APPENDIX D
THE PRODUCTIVITY PARADOX

Though generally accepted, demonstrating the positive empirical association between Information Technologies (IT) and productivity has been a major challenge. The inability to show a statistical association between Information Technology (IT) investments and productivity is commonly referred to as the *productivity paradox*, or in Solow's own words "information technology is everywhere except in the productivity statistics" (Solow 1987). Comprehensive evaluation of research covered by the US National Science Foundation's Science and Engineering Report (NSF and NSB 2000) points out how most studies have failed to find a positive and significant contribution of Information Technologies (IT) to productivity in any service or manufacturing sector, in any time (late 60s or 80s), at any level of analysis (macro economy or specific industries or sectors), and with any types of measurement (across data sets or indicators) in the U.S. economy. The only large and significant IT contributions were found using firm level databases, and even then, the contribution of Information Technologies (IT) to productivity was found only in case studies of a single industry or a small set of firms (Brynjolfsson 1993; Brynjolfsson 1996).

In contrast to inconclusive results in the U.S., micro-level analysis of productivity growth rates in the European community as a result of the use of Information Technologies yield positive empirical results. "It is this diffusion of new information and telecommunications technologies that will promote knowledge-intensive business service-firm, increase to knowledge and, ultimately, determine productivity growth" (Antonelli 1999: 241). Based on input/output statistics of the four main European economies (Germany, Italy, UK, and France) and by systematically testing the correlation between three independent factors with overall productivity growth, the findings suggest that the spread of communications and business services explain much of the innovative capability of the European community in the late 1980s. Three independent factors tested for correlation were: 1) the penetration of IT, 2) the diffusion of knowledge-intensive services, and 3) the adoption of new technological and organizational innovations. However, the extent to which firms are able to take advantage of opportunities to introduce new networking technologies affects the efficiency of the production process. Requirements for the creation of a competitive advantage and increases in productivity include: 1) a well-trained and experienced workforce, and 2) increased firm integration. In other words, IT and productivity are positively linked, but only at micro-level analysis in organizations that comply with the requirements which may be costly and time consuming. This could explain why IT appears unusually unproductive in the long term, because the long term benefits are a consequence of changes in the technology and organizational system

The explanations for the productivity paradox usually involve issues relating to the precise measurement of IT. The problem is that IT is so pervasive in society and embedded in other systems such as appliances, machine tools, and automobiles, that measurements of what constitutes IT produce little consistency. This notion is further developed by characterizing information technologies as General Purpose Technologies

(GPT) (Bresnahan and Trajtenberg 1995). A General Purpose Technology (GPT) is a technology (or technologies) which display high capabilities of adaptation to a variety of circumstances and are applicable to the production of many different outputs. This is the case of the microprocessor which through software can be adapted to many different uses. GPT has the potential of altering business models and chains of production, which in turn produce changes in the organization of industries, delivery of services, production methods, distributions channels, and supplier/buyer relations (Langlois 2001). Precise measurement of the impact on productivity of a General Purpose Technology is therefore extremely difficult.

The effects of the innovation pace and price reduction also defy the assignment of reliable dollar values to input and output effects, consumption or production indicators of information technologies (IT). Empirical economic studies overcome this difficulty by the use of hedonic estimation curves. Hedonic estimation curves take into account changes in prices along the entire product line, found for example in the computing industry. When hedonic techniques are used to estimate changes in the computer industry, positive associations to productivity are evident (Brynjolfsson 1996). Another example of the use of hedonic techniques for cross-country comparison is the study comparing the US and Brazil's hardware industry in 1995. Findings demonstrated that Brazil was years behind technical achievement across a wide class of products (Bresnahan and Greenstein 2001). The reason why hedonic techniques are not commonly used to link IT to productivity is because they require detailed product-level data over long periods of time to produce a substantial number of observations.

Another reason for the lack of correspondence between technological improvement produced by the use of information technologies and productivity growth pertains to the period of study. In the early stages of its development, information technology may have no effects in cost-reduction. In fact, it may have the opposite effect due to the investments required by the adaptation process. However, once it has reached a threshold, adoption rates of information "technology may become increasingly more sensitive to rapid, large-scale productivity consequences" (Rosenberg 1982, p. 27).

The same problems that apply to the measurement of information technologies in the US economy also apply globally. Increases in productivity in OECD countries due to the use of information and communication technologies have not been easy to prove. In much of Europe and in Japan productivity growth has not accelerated. Some have argued that the benefits of the computer and the Internet come only when they reach, say, 50% penetration and begin reducing costs in other parts of the economy. That rate was reached in the United States only in 1999. During the decade the IT-industry contribution to GDP growth had risen from 6.6% in 1990, to 15.3% in 1996, up to 19.2% in 1999. Likewise the IT industry share of US GDP had gone from 5.8% in 1991, to 7.1% in 1996 to 8.2% in 1999 (Wired 2000). It is not the number of computers that triggers higher productivity but overall change in the way the economy works (UN 2001).