Appendix

To measure capital and labor inputs and the sources of economic growth, we employ the production possibility frontier model of production and the index number methodology for input measurement presented by Jorgenson (2001). For the G7 economies we have updated and revised the data constructed by Jorgenson (2003). For the remaining 103 economies, we rely on two primary sources of data[17]: the Penn World Table (2002) and *World Bank Development Indicators Online* (2004) provide national accounting data for 1950-2003 for all economies in the world except Taiwan. WITSA's *Digital Planet Report* (2002, 2004) gives data on expenditures on IT equipment and software for 70 economies, including the G7.

U.S. data on investment in IT equipment and software, provided by the Bureau of Economic Analysis (BEA) are the most comprehensive.[18] We use these data as a benchmark in estimating IT investment data for other economies. For the economies included in the *Digital Planet Report* we estimate IT investment from IT expenditures. The *Digital Planet Report* provides expenditure data for computer hardware, software, and telecommunication equipment on an annual basis, beginning in 1992.

Expenditure data from the *Digital Planet Report* are given in current U.S. dollars. However, data are not provided separately for investment and intermediate input and for business, household, and government sectors. We find that the ratio of BEA investment to WITSA expenditure data for the U.S. is fairly constant for the periods 1981-1990 and 1991-2001 for each type of IT equipment and software. Further, data on the global market for telecommunication equipment for 1991-2001, reported by the International

---

[17] Other important sources of data include the International Telecommunication Union (ITU) telecommunications indicators, and the UNDP Human Development reports.

[18] The BEA data are described by Grimm, Moulton, and Wasshausen (2004).

Telecommunication Union (ITU), confirms that the ratio of investment to total expenditure for the U.S. is representative of the global market.

We take the ratios of IT investment to IT expenditure for the U.S. as an estimate of the share of investment to expenditure from the *Digital Planet Report*. We use the penetration rate of IT in each economy to extrapolate the investment levels. This extrapolation is based on the assumption that the increase in real IT investment is proportional to the increase in IT penetration.

Investment in each type of IT equipment and software is calculated as follows:

$$I_{c,\ A,\ t} = \eta_{c,\ A,\ t} * E_{c,\ A,\ t}$$

where $I_{c,A,t}$, $\eta_{c,A,t}$, and $E_{c,A,t}$ are investment, the estimated investment-to-expenditure ratio, and the *Digital Planet Report* expenditures, respectively, for asset A in year t for country c[19].

Given the estimated IT investment flows, we use the perpetual inventory method to estimate IT capital stock. We assume that the geometric depreciation rate is 31.5% and the service life is 7 years for computer hardware, 31.5% and 5 years for software, and 11% and 11 years for telecommunication equipment. Investment in current U.S. dollars for each asset is deflated by the U.S. price index to obtain investment in constant U.S. dollars.

To estimate IT investment for the 66 economies not covered by the *Digital Planet Reports,* we extrapolate the levels of IT capital stock per capita we have estimated for the 70 economies included in these *Reports*. We

[19] The IT expenditures for years prior to 1992 are projected by means of the following model:

$$\ln(Ec_{i\ t-1}) = \beta_0 + \beta_1 \ln(Ec_{\ i\ t}) + \beta_2 \ln(y_{\ i\ t-1})$$

where $Ec_{i\ t}$ represents expenditure on IT asset c and the subscripts i and t indicate country i in year t, and $y_{i\ t}$ is GDP per capita. The model specifies that, for a country i, spending on IT asset c in year t-1 can be projected from GDP per capita in that year and spending on asset c in period t.

assume that IT capital stock per capita for the 40 additional economies is proportional to the level of IT penetration. The details are as follows:

For computers we divide the 70 economies included in the *Digital Planet Reports* into 10 equal groups, based on the level of personal computer (PC) penetration in 2003. We estimate the current value s^i_{HW} of computer stock per capita in 2003 for an economy i as:

$$s^i_{HW} = \bar{s}^I_{HW} * (P^i_{HW} / \bar{P}^I_{HW}),$$

where $\bar{s}^I_{HW}$ is the average value of computer capital per capita in 2001 of group I for countries included in the *Digital Planet Report*, P^i_{HW} and $\bar{P}^I_{HW}$ are the PC penetration rates of economy i and the average PC penetration of group I, respectively.

For the economies with data on PC penetration for 1995, we use the growth rates of PC penetration over 1989-2003 to project the current value of computer capital stock per capita backwards. We estimate computer capital stock for each year by multiplying capital stock per capita by population. For economies lacking the data of PC penetration in 1995 and 1989, we estimate computer capital stock by assuming that the growth rates in the two periods, 1995-2003 and 1989-1995, are the same as those for the group to which it belongs.

For software capital stock, we divide the 110 countries into 10 categories by level of PC penetration in 2003. We sub-divide each of these categories into three categories by degree of software piracy[20], generating 30 groups. We assume that the software capital stock-to-hardware capital stock ratio is constant in each year for each of the 30 groups:

$$s^i_{SW} = \bar{s}^I_{SW} * (s^i_{HW} / \bar{s}^I_{HW})$$

[20] The information on software piracy is based on study conducted by the Business Software Alliance (2003).

where $\bar{s}_{SW}^{I}$ is the average software capital stock per capita of subgroup I in 2003. Since the value of computer stock per capita has been estimated for 1995 and 1989, this enables us to estimate the software capital stock per capita for these two years.

Finally, we define the penetration rate for telecommunications equipment as the sum of main-line and mobile telephone penetration rates. These data are available for all 110 economies in all three years - 1989, 1995, and 2003. We have divided these into 10 groups by the level of telecommunications equipment penetration for each year. The current value of telecommunications capital stock per capita is estimated as:

$$s_{TLC}^{it} = \bar{s}_{TLC}^{It} * (P_{TLC}^{it} / \bar{P}_{TLC}^{It})$$

where $\bar{s}_{TLC}^{It}$ is the average current of telecommunications equipment capital stock per capita in year t of group I for economies included in the *Digital Planet Reports* and P_{TLC}^{it} and $\bar{P}_{TLC}^{It}$ are the telecommunications equipment penetration rates of economy i and the average penetration rate of group I in year t.

We employ Gross Fixed Capital Formation for each of the 103 economies provided by the Penn World Table, measured in current U.S. dollars, as the flow of investment. We use the Penn World Table investment deflators to convert these flows into constant U.S. dollars. The constant dollar value of capital stock is estimated by the perpetual inventory method for each of the 103 economies for 1989 and the following years. We assume a depreciation rate of 7% and a service life of 30 years.

The current value of the gross capital stock at a year is the product of its constant dollar value and the investment deflator for that year. We estimate the current value of Non-ICT capital stock of an economy for each year by subtracting the current value of IT stock from the current value of capital stock in that year. Given the estimates of the capital stock for each type of asset, we calculate capital input for this stock, using the methodology presented of Jorgenson (2001).

Finally, labor input is the product of hours worked and labor quality:

$L_t = H_t * q_t$

where L_t, H_t, and q_t, respectively, are the labor input, the hours worked, and labor quality. A labor quality index requires data on education and hours worked for each of category of workers.

We extrapolate the labor quality indexes for the G7 economies by means of the following model:

$q_{i,t} = \beta_0 + \beta_1 \text{ Education}_{i,t} + \beta_2 \text{ Institution1}_i + \beta_3 \text{ Institution2}_i + \beta_4 \text{ Income1989}_i + \beta_5 T$

where subscripts i and t indicate economy i in year t. Education is the educational attainment of the population aged 25 or over from the data set constructed by Robert Barro and Jong-Wha Lee (2001). Institution1 = “Rule of Law” and Institution2 = “Regulatory Quality” are constructed by Daniel Kaufmann, Aart Kraay, and Massimo Mastruzzi (2004) for the World Bank; Income1990 is GDP per capita for 1990 from the Penn World Table and T is a time dummy.

Labor quality is largely explained by educational attainment, institutional quality and living conditions. The model fits well (R^2 = 0.973) and all the explanatory variables are statistically significant. We assume that hours worked per worker is constant at 2000 hours per year, so that growth rates of hours worked are the same as employment.