9	46.3	42.1	46.2
Civil engineering etc.	26.3	24.7	23.0	20.0	23.4	22.4
Transport equipment	6.4	6.0	5.5	5.1	5.5	5.3
Other machinery and eq.	26.5	25.3	24.2	24.5	24.4	21.5
Mineral exploration	0.0	0.0	0.0	0.1	0.1	0.1
Computer software	0.3	0.5	0.7	1.1	1.4	2.1
Originals	0.3	0.4	0.5	0.4	0.5	0.5
Improvement of land	3.4	3.4	3.1	2.6	2.7	2.0
Total	100.0	100.0	100.0	100.0	100.0	100.0

Source: Own calculations; data from Statistics Finland.

Figure 1 Capital services, capital quantity, GCS and NCS, volume-indexes 1975–2001, 1975=log (100)



Source: Own calculations; data from Statistics Finland.

Table 3 Growth rates of capital, 1975–2001, %

	1975–1990	**1990–1995**	**1995–2001**
Capital services (ex-ante)	2.9	-0.5	1.1
Capital services (ex-post)	2.8	-0.5	0.9
Capital quantity	2.6	-0.4	0.7
GCS	3.2	1.4	1.2
NCS	2.7	-0.1	0.5

Source: Own calculations; data from Statistics Finland.

Table 4 Growth rates of the productive capital stock by asset type, 1975–2001, %

	1975–1990	**1990–1995**	**1995–2001**
Non-resid. buildings	3.2	0.4	0.8
Civil engineering etc.	1.2	0.8	0.6
Transport equipment	1.3	-3.0	0.0
Other machinery and eq.	3.3	-2.2	0.8
Mineral exploration	15.2	2.4	2.8
Computer software	10.2	1.8	6.4
Originals	2.1	-0.2	2.2
Improvement of land	-0.4	-2.2	-3.2

Source: Own calculations; data from Statistics Finland.

Table 5 Depreciation rates of the productive capital stock by asset type, 1975–2001, %

	1975	1980	1985	1990	1995	2001
Non-resid. buildings	5.1	5.1	5.0	5.1	5.0	5.2
Civil engineering etc.	5.0	5.1	5.2	5.4	5.2	5.3
Transport equipment	16.2	15.0	14.4	15.4	14.7	15.4
Other machinery and eq.	14.0	13.7	14.7	15.2	15.4	16.8
Mineral exploration	30.0	24.5	25.5	25.0	25.5	24.9
Computer software	57.4	54.5	52.9	52.3	53.9	53.6
Originals	25.1	25.3	25.0	25.9	25.2	25.4
Improvement of land	5.7	6.0	6.2	6.4	6.9	7.9
Total	8.4	8.3	8.6	9.3	8.9	9.7

Source: Own calculations; data from Statistics Finland.

Table 6 shows the average annual growths of the prices of new investment goods. The most moderate price increases are to be seen in machinery and equipment. By 2001 the price development has been most rapid in software, non-residential buildings and mineral exploration.

Table 6 Average annual growths in prices of new investment goods, 1975–2001, %

	1975–1990	1990–1995	1995–2001
Non-resid. buildings	9.0	-2.7	4.3
Civil engineering etc.	7.6	1.6	2.5
Transport equipment	7.9	5.1	2.4
Other machinery and eq.	6.7	2.3	0.5
Mineral exploration	9.9	2.8	3.4
Computer software	10.0	2.5	4.4
Originals	9.6	4.4	1.6
Improvement of land	9.4	1.9	2.0

Source: Own calculations; data from Statistics Finland.

The small share of profits in national income keeps the ex-post rate of return smaller than the ex-ante rate of return during the recession of the early 1990s (Table 7). Correspondingly the late 1990s boom years are reflected as ex-post rates of return being higher than their ex-ante equivalents. Ernst Berndt and Melvyn Fuss observe in a study of the U.S. manufacturing industry[43], where they treat capital as a quasi-fixed production factor, that the use of the ex-ante rate of return during cyclical swings leads to the marginal product of capital differing from capital's income share. When using the ex-post rate of return there is no such problem. According to

[43] Berndt, Ernst R. and Fuss, Melvyn A., Productivity Measurement with Adjustments for Variations in Capacity Utilization and Other Forms of Temporary Equilibrium, *Journal of Econometrics,* Vol. 33, October-November 1986, 7-29.

Paul Schreyer, Pierre-Emmanuel Bignon and Julien Dupont this is only so when the quantity of capital cannot be adjusted during the period of production.[44] Furthermore, the ex-post measure is prone to measurement errors and it requires knowledge of levels of capital stocks. Estimates of capital stock levels are usually less reliable than measures of changes in capital.

Table 7 Rates of return, 1975–2001 (arithmetic averages), %

	1975–1990	**1990–1995**	**1995–2001**
Ex-ante	8.5	7.2	4.4
Ex-post	11.5	5.7	14.4

Source: Own calculations; data from Statistics Finland.

The capital productivities (Table 8) reinforce the picture given in Table 3. The gross capital stock has grown most rapidly during the observation period; hence capital productivity measured with the GCS is always the lowest. The net capital stock usually overestimates the relative change in capital productivity (except during the recession). The most eye-catching feature of Table 8 is the significant increase in capital productivity during the latter part of the 1990s. However, as we have not included inventories and land in our measure of capital stocks, our ex-post rates of return are likely to be somewhat overstated. Still capital's growth contributions calculated with both ex-ante and ex-post measures are nearly identical (Table 9). Neither do the growth contributions of gross and net capital stocks differ that much from that of the capital services, except during the recession when the GCS overestimates capital's contribution. After the recession the contribution of the NCS is slightly smaller than that of the other kinds of capital. Gauged by all measures of capital both the absolute and relative impact of capital on Finnish economic growth has diminished.

The results in Tables 7 and 8 can be used to offer a resolution to the Artto-Pohjola paradox. Our figures show that capital productivity growth was very low in the period 1975-1990. In this sense we corroborate Matti Pohjola's view on capital being inefficient during this period.[45] However, a recent study by Marcel Timmer, Gerard Ypma and Bart van Ark reports that the ratio of labour productivity growth to MFP growth in 1980-95 is very similar in Finland, the U.S. and the EU. Finnish labour productivity (LP) grew 1.9 times faster than MFP and the ratios were 2.0 and 2.1 respectively in the U.S. and the EU.[46] These findings imply that the contribution of Finnish capital productivity growth to MFP was not that different from the EU and U.S. averages. That Eero Artto would find high returns on capital in the paper in-

[44] Schreyer, Paul, Bignon, Pierre-Emmanuel and Dupont, Julien, *OECD Capital Services Estimates: Methodology and A First Set of Results,* OECD Statistics Directorate Working Paper (forthcoming).

[45] Pohjola, *Tehoton pääoma.*

[46] Timmer, Ypma and van Ark, *IT in the European Union.*

dustry in the same period that Pohjola coined as inefficient we also find plausible as we report a double-digit ex-post rate of return for the whole economy in 1975-90.[47] Our results were preceded by Olli Haltia and Mikko Leppämäki who mathematically showed that it is possible for shareholders' financial return to grow faster than capital productivity.[48] They showed that this can happen if the growth in the value of shareholders' equity is positive, but that the financial return would be higher if the shareholders invested elsewhere. Thus the owners do not interfere with the managers' unsuccessful investments that are depleting the value of the firm. Also Jukka Jalava implicitly showed that there was a major increase in capital productivity growth after 1995, as he reported a simultaneous increase in MFP growth and decrease in labour productivity growth (MFP is the geometric average of labour and capital productivity, so if MFP growth goes up and LP growth down then CP growth must also go up).[49] However, here we explicitly showed that growth in capital productivity was low although the rate of return on capital was quite reasonable. This is intuitively understandable since when the return on capital is high (the rate of return on capital equals capital's marginal product), there is not necessarily a need to improve capital's average productivity (Table 8 shows the average productivities) until the rate of return goes down. Only faced with declining returns the firms take action to utilize capital more efficiently.[50] Therefore we concur with Haltia and Leppämäki's conclusion that the paradox is actually no paradox at all. It would seem that Artto failed to discern the difference in capital's good performance in gaining a reasonable return on capital (its marginal product) with its less than good performance in average productivity growth.

Table 8 Capital productivity, 1975–2001, %

	1975–1990	**1990–1995**	**1995–2001**
Capital services (ex-ante)	0.0	-0.1	3.5
Capital services (ex-post)	0.1	-0.1	3.7
GCS	-0.3	-1.9	3.5
NCS	0.3	-0.4	4.1

Source: Own calculations; data from Statistics Finland.

[47] Artto, *Performance and International Competitiveness*.

[48] Haltia and Leppämäki, Do Shareholders Care About Corporate Investment Returns?

[49] The exceptional increase in Finnish capital productivity is also corroborated by the results of Timmer *et al.* as the Finnish LP/MFP growth ratio declined to 1.1 in 1995-2001, whereas it was 2.3 in the U.S. and 2.8 in the EU. Jalava, Accounting for Growth and Productivity. Timmer, Ypma and van Ark, *IT in the European Union.*

[50] Our intuition is reinforced by Figure 13 in a recent paper by Pekka Sauramo. Sauramo, Pekka, *Funktionaalinen tulonjako Suomessa: ollaanko tasapainossa?,* Discussion Papers 192, Labour Institute for Economic Research, December 2003.

Table 9 Alternative growth contributions of capital, 1975–2001

		1975–1990	1990–1995	1995–2001
GDP at basic prices (excl. dwellings), average annual volume growth[1]		2.9	-0.5	4.7
Contribution[2]				
	Capital services (ex-ante)	0.6	-0.1	0.3
	Capital quantity	0.5	-0.1	0.2
	Capital quality	0.1	0.0	0.1
	Capital services (ex-post)	0.5	-0.1	0.3
	Capital quantity	0.5	-0.1	0.2
	Capital quality	0.1	0.0	0.0
	GCS	0.6	0.3	0.3
	NCS	0.5	0.0	0.2
Capital's income share[1]		19.3	19.9	27.1

1 Per cent. 2 Percentage points. Numbers may not add to totals due to rounding.
Source: Own calculations; data from Statistics Finland.

Table 10 shows the MFP estimates by alternative types of capital. Labour input is here hours worked unadjusted for quality changes. The tendency of the NCS to overestimate capital productivity is not reflected that much in MFP due to capital's small income share. In the late 1990s the relative change in MFP is ever so slightly larger when using the NCS than when using the other measures of capital, due to both an increase in capital's share of income and the faster growth rate of the net stock. The picture given by the GCS during the recession once again differs the most from that of the capital services. On the whole, when comparing the MFP growth rates in Table 10 with the growth of GDP it is clear that the residual is and has been the most important contributor to economic growth in Finland during the whole observation period.

Table 10 Alternative multi-factor productivity measures, %

	1975–1990	1990–1995	1995–2001
Capital services (ex-ante)	2.4	2.6	2.9
Capital services (ex-post)	2.5	2.6	2.9
GCS	2.4	2.2	2.9
NCS	2.5	2.5	3.0

Source: Own calculations; data from Statistics Finland.

Conclusion

The starting point of this paper was methodological as we introduced state-of-the-art tools of economic analysis to the Finnish case and extensively discussed what kind of theoretical and empirical choices have to be made in quantifying capital and its contribution to growth and productivity. The use of capital services, instead of gross or net capital stocks, does not alter the previously held view of the development of capital input during the period 1975-90. During the early 1990s economic recession the volume index of capital services shows a much greater decline in capital input than does the net stock. Correspondingly in the late 1990s capital services grow faster than does the net stock. The gross stock grows during the whole observation period at the most rapid rate. The calculations based on the net capital stock somewhat exaggerate the decline in capital productivity in the early 1990s and overstate the growth in capital productivity after 1995. The most significant feature observed is common to all measures of capital, i.e. a marked increase in capital productivity in the latter part of the 1990s.

The differences in growth contributions are not that striking either. The contribution of capital to Finnish economic growth looks rather similar both when using the theoretically correct capital services measure and when using gross or net capital stocks. During the recession the gross stock clearly overstates the case though. After the recession the contribution of the net stock is slightly smaller than that of the other capital types and both the growth rate and the contribution of the gross stock are closer to the correct one. The effect (of which alternative capital measure is used) on multi-factor productivity is minor at the level of the whole economy. Although the composition of capital has shifted into a more short-lived and intangible direction, the good old K in the production function is by no means obsolete. It has just transformed, which poses a great challenge for a historical analysis of the proximate sources of our economic growth.

We also observed how our new estimates accorded with the previous view on how capital has influenced recent Finnish economic history. Our empirical findings show that reasonably high rates of return on capital and low productivity growth of capital did coexist in Finland in 1975-1995. This confirms the theoretical result to this effect obtained by Olli Haltia and Mikko Leppämäki. Therefore we concur with their conclusion that the Artto-Pohjola paradox is no paradox at all. The era of low capital productivity growth ended with a step-up after 1995. The increase in capital productivity notwithstanding, the contribution of capital to Finnish economic growth has declined significantly. This is because the Finnish economy relies more on MFP after the 1990s recession than previously as growth has become more intensive than before. The diminishing importance of capital stems from the fact - as Paul David[51]

[51] David, Paul, *Does the New Economy Need All the Old IPR Institutions? Digital Information Goods and*

points out - that the focus in developed countries' production has shifted from the mere efficient management of routines to the ability to solve problems and innovate. Hence work on better understanding the measure of our ignorance, i.e. MFP, is called for. Especially as the residual is the most important contributor to Finnish economic growth, or put another way, the greater part of our growth is presently left unexplained.

Access to Knowledge for Economic Development, paper presented at WIDER Conference on The New Economy in Development, May 2002, Helsinki.

Appendix

Table A1 Volume indexes of the capital series, 1975=100

	Capital services (ex-ante)	Capital services (ex-post)	Capital quantity	GCS	NCS
1975	100.0	100.0	100.0	100.0	100.0
1976	105.0	104.6	103.9	104.5	104.0
1977	108.1	107.6	106.7	108.5	107.2
1978	108.9	108.5	107.9	111.7	108.9
1979	110.3	110.0	109.6	114.9	110.9
1980	113.1	112.8	112.3	118.7	113.7
1981	116.6	116.0	115.2	122.6	116.7
1982	120.2	119.5	118.4	126.6	120.0
1983	123.7	122.9	121.8	130.8	123.5
1984	126.7	125.9	124.6	134.6	126.4
1985	130.1	129.3	127.8	138.8	129.7
1986	134.1	133.2	131.1	143.1	133.1
1987	138.7	137.6	134.8	147.7	137.0
1988	144.5	143.1	139.2	153.0	141.5
1989	152.7	150.6	145.1	159.2	147.4
1990	158.1	155.8	149.6	164.9	152.1
1991	158.6	156.3	150.7	168.5	153.5
1992	157.2	154.9	149.4	170.7	152.8
1993	153.9	151.6	146.2	171.4	150.2
1994	150.1	148.0	143.0	171.8	147.5
1995	148.5	146.5	141.6	172.7	146.1
1996	148.2	146.2	141.4	174.1	145.6
1997	149.7	147.5	142.3	175.9	146.1
1998	152.9	150.1	144.3	178.3	147.5
1999	155.6	152.2	145.9	180.6	148.9
2000	157.8	154.3	147.8	183.0	150.6
2001	162.2	157.8	150.7	186.1	153.2

Source: Own calculations; data from Statistics Finland.