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# New Economy in Growth and Development

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**Abstract**

The benefits from the New Economy should accrue as improvements in productivity and economic growth. But while the use of information and communication technology seems to have had a substantial impact on the performance of the United States economy, the evidence for other countries is much weaker. This study does not find any significant correlation between ICT investment and economic growth in the period 1985-99 for a sample of 42 countries for which ICT spending data are available. Even more surprisingly and in contrast with some previous studies, the relationship is not statistically significant for the subsamples of industrial or high-income countries either.

There are at least three possible explanations for this apparent ‘productivity paradox’. The most obvious one is the fact that not many countries, other than the US, have yet invested much in ICT. The second reason is that even if they have done so, they may not have invested enough in complementary infrastructure, like education and skills, in order to reap the benefits from ICT investment. Technology by itself is not a solution to any development problem; it only provides an opportunity. The third and the most controversial explanation is that the neoclassical method applied in assessing the

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Keywords: economic growth, ICT, information and communication technology, New Economy, productivity, productivity paradox, technological change

JEL classification: O11, O30, O41, O47, O57



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benefits may not capture the most essential aspects of the New Economy or the ICT revolution. The benefits may not lie in the supply side of the economy but instead in the demand side.


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## I Introduction

The concept of the 'New Economy' was coined in the business press in the mid-1990s to mean an economy which is able to benefit from the two trends shaping the world economy today—the globalization of business and the revolution in information and communication technology (ICT) (see Pohjola 2002). The first trend can be defined simply as the triumph of capitalism after the collapse of socialism. Markets are being liberalized, and trade and capital flows are being deregulated all over the world. It is evident that international trade and investment now play a greater role in most countries' economic policies than 15-20 years ago. The driving forces of the second trend are the rapid improvement in the quality of ICT equipment and software and the sharp decline in their prices, the convergence in communication and computing technologies and the fast growth in network computing via the Internet.

In the New Economy debate, it is also argued that the benefits from the globalization of business activities and from the ICT revolution should accrue in the form of improvements in productivity and economic growth. The strong performance of the US economy in the 1990s is generally offered as evidence that there exists at least one economy which has passed the test. Many US firms are seen to have learnt to take advantage of the two forces shaping the world economy in ways which improve productivity.

The prevailing view in economics is that economic growth is indeed driven by advances in technology, that is, ideas about how to produce more efficiently. Given that information and communication technology is generally regarded as the current manifestation of the ongoing sequence of technological revolutions, ICT can be seen as the key factor driving economic growth in present-day societies.

But while ICT has many visible effects on the modern economy—the growth in the use of computers in general and the Internet in particular—its impact on productivity and economic growth has been surprisingly difficult to detect. There is increasing evidence that ICT investment is associated with an improvement in both firm and macroeconomic performance at least in some industrial countries, but studies that look at larger samples of countries find little correlation between ICT investment and overall productivity in the rest of the world.

From the viewpoint of the developing countries, the problem is that differential access to ICT is even more pronounced than national income inequalities across the world. At present, 55 countries account for 98 per cent of the worldwide investment in ICT equipment, software and services (WITSA 2000). The high-income OECD countries, having 14 per cent of the world's population, produce 54 per cent of the world's GDP but constitute 79 per cent of the Internet users (UNDP 2001: 40). Therefore, if information and communication technology is the new source of economic growth, there is indeed cause for concern that ICT will become a factor contributing to the widening of income differentials between countries. But would investment in ICT be a feasible solution for countries lagging behind the world's leaders in income per capita?

Various international organizations and many national governments have answered this question in the affirmative and have introduced policy initiatives aimed at bridging the 'digital divide' or at eradicating 'information poverty' by promoting the production and/or use of ICT technologies. For example, the European Commission has launched the *e*Europe initiative to ensure that the 'information society' will bring benefits to all Europeans. The key objectives are to introduce all citizens, businesses and administrations into the digital age and bring them 'online', to create a digitally literate Europe, and to ensure that the whole process is socially inclusive, builds consumer trust, and strengthens social cohesion (European Commission 1999). In fact, it can be argued that the benefits of the New Economy would be greater in Europe than in the United States if the Internet, by increasing price transparency and competition, will make businesses and markets more efficient. This is because the European economies are generally believed to be more inefficient than the US economy. Consequently, there is more to gain from the New Economy in Europe than on the other side of the Atlantic.

Under the United Nations umbrella, an unprecedented new initiative was launched by the Ministerial Declaration of the Economic and Social Council of 2000 (ECOSOC 2000). It requested the Secretary-General to establish an information and communication technologies task force as a public-private partnership in which the UN member states, the private sector and other stakeholders participate as equal partners to help to bridge the digital divide. ICT is seen here as a potent instrument for accelerating broad-based growth and sustainable development and for reducing poverty. The role of the Task Force is to serve as a strategic instrument for developing new and innovative approaches to devise technological solutions that can help the poor countries and people leapfrog traditional technologies and stages of development. The Task Force held its inaugural meeting in November 2001.

The Republic of South Africa, as the international spokesperson of the developing world in promoting ICT for development, can be singled out as a country-level example. Its policymakers have made numerous movements towards creating a more liberalized telecommunications sector and promoting the development and use of ICT (Cogburn and Adeya 2001). The share of ICT expenditure in GDP is larger in this country than in many high-income OECD economies. Internet penetration, as measured by hosts per capita, is also higher than in countries with comparable levels of GDP per capita.

These examples illustrate policymakers' firm belief in the possibilities of ICT to promote economic growth and welfare. This paper looks at what can be expected from ICT in the light of research findings based on cross-country analyses. The next section presents some indicators of the diffusion of ICT across countries as well as measures of the digital divide. Sections 3-6 review how the impact of ICT on economic growth can be modelled and what the empirical findings are. Section 7 provides some explanations for the observed weak impacts and section 8 concludes.

## 2 ICT diffusion and the digital divide

Two types of data exist for describing the world's information infrastructure and for illustrating the digital divide. The first type consists of information, compiled by various international agencies and consulting companies, on ICT equipment and its use in both industrial and developing countries. The second type of data contains information, provided by private consulting and other agencies, on ICT spending. For example, the World Information Technology and Services Alliance (WITSA) publishes a biennial report on spending on information and communication technology in about 50 countries. The report is based on research conducted by International Data Corporation

(IDC). It presents data on spending by businesses, households, government and education on IT hardware, other office equipment, IT software, IT services and telecommunications. This information may not be as accurate or as reliable as that produced by national statistical agencies but it has the advantage of symmetric treatment of all countries. Moreover, national income and product accounts do not give information about ICT investment and consumption except in a few advanced economies.

Table 1 displays data about ICT equipment and its use. It is apparent that, at present, the average developing country does not have large-scale access to the ICT technology, no matter how global or inexpensive it is. In this sense, not many—if any—New Economies can exist outside the high-income OECD group. The number of personal computers and Internet users per 1,000 people is ten times higher in the rich countries than in the developing countries. The number of telephones is six times higher, and the number of mobile phones seven times higher. It seems that the relative divide is becoming narrower over time but the absolute differential is, however, increasing. The contrast is even more stark when the rich countries are compared with the least developed ones. The fact is that there are as many Internet users in Finland, with a population of 5 million, as there are in Sub-Saharan Africa, with a population of 643 million.

Table 1
Information and communication infrastructure in the 1990s
(per 1,000 people)

| | Personal computers | | Internet users | | Telephone mainlines | | Mobile phones | |
|---|---|---|---|---|---|---|---|---|
| Country groups[1] | 1995 | 2001 | 1995 | 2001 | 1990 | 2001 | 1995 | 2001 |
| Income breakdown | | | | | | | | |
| High-income OECD | 188 | 363 | 34 | 360 | 455 | 574 | 89 | 690 |
| Developing countries | 14 | 34 | 2 | 37 | 52 | 104 | 4 | 94 |
| Least developed | .. | 4 | .. | 3 | 3 | 7 | 0 | 8 |
| Region breakdown | | | | | | | | |
| Northern America | 273 | 623 | 68 | 467 | 555 | 660 | 108 | 382 |
| Western Europe | 174 | 325 | 30 | 345 | 445 | 572 | 84 | 747 |
| Eastern Europe & Central Asia | 26 | 81 | 5 | 65 | 130 | 232 | 4 | 199 |
| East Asia & Pacific | 82 | 158 | 14 | 177 | 148 | 222 | 36 | 278 |
| Middle East & North Africa | 28 | 62 | 1 | 61 | 89 | 147 | 16 | 163 |
| Latin America & the Caribbean | 17 | 49 | 1 | 63 | 66 | 145 | 9 | 142 |
| South Asia | 0 | 4 | 0 | 4 | 5 | 20 | 1 | 9 |
| Sub-Saharan Africa | .. | 12 | .. | 9 | 9 | 19 | 1 | 30 |

Note: .. = data not available, 0 = less than half the unit shown.

[1] The classifications are based on the definitions in the World Bank's Development Indicators Database, but all countries with population below one million are excluded. The group average has been calculated when data for at least half of the countries are available.

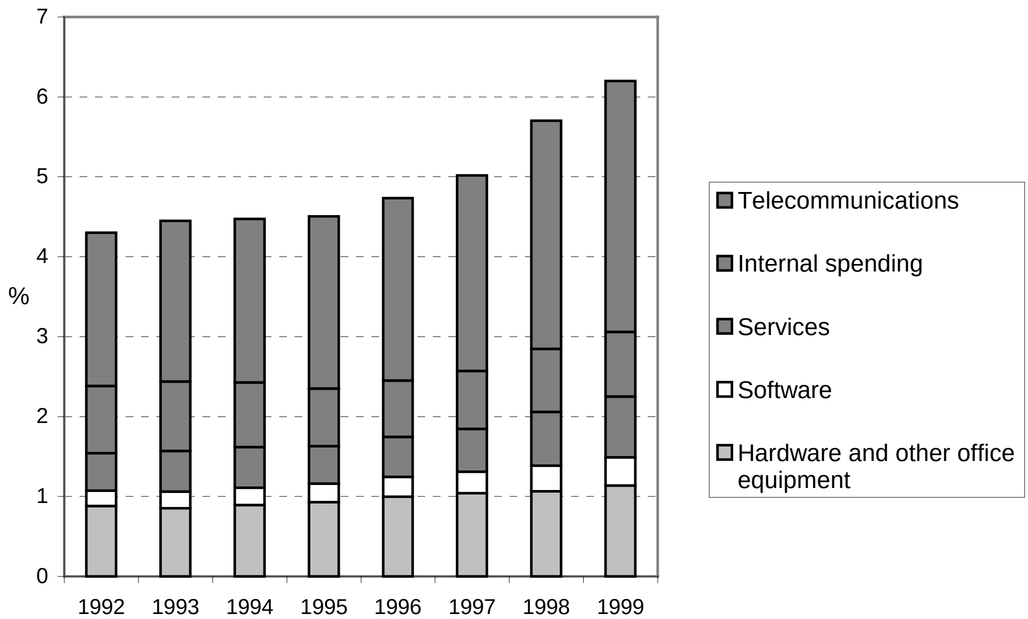
Source: ITU (2002).

The lower panel of the table illustrates the digital divide across regions which are ranked according to the number of telephone mainlines per 1,000 people. The world can be divided into three broad blocks in terms of access to the information and communication infrastructure. The two extreme blocks in terms of ICT density are Northern America and Western Europe on the one hand and South Asia and Sub-Saharan Africa are on the other. The rest of the world falls in between, East Asia and Pacific being the leading region within this block.

Table 1 also highlights the rapid growth in the use of computers, the Internet and mobile phones in the 1990s. In developing countries, the number of personal computers per capita increased twofold, whereas Internet and mobile phone densities rose 20-fold in the second half of the 1990s.

ICT-spending data also display the increasing importance of the new technology for businesses, households, government and education. Figure 1 presents the average GDP shares of the ICT-spending components in 51 countries from 1992 to 1999. Unfortunately, data for earlier years are not available. Spending on IT hardware is combined here with expenditure on other office equipment which is too small to be shown separately. The combined GDP share of hardware and office equipment has risen from 0.9 per cent in 1992 to 1.1 in 1999. It is still the largest IT component even though both software and services have increased their GDP shares at a faster rate. Software spending accounted for 0.2 per cent of GDP in 1992 and 0.4 per cent in 1999. Spending on IT services has increased from 0.5 to 0.8 per cent of GDP in the period under consideration.

Figure 1
ICT spending by components, average GDP shares in 51 countries, 1992-99



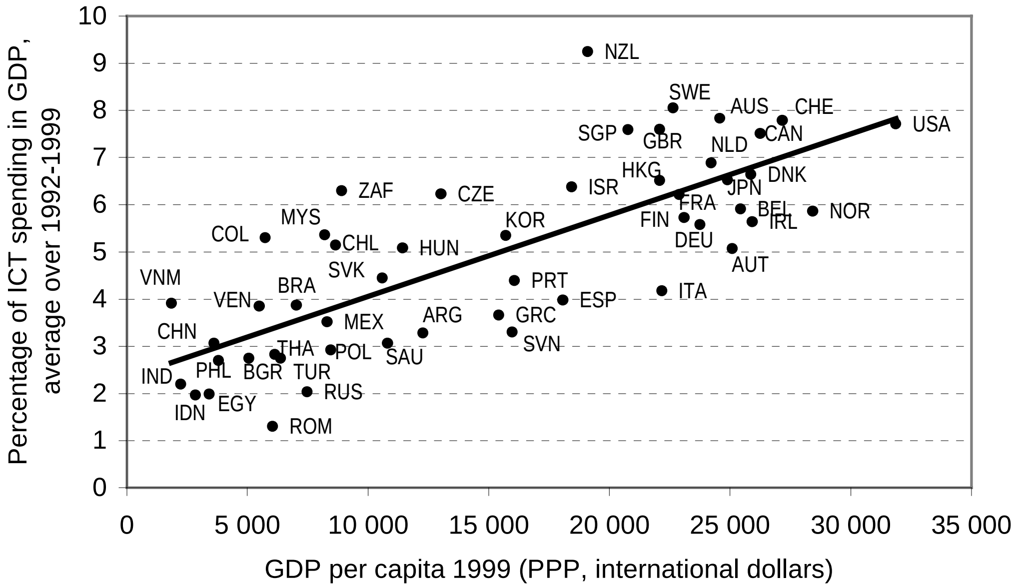
Sources: WITSA (2000) for the ICT spending data; World Bank (2001) for the GDP data.

The WITSA data on hardware, software and services spending include the purchase of these items from external agents or corporations. While this external spending covers the tangible portion of the IT market, internal spending is made up of the intangible portion, i.e. of expenses that cannot be attributed to a vendor (WITSA 2000: 24). As shown in Figure 1, its GDP share has been rather constant, 0.8 per cent, in the period from 1992 to 1999.

The total spending on information technology is the sum of the components described above. Its average GDP share was 2.4 per cent in 1992 and 3.1 in 1999 in the 51 countries covered by the data presented in Figure 1. Telecommunication spending accounted for an additional 1.9 and 3.1 per cent of GDP in the same years. This measure incorporates expenditure on public and private network equipment and telecommunication services.

The share of ICT spending in GDP is strongly correlated with the level of income across countries. This is shown in Figure 2 which displays the relationship between the average ICT-spending ratio in 1992-99 and GDP per capita in 1999 in 50 countries. The ratios are 4-5 times higher in the rich countries than in the poor ones. However, significant disparities exist between countries at similar income levels, as can be seen by comparing, for example, Colombia (COL) and South Africa (ZFA) with Romania (ROM) and Russia (RUS), or New Zealand (NZL) with Italy (ITA). Consequently, other factors affecting both ICT spending and the standard of living need to be accounted for before any conclusions can be drawn about the relationship between ICT and GDP per capita.

Figure 2
ICT spending and GDP per capita in 50 countries




Sources: WITSA (2000) for the ICT spending data; World Bank (2001) for the GDP data.

This relationship is analysed next by characterizing the various ways in which ICT can contribute to increases in the standard of living and by assessing their significance. The analysis is carried out by applying the basic principles of the theory of economic growth.

## 3 Accounting for the impacts of ICT

Information and communication technology plays a dual role in the modern economy. It is both an output from the ICT-producing industries and an input into the ICT-using industries. As mentioned above, the current technological revolution is characterized by fast improvement in the quality of ICT equipment and software, and the resulting sharp decline in their quality-adjusted prices. Utility-maximizing consumers and profit-maximizing firms respond to the change in relative prices by substituting ICT equipment, software and services for other goods and services. The rapid technological advance makes it possible for the shares of ICT to increase in both gross domestic product and in capital stock while ICT prices decline.

To identify the channels through which ICT affects output, productivity and economic growth, it is helpful to express the aggregate production function in the form

$$Y_t = Y(Y_t^{ICT}, Y_t^{O}) = A_t F(C_t, K_t, H_t, L_t) \qquad (1)$$

where, at any given time *t*, aggregate value added *Y* is assumed to consist of ICT goods and services $Y^{ICT}$ as well as of other production $Y^{O}$. These outputs are produced from aggregate inputs consisting of ICT capital *C*, other (i.e. non-ICT) physical capital *K*, human capital *H* and labour *L*. The level of technology is here represented in the Hicks neutral or output augmenting form by parameter *A*.

Information and communication technology can now be seen to affect output and economic growth in the following three basic ways. First, the production of ICT goods and services $Y^{ICT}$ forms part of the total value added generated in an economy. Second, the use of ICT capital *C* as an input in the production of all goods and services generates economic growth. Finally, ICT can enhance economic growth via the contribution of ICT industries to technological change. If the rapid growth of ICT production is based on efficiency and productivity gains in these industries, this contributes to productivity growth at the macroeconomic level as well. The problem, however, is that this impact cannot be directly deduced from the estimation of the production function. The analysis has to be accompanied by an evaluation of the part of the change in technology *A* attributed to the ICT industry.

## 4 Benefits from ICT production

As described above, there are two ways in which the production of ICT can contribute to economic growth. The first is the direct contribution of ICT goods and services to real GDP growth and the second is the contribution of ICT industries to technological progress. To assess the direct contribution, differentiate the left-hand side of (1) with respect to time *t* to obtain

$$\hat{Y} = w_{ICT}\hat{Y}^{ICT} + w_O\hat{Y}^O \qquad (2)$$

where the ^-symbol denotes the rate of change, and the weights $w_{ICT}$ and $w_O$ are the nominal output shares of ICT and other goods and services, respectively. The time index *t* is here suppressed for the economy of notation.

ICT's direct contribution to GDP growth—$w_{ICT}\hat{Y}_{ICT}$ in equation (2)—is calculated by multiplying the nominal output share of ICT goods and services by the growth rate of their volume of production. OECD (2000b) estimates that in member countries these goods and services typically constitute between 3 and 9 per cent of total GDP at current prices. The shares are somewhat higher when only the business sector is considered. Table 2 shows that in 1997 they ranged from 4 per cent in Australia to 11 per cent in Korea. But their growth contribution can be larger than what these shares imply if ICT industries grow faster than the rest of the economy. The last column of Table 2 contains estimates for those countries for which information is available in OECD's (2000b) report. In the mid-1990s, ICT's direct contribution to output growth ranged from 5-8 per cent in Australia to 25-30 per cent in Finland.

Table 2
ICT's direct contribution to valued added in the business sector in OECD countries

| | Share in value added in 1997, % | Share in GDP growth in the mid-1990s, % |
|---|---|---|
| Korea, Rep. | 10.7 | .. |
| Sweden | 9.3 | .. |
| Hungary | 9.2 | .. |
| United States | 8.7 | 15 |
| United Kingdom | 8.4 | 4-25 |
| Finland | 8.3 | 25-30 |
| Austria | 6.8 | .. |
| Canada | 6.5 | 10-20 |
| Norway (1995) | 6.4 | 8-11 |
| Germany | 6.1 | .. |
| Belgium | 5.8 | .. |
| Italy | 5.8 | .. |
| Japan | 5.8 | .. |
| Portugal | 5.6 | 9 |
| France | 5.3 | 3-14 |
| Netherlands | 5.1 | 9-13 |
| Czech Rep | 4.7 | .. |
| Australia (1998-99) | 4.1 | 5-8 |
| G7 | 7.4 | |
| European Union | 6.4 | |
| Total OECD | 7.4 | |

Note: .. = information not available.
Source: OECD (2000b).

Unfortunately data for other than OECD countries are not easily obtainable. But OECD (2000a) estimates that in 1997 its members accounted for more than 80 per cent of the world production of ICT goods. In addition, Singapore produced 5 per cent, Malaysia and Taiwan 3 each, Brazil 2, and Hong Kong and Thailand 1 per cent each. Consequently, the production of ICT goods is very heavily concentrated in the industrial countries and in a few newly industrialized Asian countries. This means that there cannot exist many economies outside the OECD in which the direct contribution of ICT goods to output growth is as large as in the countries displayed in Table 2, Singapore being the most obvious candidate. Wong (2001) estimates that the GDP share of ICT goods and services was over 14 per cent in Singapore in the mid-1990s and that the production of ICT goods accounted for 12 per cent of economic growth in 1970-95.

India's much celebrated success in the software industry is often regarded as the example that other developing countries could follow. As is well known, India's specialization in software has been driven by wage advantages. The impact of the software industry has, however, been limited to a small section of the economy as its GDP share is only one per cent and as there are not more than 400,000 people employed in the industry. The whole ICT industry produced about 2 per cent of the Indian GDP in 1999-

2000.[1] But the software industry has grown quite rapidly and has made a significant contribution to export and GDP growth. Some estimates indicate that it has accounted for over 7 per cent of output growth in India (Arora and Athreye 2002).

It may, in fact, be unrealistic to expect that a large developing economy like India could have a high share of ICT in GDP. This would mean that the ICT sector should be quite big in absolute terms which is incompatible with India being a low income, mainly agrarian economy.

Besides their direct contribution to GDP, ICT industries are also an important source of technological progress. But this impact is even harder to assess than the output contribution because industry-level data on the factors of production are needed to estimate the sources of total factor productivity. Applying methodologies based on the dual price approach to measuring productivity, Jorgenson (2001) allocates 0.5 percentage points of total factor productivity growth to ICT production in the United States in the second half of the 1990s. Since the TFP growth rate was 0.75 per cent, this means that ICT industries accounted for two-thirds of the advance in technology, as measured by total factor productivity. Pilat and Lee (2001) estimate that in Finland this contribution was 20 per cent in the same period: 0.6 percentage points out of 3.2 per cent TFP growth rate. Information for other countries is not available.

## 5 Modelling the impacts of ICT investment

Whereas it may not be possible for all countries in the world to become producers of ICT, it is certainly feasible for them to become its users. The rapid decline in the relative price of computing and communication equipment and software makes investment in them attractive. But how can the benefits be measured?

The estimation of the impact of ICT investment has been approached in three principal ways in the literature: production function estimation, growth accounting and applied growth theory. To begin with the production function approach, suppose that function (1) assumes the simple Cobb-Douglas form

$$Y = AC^{\alpha_c} K^{\alpha_k} H^{\alpha_h} L^{\alpha_l} \tag{3}$$

where the time index has been suppressed for the economy of notation. Taking natural logarithms results in the following linear equation in levels

$$\ln Y = \ln A + \alpha_c \ln C + \alpha_k \ln K + \alpha_h \ln H + \alpha_l \ln L . \tag{4}$$

Given information about the observable variables *Y*, *C*, *K*, *H* and *L*, one can estimate the parameters *A*, $\alpha_c$, $\alpha_k$, $\alpha_h$ and $\alpha_l$. This could be done in a time series analysis for one country at a time or, if one is willing to assume that the α-coefficients are the same in all countries, in a cross-section analysis for a group of countries.

[1] I am grateful to K. Lal for this information.

However, because the estimation in levels raises numerous problems, the analysis is often carried out for growth rates. Differentiating (4) with respect to time *t*, one obtains

$$\hat{Y} = \hat{A} + \alpha_c \hat{C} + \alpha_k \hat{K} + \alpha_h \hat{H} + \alpha_l \hat{L} \tag{5}$$

where the ^-symbol denotes the rate of change. This could again be statistically estimated over time or across countries. However, if one is prepared to make the assumption that constant returns to scale prevail in production and that all factors are paid their marginal products, the $\alpha$-coefficients represent the respective factor shares in total income and sum to one. The standard technique of growth accounting can then be applied directly to assess the output growth contributions of the factors of production. Given that all the other factors in (5) are observable, except the rate of technological change $\hat{A}$, it is obtained as the residual and is often called the growth rate of total or multifactor productivity.

The practical problem with applying either the production function or the growth accounting approach is the poor availability of data for ICT capital and its share in national income. Except in a few advanced economies, national income and product accounts do not in general provide sufficiently detailed information about ICT investment and its quality-adjusted price indices for measuring the ICT capital stock. The lack of official data makes international comparisons difficult. Analyses have to rely on alternative sources of data and use simplifying assumptions in the estimation of ICT investment, prices and capital stocks, see e.g. Schreyer (2000) and Daveri (2002). Neither are data for human and physical capital readily available for cross-country estimations of (4) or (5). Those that do exist, do not cover the 1990s—the decade of the New Economy.

The estimation of capital stocks can be avoided by applying growth theory. The augmented neoclassical model of economic growth extends the basic Solow model to include more than one type of capital (Mankiw, Romer and Weil 1992). Let us write the production function in a form slightly different from (3):

$$Y = C^{\alpha_c} K^{\alpha_k} H^{\alpha_h} (AL)^{1-\alpha_c-\alpha_k-\alpha_h} . \tag{6}$$

The difference is that technological change is here assumed to be of the labour-augmenting type and that constant returns prevail in production. The model can be closed by specifying the accumulation of each of the three types of capital stocks—ICT, other physical and human capital. The Solow model assumes that a constant fraction of output is invested in each type of capital. Defining *y* as the level of output per effective labour, $y = Y / AL$, and *c*, *k* and *h* as the respective stocks of capital per unit of effective labour, the following differential equations govern the evolution of the stocks:

$$\begin{aligned} \frac{dc(t)}{dt} &= s_c y(t) - (a + n + \delta_c) c(t), \\ \frac{dk(t)}{dt} &= s_k y(t) - (a + n + \delta_k) k(t), \\ \frac{dh(t)}{dt} &= s_h y(t) - (a + n + \delta_h) h(t). \end{aligned} \tag{7}$$

Here the $s$-coefficients are the savings rates in each type of capital, and $\delta$ 's are the rates of their depreciation. Labour input is assumed to grow and technology to advance at the exogenous rates of $n$ and $a$, respectively.

Solving (7) for the steady-state values of the capital stocks and inserting into the production function (6) results in

$$\ln\frac{Y}{L} = \alpha_0 + \frac{\alpha_c}{1-\beta}\ln s_c + \frac{\alpha_k}{1-\beta}\ln s_k + \frac{\alpha_h}{1-\beta}\ln s_h - \frac{\alpha_c+\alpha_k+\alpha_h}{1-\beta}\ln(a+n+\delta) \qquad (8)$$

where $\alpha_0 = \ln A(0) + at$, $\beta = \alpha_c + \alpha_k + \alpha_h$. Here the depreciation rates $\delta$ are assumed to be the same for all types of capital, and $\beta < 1$ by assumption. The conclusion is that the steady-state level of output per worker, i.e. of labour productivity, is positively related to the rates of saving in each type of capital but negatively related to the rates of population growth and depreciation of capital. Consequently, labour productivity should be higher in those countries which invest more than the others in ICT capital, other things being equal.

Equation (8) can be estimated, say, for a cross-section of countries if data are available on the rates of investment (i.e. saving) in each type of capital. There is thus no need to measure the capital stocks.

There are, however, at least three problems associated with the model specified above. First, the Cobb-Douglas specification of the production technology implies that the income generated by the ICT capital stock should account for a constant share of national income. This is unlikely to be true at a time of increasing ICT adoption. Second, the use of the same depreciation rate for both ICT and non-ICT capital is problematic as well, given that ICT equipment is known to have a much shorter service life than other types of capital. Third, equation (8) is based on the assumption that countries are in their steady states. This may be unrealistic, given that convergence to the steady state is known to be slow.

It is difficult to relax the first two simplifying assumptions, and they can only be justified on pragmatic grounds. The third problem can, however, be easily fixed by modelling convergence to the steady state. The estimable equation is specified as

$$\ln\frac{Y(t)}{L(t)} - \ln\frac{Y(0)}{L(0)} = \theta\ln A(0) + at + \theta\,\frac{\alpha_c}{1-\beta}\ln s_c + \theta\,\frac{\alpha_k}{1-\beta}\ln s_k$$
$$+\theta\,\frac{\alpha_h}{1-\beta}\ln s_h - \theta\,\frac{\alpha_c+\alpha_k+\alpha_h}{1-\beta}\ln(a+n+\delta) - \theta\ln\frac{Y(0)}{L(0)} \qquad (9)$$

where $Y(0)$ and $L(0)$ denote output and labour in the initial period and where $\theta = (1-e^{-\lambda t})$ with $\lambda = \beta(a+n+\delta)$ measuring the speed of convergence (see Mankiw, Romer and Weil (1992) for the details). This equation predicts that labour productivity grows faster temporarily, i.e. until a higher steady state is reached, in those countries which invest more than the others in ICT capital, other things being equal.

## 6 Impacts of investment in ICT

Let us start the review of the empirical findings with an application of the production function approach. Dewan and Kraemer (2000) have estimated an inter-country Cobb-Douglas function of the type specified in equation (4)—with GDP as output and IT capital, non-IT capital and labour hours as inputs—by pooling annual data from 36 countries over the period 1985-93. Data on GDP and non-IT capital are from the Penn World Table. A measure of IT capital is constructed from information, provided by International Data Corporation (IDC), on the value of IT shipments, which is the revenue paid to vendors for computer hardware, data communication equipment, software and IT services. Computer and software price indices are applied in converting these data from current to constant dollars. IT-spending flows are aggregated into net capital stocks by using depreciation profiles provided by the Bureau of Economic Analysis. The analysis focuses on ‘end use’ computers and software. It does not include investment in embedded electronics or telecommunications.

It should be noted, however, that this approach to measure IT investment is likely to overstate the value of the IT capital stock for two reasons. For one, the data may include spending by households for consumption. For another, IT services are regarded as investment.

Dewan and Kraemer’s benchmark estimation results indicate that the returns from IT capital investments are positive and statistically significant for developed countries, but non-significant for developing countries. For the 22 developed countries in their sample, the output elasticities of IT capital, non-IT capital and labour are 0.057, 0.160 and 0.823, respectively. Thus, a 10 per cent increase in IT capital stock increases annual output by 0.57 per cent. This estimate implies that the marginal social product of IT capital, defined as

$$\frac{\partial Y}{\partial C} = \alpha_c \frac{Y}{C} = \alpha_c \frac{Y}{K}\frac{K}{C} \qquad (10)$$

lies in the range of 50 to 100 per cent if the share of IT capital in the total capital stock is assumed to be 3-4 per cent and if the value of the capital output ratio is between 2 and 3. For the average values of these variables in the authors’ sample, the return to IT capital is 79 per cent. The net return is presumably much lower but its estimation would entail the measurement of net output.

By contrast, Dewan and Kraemer’s analysis indicates that in the 16 developing countries included in their sample, non-IT capital investments are quite productive whereas the evidence on IT investments is inconclusive. The output elasticity of non-IT capital is 0.593 but the IT elasticity is statistically indistinguishable from zero. This finding leads the authors to conclude that a substantive base of capital stock and infrastructure is a prerequisite for IT investments to be productive.

One weakness of this study is the fact that human capital is not included in the production function. The results obtained for developed countries are likely to be quite sensitive to its inclusion, since investment in information technology is known to be strongly correlated with investment in human capital (Pohjola 2001). Also, their conclusions regarding the contribution of information technology capital to GDP growth in developed countries seem to be grossly at odds with growth accounting studies. The annual growth rate of IT capital stock, averaged over the 22 developed countries, was 27.77 per cent in the period 1985-93. Multiplying this by Dewan and Kraemer's estimate of the output elasticity of IT capital, 0.057, gives the result that the GDP growth contribution of IT capital was 1.58 percentage points on average. A similar calculation for the United States yields 1.21 percentage points. These numbers are, however, over one percentage point higher than the estimates obtained in growth accounting analyses of the EU and OECD countries for the same period.

Growth accounting analyses have been carried out for developed countries only. But besides analyses of individual countries, nowadays there also exist studies which assess across countries the GDP growth contribution from ICT capital by applying the growth accounting model (5). Schreyer (2000) has done this for the G7 countries, Daveri (2002) for 14 European Union countries and the United States, and Colecchia and Schreyer (2001) for nine OECD countries. The studies differ from each other with respect to the sources of data for constructing ICT capital stocks. Schreyer and Daveri exploit the WITSA (2000) data for expenditures on IT hardware, software and telecommunications equipment whereas Colecchia and Schreyer resort to OECD's national accounts and other data. To construct ICT deflators, Daveri assumes that ICT prices in Europe follow those in the United States, whereas the two other studies are based on the assumption that the ratios between ICT and non-ICT assets evolve in a similar manner across countries, the United States being the benchmark country.

There are two basic lessons to be noted from these studies. The first is that ICT's contribution to GDP growth varies considerably between countries. For example, Daveri (2002) finds that Europe seems to have benefited much less from ICT than the United States in the 1990s. In the US, ICT's average annual growth contribution was close to one percentage point whereas the European average was only half of this, reflecting the much lower ICT to GDP ratio in Europe (2.1 per cent) than in the US (3.6 per cent). UK, Sweden, Netherlands and Ireland are the European leaders while Italy, Greece and Spain lag behind.

The second lesson is that the output contributions from ICT use have in general increased over time. Colecchia and Schreyer (2001) find in nine OECD countries that while ICT accounted for 0.2-0.5 percentage points of the annual GDP growth in 1980-95, the contribution increased to 0.3-0.9 in the second half of the 1990s. The acceleration was fastest in the United States, Australia, Finland and Canada. This is consistent with the country case studies which have documented the doubling of the ICT contribution in both the United States (Oliner and Sichel 2000; Jorgenson 2001) and Finland (Jalava and Pohjola 2002).

One of the weaknesses of the growth accounting approach is that it yields only a mechanical decomposition of the growth of output into growth of inputs and total factor productivity. It does not explain economic growth by relating the changes in inputs and productivity to the more fundamental elements of the economy such as preferences, technology and government policies. This can be taken care by modelling the process of economic growth.

Pohjola (2001) applies the augmented version of the neoclassical growth model, displayed in equations (6)-(9) above, in exploring the impacts of information technology investment on economic growth in a cross-section of 39 countries in the period 1980-95.

This study is based on information about IT investment provided by International Data Corporation (IDC). The results for the full sample of 39 countries indicate that physical capital has been a key factor in the growth of GDP per worker in both developed and developing countries in the period considered. But neither human capital nor information technology seems to have had a significant impact. However, investment in information technology has had a strong influence on growth in the smaller sample of 23 developed (OECD) countries. Its impact has been almost as large as that of the rest of the capital stock.

Table 3 contains the results from the re-estimation of this model displayed in equation (9) for a sample of 42 countries as well as for a sample of 24 high-income countries in the period 1985-99 (see the Appendix).[2] The countries are those in the WITSA (2000) dataset for which data on the relevant explanatory variables are available. The dependent variable is the change in the real GDP per working age population from the year 1985 to 1999. Data for the years 1985-98 come from the latest version of the Penn World Table, and the value for 1999 is obtained by extrapolation using the GDP volume and working age population growth rates available in the World Bank's (2001) World Development Indicators database. Investment in physical capital is measured by the average of annual real investment shares of GDP in 1985-99. The source is again the Penn World Table.

2 The models are estimated in restricted form by imposing on the parameters of eq. (9) the constraint that the sum of the coefficients of $\ln s_c$, $\ln s_k$ and $\ln s_h$, should equal the negative of the coefficient of $\ln(a+n+\delta)$. Following Mankiw, Romer and Weil (1992), $a+\delta$ is set equal to 0.05 in all countries. The data do not reject the imposed parameter restriction for any of the models estimated in Table 3.

Table 3
Growth regression results for the period 1985-99

| | All 42 countries | | | 24 high-income countries |
|---|---|---|---|---|
| | (1) | (2) | (3) | (4) |
| Constant | 2.66*** (0.51) | 3.08*** (0.55) | 3.32*** (0.97) | 8.64*** (1.80) |
| Physical capital | 0.41*** (0.09) | 0.35*** (0.09) | | |
| - Non-ICT capital | | | 0.31*** (0.09) | 0.07 (0.16) |
| - ICT capital | | | 0.05 (0.12) | 0.09 (0.14) |
| Human capital | | 0.17* (0.09) | 0.16 (0.09) | 0.07 (0.14) |
| Initial productivity | -0.19*** (0.05) | -0.27*** (0.06) | -0.27*** (0.07) | -0.78*** (0.16) |
| Adjusted R2 | 0.39 | 0.42 | 0.41 | 0.55 |
| Implied αk | 0.68 | 0.44 | 0.39 | 0.17 |
| Implied αc | | | 0.07 | 0.21 |
| Implied αh | | 0.21 | 0.20 | 0.17 |
| Implied λ | 0.01 | 0.02 | 0.02 | 0.11 |

Note: Standard errors are in parentheses. * = significant at 10 per cent, ** = at 5 per cent and *** = at 1 per cent level.

Column (1) presents the estimation of the standard textbook Solow model including investment in physical capital only. Column (2) contains the augmented model proposed by Mankiw, Romer and Weil (1992). It covers investment in both physical and human capital. The latter is measured here by the average years of schooling in secondary education in the period 1985-2000. This is the schooling variable available in the Barro and Lee (2001) dataset which performs best in the regressions. It should be noted, however, that it measures the stock of human capital and not the rate of investment in it. Its use can be justified if the stock measure is highly correlated with the steady-state level of human capital.

The estimation results confirm the standard neoclassical conclusion whereby investment in both physical and human capital matters for growth in productivity. The implied elasticity of output with respect to physical capital $\alpha_k$ is around 0.4 whereas the elasticity with respect to human capital $\alpha_h$ is about 0.2. The augmented model also displays convergence from the initial level of output per worker to the steady-state level at the rate of 2 per cent per year.

Column (3) includes investment in ICT capital as measured by the share on ICT-investment spending in GDP at current prices. The implicit assumption is that the relative prices of ICT are the same in all countries, implying that purchasing-power parity holds in the strong form. This is admittedly unrealistic, but it is the only way to proceed here, given the fact that ICT price indexes are not available for other countries than the United States.

As data are available only for the period 1992-99, ICT spending in 1992 is used for the earlier years. In the data displayed in Figure 2, only spending on IT hardware, software and telecommunication equipment qualifies as investment. The problem with these data is that spending on telecommunication equipment cannot be separated from spending on telecommunication services. While the former qualifies for investment, the latter does not. Schreyer's (2000) approach is followed here by assuming that a 30 per cent share constitutes a lower bound for the investment expenditure part on telecommunication spending. Schreyer arrived at this particular approximation by comparing US official statistics with the information on the United States in the WITSA dataset. But the estimation results are not sensitive with respect to this assumption and a 50 per cent share could be used as well.

Column (3) reveals that ICT is not statistically significant in the cross-section estimation of economic growth in 42 countries in 1985-99. Only physical capital seems to matter, but human capital is also close to being significant at 10 per cent level. The inclusion of ICT investment in the regression reduces the significance of human capital because of the strong correlation (0.67) between these two variables in the data.

The conclusion concerning the poor performance of ICT investment in explaining cross-country growth differences contradicts many popular views on the influence of the ICT revolution and the New Economy. It is, however, well in line with the findings of Dewan and Kraemer (2000) and Pohjola (2001). The difference is that, unlike in these two studies, ICT is not a good explanatory factor of economic growth in OECD or high-income countries either. This is shown in the last column of Table 3 which contains the estimation results for the subsample of 24 high-income countries as defined in the World Bank's (2001) WDI database. An interesting fact is that neither ICT, other physical nor human capital investment is statistically significant. This may be due to the rather small sample size or the short time period considered. But it may also reflect the fact that the neoclassical model applied here does not capture all the relevant explanatory variables.

## 7 Explanations for the weak impacts of ICT investment

There are at least three reasons why the impact of ICT investment does not show up as improved productivity growth at the macroeconomic level except perhaps in a few advanced economies. The most obvious one is the fact that, as demonstrated in section 2 above, most countries have not yet invested much in ICT. The second reason is that even if they have done so, they may not have invested enough in complementary organizational infrastructure in order to reap the benefits from ICT investment. Technology by itself is not a solution to any development problem; it only provides an opportunity. The third and the most controversial explanation is that the neoclassical method applied in assessing the benefits may not capture the most essential aspects of the New Economy or the ICT revolution. The evidence has been looked for in the wrong place.

Regarding insufficient investment in ICT, Figure 2 above shows that rich countries have indeed spent a much larger share of their GDP on ICT than poor countries. This is even more true if we consider the differences in the diffusion of ICT equipment between the developed and developing countries as displayed in Table 1. However, investment in ICT turned out to be a poor explanatory factor of economic growth even in the high-income OECD economies. Consequently, it cannot by itself be the solution to the world's development problems.

If it were, then the policy conclusions would be rather straightforward: promote investment in ICT by whatever means available. But this would lead back to the old-fashioned development doctrine known as capital fundamentalism, the dominant theory of economic development in the 1950s and 1960s. Under this view, differences in national stocks of capital are the main determinants of differences in national product. Correspondingly, capital fundamentalists like Arthur Lewis and W. W. Rostow viewed rapid capital accumulation as central to increasing the rate of economic growth. The doctrine provided a coherent foundation for giving advice on development problems: national and international policies designed to increase a nation's physical capital stock were the best way to foster economic development.

The modern view of growth and development (see, e.g., Easterly and Levine 2001) is more sceptical. There seems to be little support for the view that factor accumulation alone should guide our policy advice—increases in total factor productivity are at least equally important. Although international differences in physical and human capital per person play an important role in the explanation of the differences in output per person across countries, they cannot explain all of them. The problem is, however, that not much is yet known about the factors determining total factor productivity.

The second possible explanation for the weak impact of ICT investment is that many countries have not been able to reap its benefits because of poor organizational and other infrastructure. Dewan and Kraemer (2000) and Mansell (2001), for example, argue that developed countries have already built up a mature stock of physical infrastructure, human capital and appropriate government policies which enhance and amplify the effects of investments in information and communication technology. Developing countries, on the other hand, lack such ICT-enhancing complementary factors, making it much more difficult for them to benefit from the modern advances in technology that enable the redesign of production, work as well as business management practices. Thus, ICT is likely to result in higher economic growth in developed than in developing countries.

The problem with this explanation is that the impacts of ICT investment on output and labour productivity growth have been much smaller in the European Union countries than in the United States although their infrastructures should not be that different. Why then is the United States superior to others? Chandler and Cortada (2000) emphasize the role that systems have had in the evolution of the US information infrastructure, such as the US Postal System, the Bell Telephone System, RCA's National Broadcasting System, IBM's System 360 computers and Microsoft's Operating System. These systems were created to assure a high-volume flow of information, and they were embedded in large business enterprises. In their view, the New Economy is nothing but the current phase in the development of the information infrastructure that started already 300 years ago. Through such systems, the United States has been more efficient that the other economies in disseminating new ICT technologies.

There is, however, one interesting difference in infrastructures between the United States and Europe or Asia.[3] The US telecommunication infrastructure seems to be better suited for the transmission of data. Telecommunication investment in Europe and Asia has focussed on voice, resulting in a system which is expensive for the use of data. This difference is likely to become more important over time, given the growing role of digital databases in business and science (David 2002).

The McKinsey Global Institute (see Lewis *et al.* 2002) argues that the secret behind the US economy is not ICT as such but competition and managerial innovation. Their industry-level study of productivity growth in the late 1990s reveals that in those sectors where ICT did play a role, it was a necessary but not a sufficient enabler of productivity gains. Businesses need to implement changes in their strategies and operational processes to reap the benefits from technological innovations. In this sense, ICT is no different than any other technology. Proper incentives for investment need to be in place for them to become successful. Baily and Lawrence (2001) conclude that competition, often on a global scale, has provided the right incentives for firms in the US service industries to seek out new technologies to improve productivity. ICT innovations have been driven by the demand for improved technologies in the using industries.

The third explanation for the observed weak evidence on the New Economy is that we have searched in the wrong place. It is not to be found in the supply side of the economy, as the models used above assume, but in the demand side. Quah (2001, 2002) argues that the most profound impact of the ICT revolution is that it makes modern economies increasingly weightless or dematerialized in the sense that an increasingly greater fraction of gross domestic product comes to reside in knowledge products. These are the goods and services whose economic properties in consumption are the same as those of knowledge: they are infinitely expansible (i.e. non-rival) and they disrespect geography. Once invented, they can be copied and transferred at negligible costs. Their use by one person or one country does not prevent other persons or countries from using them. Such knowledge products include all goods and services that can be expressed in digital form—encoded as a stream of bits—such as computer software, telecommunications, biological algorithms, financial services, electronic databases and libraries, media entertainment and Internet delivery of goods and services.

According to this view, the most significant benefits of the New Economy should show up as an improvement in the welfare of consumers of knowledge products. However, there do not seem to exist any other empirical studies assessing these impacts than a study by David (2001) which presents some partial evidence on underinvestment in product development. The demand-side view also explains the weak correlation between productivity growth and the use of ICT by the fact that potential users of the new technology have chosen not to use it (Quah 2002). Policymakers should then promote measures that encourage consumers and other ICT users to participate in the New Economy. Attention is thus drawn to the factors that prevent the dissemination of knowledge products. Many of them are the same as those which prevent the dissemination of knowledge itself.

[3] I owe this point to Paul David.

## 8 Conclusions

The New Economy is not a panacea for economic development. But the fact is that the two trends—the globalization of business activities and the ICT revolution—shaping the world economy today will remain there for the foreseeable future. The bursting of the 'dotcom bubble' in the stock market has no impact on these underlying forces. It only reflects the failure of one type of business model in the New Economy as many public online electronic marketplaces have turned out to be unprofitable. But new models will be tried, and the current trend seems to be towards private exchanges connecting businesses with their partners and suppliers over the Internet.

The fact is also that many countries—developed and developing—have already benefited from the New Economy as producers of ICT goods and services. While their production is still very heavily concentrated in the high-income OECD countries, also the Asian countries have captured a disproportionately high share of global ICT production. In 1998, they accounted for almost 40 per cent of the value of all electronics production in the world (Wong 2002). However, these countries are not generally regarded as New Economies, the explanation being that they are laggards in the adoption and use of information and communication technology.

As argued above, it is not possible for all countries in the world to become significant producers of ICT but they all can become its sophisticated users. The benefits from ICT use are likely to exceed the benefits from production in the long run. The success of the US and some European countries shows that in the global New Economy the sources of competitive advantage no longer lie in low-cost manufacturing but in the adoption of technological, organizational and managerial innovations that enhance productivity. Given its continuously improving quality and declining price, ICT will become an enabler in this adoption process more often in the future than it has done in the past.

The cross-country growth regressions estimated in this paper did not display significant returns to ICT investment in terms of productivity growth. One explanation is that the countries in the sample have not yet invested enough in the new technology. The digital divide is indeed wide, but not much is known about the patterns of ICT diffusion across countries and about the determinants of its adoption. The importance of human capital, openness to trade and direct investment, telecommunication infrastructure, and Internet access costs are emphasized in the studies which exist (Caselli and Coleman 2001; Lee 2001; Shih, Kraemer and Dedrick 2001; Kiiski and Pohjola 2002). But even their impacts seem to be different between the developed and developing countries. It is evident that given the dissimilarities in the production and consumption profiles between these two groups of countries, the optimal ways to benefit from ICT are likely to be different as well. More research is needed on the factors affecting the adoption of ICT.

Another explanation is that a mere 'me too' investment is not likely to result in any improvements in productivity. There are countries, South Africa for example, which have invested in ICT much more than others at similar income levels, but have had no any visible impacts on economic growth. Providing access to the latest technology is not enough if the incentives for using it are missing. Economic growth occurs when agents are willing to sacrifice current consumption for future payoff. The declining price of ICT makes the cost of investment low in terms of foregone consumption but it does not determine the future payoffs. They depend on many other factors such as the business model, market access, competitive environment, human capital, and government policies. Here, the problems of development are the same in the New as in the 'Old' Economy. Moreover, while technology defined in these broad terms is central to economic growth, it is unrealistic to expect the impacts of any particular invented technology, such as the Internet, to be enormous (for a discussion, see Kenny 2002).

But what then is new in the New Economy? Given that economic growth is driven by advances in technology, the countries that lag behind the world's leaders in technology should be able to improve their growth performance simply by adopting the technologies created by others. The new aspect that ICT provides here is that knowledge products—the weightless or intangible components of ICT—can be copied and transferred at negligible costs. Therefore, the barriers to riches should be lower for developing countries in the New than in the Old Economy.

But they do not seem to be. Income differences between the rich and the poor countries are increasing when they should be declining. The challenge for the research community is to identify the barriers and for the policymaking community to remove them.

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