The Information Society

ISSN: 0197-2243 (Print) 1087-6537 (Online) Journal homepage: http://www.tandfonline.com/loi/utis20

Methodological Challenges of Digital Divide Measurements

Vasja Vehovar , Pavle Sicherl , Tobias Hüsing & Vesna Dolnicar

The Information Society, 22: 279–290, 2006

ISSN: 0197-2243 print / 1087-6537 online
DOI: 10.1080/01972240600904076

Methodological Challenges of Digital Divide Measurements

Vasja Vehovar

Faculty of Social Sciences, University of Ljubljana, Ljubljana, Slovenia

Pavle Sicherl

Faculty of Law, University of Ljubljana, Ljubljana, Slovenia

Tobias Hüsing

Gesellschaft für Kommunikations- und Technologieforschung, Bonn, Germany

Vesna Dolnicar

Faculty of Social Sciences, University of Ljubljana, Ljubljana, Slovenia

The term "digital divide" has been used for almost a decade and typically relates to sociodemographic differences in the use of information and communication technology. However, the corresponding measurement is still relatively imprecise. Very often it is simply reduced to comparisons of Internet penetration rates. This article extends the measurements above the usual bivariate comparisons. Within this context, three essential approaches are presented and critically evaluated. First, loglinear modeling is used to address the interactions among the factors affecting the digital divide. Second, compound measures (i.e., the Digital Divide Index) that integrate a number of variables into a single indicator are discussed. Third, time-distance methodology is applied to analyze changes in the digital divide. The article argues that these approaches often yield entirely different conclusions compared to simple bivariate analysis. The examples are presented as a general warning against an oversimplified methodological approach to digital divide studies.

Keywords digital divide, multivariate analysis, time-distance methodology

The digital divide concept initially appeared in media and government reports (e.g. "Falling Through the Net" and "A Nation Online"; NTIA, 1995; 1997, 1999, 2000, 2002, 2004). In February 1996, the then U.S. Vice-President Al Gore was one of the first to mention this term when emphasizing that the United States was "beginning to close the digital divide" (Office of the Vice-President, 1996). As a consequence, the U.S. government formulated relatively active policies on computer literacy as well as on the general facilitation of information and communication technology (ICT) usage.

Development of the information society has also become an important priority for many other countries, including those of the European Union (EU). The Action Plan "eEurope 2005: An Information Society for All" contains numerous measures for facilitating modern public services (e.g., e-government, e-learning, e-health, etc.) and a dynamic e-business environment. Giving every citizen the possibility to participate in the global information society was also a goal that formed part of the strategy set out at the Lisbon European Council in March 2000 (European Commission, 2000).

Digital divide issues have also become an attractive subject for academic research. The first scholarly papers appeared around 1997 (e.g., Katz & Aspden, 1997) and were followed by a growing series of publications. For example, at the beginning of 2006 the ISI Web of Science database contained over 440 papers related to the digital divide. We can also find various monographs addressing specific dimensions of the digital divide, from racial (Lawson Mack, 2001) and global divides (Norris, 2001) to

Received 22 August 2005; accepted 3 June 2006.
Address correspondence to Vasja Vehovar, Project RIS, Faculty of Social Sciences, University of Ljubljana, Kardeljeva ploscad 5, 1000 Ljubljana, Slovenia. E-mail: vasja.vehovar@guest.arnes.si

multidimensional aspects (Compaine, 2001; Mossberger et al., 2003). Some authors also cover the relationship between ICT and social inclusion (Warschauer, 2003a) or they address the digital divide as a problem of persistent inequality (Servon, 2002).

Despite these efforts, there is a clear lack of a general conceptual framework. In principle, certain theories from other areas can be applied here, for instance, diffusion of innovation (Rogers, 1995), audience theories, particularly the uses and gratifications theory (Blumler & Katz, 1974), or the general knowledge gap theory (Tichenor et al., 1970). Theories studying the individual and structural levels of social exclusion and social inequality (e.g., economic, gender, racial, and ethnic inequality) can also be used (e.g., Atkinson & Hill, 1998; Muffels et al., 2002; Rodgers et al., 1995; Silver, 1994). However, the relationship between old (social) and new (digital) divides still has to be explained (Hüsing, 2004): Namely, it is unclear whether the digital divide is a particular type of social divide or ICT functions here as a factor that bridges social divides. Unfortunately, it often seems that the explosive growth of the Internet is exacerbating the existing inequalities (Menou, 2001; Norris, 2001; Vehovar, 2001). Further, Parayil (2005) argues that the digital divide is both a symptom and a cause of broader social and economic inequality. In any case, it is generally agreed in the academic literature that the digital divide is closely related to social inequality (e.g., Attewell, 2001; Bonfadelli, 2002; DiMaggio et al., 2001; Menou, 2001; Warschauer, 2003b).

Contrary to the absence of theoretical discussions, we can observe many empirical studies that typically relate to Internet usage. The usual control variables are income, level of education, type of household, age, gender, race, and language (Primo Braga et al., 2000). The digital divide can also be regarded as a consequence of varying individual capabilities or digital experiences (e.g., Nurmela & Viherä, 2000; van Dijk & Hacker, 2003). In addition, the differences can be studied in terms of the relevance of information and services to users (e.g., Stanley, 2003; Welling & Kubicek, 2000).

In any case, the existing digital divide literature predominantly focuses on substantial issues, and we rarely find work discussing corresponding research methodologies. It is true that methodological aspects are in large part covered within the fields of comparative research, general social science methodology, and statistics. Nevertheless, we should clearly state at the very beginning that in this article we do concentrate on methodology. The conceptual issues are addressed only to the extent needed to deal with methodological questions.

We focus here on some well-elaborated methodological approaches where several variables are simultaneously observed (i.e., multivariate analysis, compound measures, and time distance). We demonstrate that these approaches cannot be ignored when conducting proper empirical research on digital divide phenomena. At the same time, we summarize typical problems that occur in digital divide studies when an oversimplified approach is applied. In other words, the article systematically overviews the key methodological fallacies of digital divide research.

In the following sections we start off by discussing the conceptual complexity of digital divide measurements. We review the corresponding typologies and address general methodological problems. Next, we concentrate on three advanced statistical methods (loglinear modeling, compound index measurements, and time distance) and illustrate them. Finally, we summarize the findings and evaluate the role of methodology in digital divide research. The discussion is mainly (but not exclusively) restricted to the case of the Internet. However, by a simple analogy we can also apply these principles to other ICT.

DEFINING THE DIGITAL DIVIDE

The OECD (2001) defines the digital divide as differences between individuals, households, companies, or regions related to the access to and usage of ICT. The divide may appear due to historical, socioeconomic, geographic, educational, behavioral, or generation factors, or due to the physical incapability of individuals (Cullen, 2001, p. 311). Such an understanding of the digital divide is generally unproblematic. Difficulties arise from the lack of a more standardized and elaborated operationalization. As a consequence, the measurement process may lead to the development of incomplete and misleading indicators.

One aspect of the complexity lies in the multiple technologies that are involved. It is true that the term "digital divide" only appeared after the Internet's expansion in the mid-1990s; however, it does not refer exclusively to the Internet. Other important ICTs (e.g., personal computers, cellular phones, ["cell"] etc.) are also highly relevant to digital divide issues.

Even if we narrow down the focus to Internet-related differences, the topic remains relatively complex. This is partly due to difficulties in defining Internet usage itself. One of the most general definitions describes the Internet as "a network of computer networks and systems that allows computers to communicate with one another on a global basis" (Elliott & Starkings, 1997). However, users are not merely passive recipients of technology—they actively engage in it, thus giving meaning to ICTs. In other words, the Internet is socially shaped. When defining Internet usage, the main methodological problems arise from questions related to the frequency of usage (e.g., weekly, monthly etc.), age of the target population (e.g., 10–75, 15–65), services used (e.g., e-mail, Web, instant messaging, etc.), relation to ICT (e.g., access, usage, perception, etc.) and devices employed (e.g., PC, cell phones, WebTV, personal digital assistant [PDA], etc.). Similar problems accompany technical measurements such as the number of "hosts" or number of "unique users" measured by so-called "cookies." For a further discussion of these problems, see Vehovar and Dolnicar (2004).

We should also draw attention to the fact that the digital divide is not a simple binary Yes/No question (Chen & Wellman, 2003). Rather, the digital divide is a continuum ranging from physical, cognitive, and content access to political access (Wilson, in Chen & Wellman, 2003). The notion of a binary divide is thus inaccurate as it fails to value the social resources of diverse groups (Warschauer, 2003b, p. 297). DiMaggio and Hargittai (2001) point out that there are at least five dimensions of digital inequality: equipment, autonomy of use, skill, social support, and the purpose of using the Internet. Similarly, Mossberger, Tolbert, and Stansbury (2003) distinguish between an *access* divide, a *skills* divide, an *economic opportunity* divide, and a *democratic* divide.

The multiplicity of divides can be roughly structured in a few core categories. The first and more "usual" (also labeled *first* or *basic*) digital divide is typically defined as simple differences with respect to the availability of Internet access (or any other ICT) or the frequency of usage.

Taking a second step, nonusers can be further differentiated with respect to the obstacles for not using the Internet, such as a lack of interest or lack of awareness of what computers can offer. Research indicates that computer nonusers would be more willing to engage with new technology if their assumptions, fears, and preconceived ideas about computers were properly addressed (Stanley, 2003, p. 413). The divide among nonusers is sometimes labeled a *dual* digital divide (Reddick et al., 2000).

On the other side, Internet users can be also further segmented on the basis of skills and experience. This is often labeled as the *second digital divide* (e.g., Gartner Group, 2001; Hargittai, 2002). Those who know how to use more advanced options have an advantage over those who only use simple services. The first digital divide—which refers to differences in access and usage—will inevitably disappear when the Internet becomes universally accessible. However, the digital divide relating to experience and advanced usage will exist after this takes place. Carvin (2000) identifies six types of literacy skills needed by a user in order to take full advantage of the Internet: basic literacy (the ability to read and write), functional literacy (the ability to apply basic literacy to everyday tasks), occupational literacy (the skills necessary to succeed in a professional setting), technological literacy (the ability to use technological tools), information literacy (the ability to determine the quality of informational resources), and adaptive literacy, that is, the ability to develop new skills (Dávila, 2004). Moreover, van Dijk and Hacker (2003) distinguish between informational, instrumental, and strategic skills. In addition, Mossberger, Tolbert, and Stansbury (2003) developed two different indices of skill, one for technical competence and one for information literacy. Internet users can also be differentiated according to the technology used. Users with fast (e.g., broadband) and more convenient (e.g., wireless, cell phone) access or those with more advanced (and expensive) devices can take full advantage of the new generations of services and technologies. On the other hand, users with slow access (e.g., ordinary dial-up access) and/or those with more primitive devices are at a disadvantage.

From the preceding discussion we can clearly see that there are many ways to conceptualize the digital divide. Nevertheless, whichever concept of the digital divide we use—theoretically grounded or not, simple or complex—it will inevitably face some standard methodological problems. We thus focus on these essential methodological issues that accompany any empirical research on the digital divide. Consequently, conceptual issues only take second place in this article, behind methodological issues.

In the remainder of the article we present three advanced methods that are highly relevant to any type of digital divide measurements. We demonstrate that the simple comparisons (e.g., percentage differences of Internet usage between segments) that often prevail in empirical studies may not be sufficient and can sometimes be even directly misleading.

For practical reasons, we have limited our discussion to the first (i.e., basic) digital divide and predominantly to Internet usage. However, the approach can be equally applied to other measures related to any type of digital divide, any type of population (e.g., persons, households, companies, education institutions, countries, etc.) and any type of ICT.

ADVANCED APPROACHES TO MEASURING THE DIGITAL DIVIDE

When studying the digital divide we often compare Internet usage across various population segments, where bivariate analysis may not reveal the true relationships. At this point, we demonstrate how advanced statistical measures—which incorporate more variables simultaneously—can dramatically change the research findings.

Interactions Among Variables: Multivariate Loglinear Modeling

Let us observe the complexity of multivariate interactions in the example of the rural–urban effect from the Slovenian General Social Survey (GSS)[1] 2000 (Tos, 2004). As in other countries, the digital divide in Slovenia varies according to standard control variables: age, gender,

TABLE 1
Bivariate analysis of Internet use (GSS, 2000, $n = 986$)

Label	Variable	Category	Percentage of Internet users (I)	t Value for percentage difference[c]
A	Age	40 Years and more	17%	12.9
		Below 40 years	57%	
E	Education	Below 12 years	11%	17.3
		12 Years or more	57%	
S	Social status[a] (subjective)	Lower	13%	12.0
		Higher	47%	
U	Urban/rural	Rural	27%	4.3
		Urban	37%	
R	Religion[b]	Religious	24%	5.6
		Not religious	41%	
G	Gender	Female	28%	3.0
		Male	36%	
M	Monthly income	Below 1st quartile	16%	7.3
		Above 1st quartile	37%	

[a]Social status was measured with the question "Which social class would you say you belong to? Is it the lowest stratum of society, the working class, the middle, upper middle or the upper class?" *(The lowest and working classes have been recoded as "lower" and the other three possible answers as "higher" categories.)*

[b]Religion was measured with the question "Can you tell us whether you are religious or not?" where a 5-point measurement scale was dichotomized afterward.

[c]Significance values for all the tests are less than .001. Similarly, the chi-square test is also significant for all pairs of variables.

education, religious belief, social status, monthly income of the household, and level of urbanization (Dolnicar et al., 2002). Here, the rural/urban component refers to the settlement size: Settlements with less than 2000 inhabitants are labeled rural while those with 2000 or more are labeled urban.

As shown in Table 1, the bivariate analysis reveals some significant differences in Internet usage.[2] Among others, we can observe that individuals from rural areas seem to use the Internet much less often (27%) than people from urban districts (37%). The corresponding percentage difference is highly statistically significant ($t = 4.3$, sig. $= .000$).

However, this bivariate link may result from some higher level interactions among the variables, something that cannot be discovered through bivariate cross-tabulations. We used loglinear modeling in order to simultaneously analyze a number of variables.[3] At this stage we do not discuss any technical details; instead, we just show the final results.[4] The final model preserves the link between Internet usage (I) and social status (S), that is, SI, between Internet usage and gender (GI), and between Internet usage and monthly income (MI), while education (E) and age (A) are interrelated to Internet usage in the interaction of three variables (AEI): Age determines how the level of education differentiates Internet usage.

The urban/rural component (UI) entirely disappeared in this multivariate model, although it initially demonstrated a much higher bivariate significance ($t = 4.3$ in Table 1) than gender ($t = 3.0$), which in fact remained in the model (GI). The impact of settlement type (UI) was thus only a spurious effect and the urban/rural variable has no true impact on Internet usage. A similar finding applies to the role of the religion variable (RI).[5]

We can further illustrate this (Table 2) with a simple control over the education level, which shows that education—as a control variable—alone already explained the spurious link between Internet usage and urban/rural variable (UI). From Table 2 it can be seen that among less educated respondents (less than 12 years of education) there is almost no difference (11% vs. 10%) in Internet usage with respect to rural or urban settlements. The same also holds true for educated respondents with 12+ years of education (56% vs. 58%).

The preceding analysis demonstrates a textbook example (e.g., Churchill, 1999; Davis, 1985; Neuman, 2003) of the benefits arising from a multivariate approach. Nevertheless, bivariate methods often prevail in digital divide research (e.g., NTIA, 1995, 1997, 1999, 2000, 2002, 2004; Bell et al., 2004; Kalkun & Kalvet, 2002; Cole et al., 2004). Even in these prominent national studies the multivariate approach is relatively rare, typically limited to interrelations of at most three variables. On the other hand, it is also true that some digital divide studies have extensively used a multivariate approach and corresponding

TABLE 2
Education, type of settlement, and Internet use (GSS 2000, $n = 1067$)

Education (E)	Type of settlement (R)	Use of Internet (I)	t Value for percentage difference	Significance (p Value)
Less than 12 years	Rural	11%	0.39	.535
	Urban	10%		
12 Years and more	Rural	56%	0.19	.659
	Urban	58%		

model testing (Cava-Ferreruela & Alabau-Munoz, 2004; Cho et al., 2003; Corocher & Ordanini, 2002; Grigorovici et al., 2004b; Martin, 2003; Mossberger et al., 2003; Quibria et al., 2003; Wilhelm, 2000).

Of course, in nonexperimental research we can never really know whether another (additional) variable exists that would change all of the findings. Therefore, besides an appropriate methodological approach, the corresponding theory-driven variables should be carefully selected. We should add that multivariate models are sometimes very sensitive to manipulations carried out by the investigators. Nevertheless, proper modeling and the inclusion of the right variables are two key elements for successful empirical research.

Compound Measurements: Digital Divide Index

Sometimes digital divide indicators take different or even contradictory values. Such an example is presented in Figure 1, where two European countries (Slovenia and Estonia) are compared according to three ICT indicators. If we only take Internet usage into account, the gap between the two countries will be relatively high (Slovenia 37% vs. Estonia 52%). However, in the case of Internet users at home, Slovenia is in a better position (34% vs. 27%). A simple compound measure, the average across three variables, would result in a much smaller gap: 40% (Slovenia) versus 45% (Estonia). Of course, such a trivial calculation requires a solid justification as it enables a very powerful manipulation of the results.

Recently, various compound ICT measures have appeared, such as the Digital Access Index (ITU, 2003), the Digital Opportunity Index (ITU, 2005), the Networked Readiness Index (Dutta & Jain, 2004), the Technology Achievement Index (UNDP, 2001), the Information Society Index (IDC, 2001), the Internet Connectedness Index (Jung et al., 2001), and the Infostate, which is a global set of indicators composed of two components, namely, Infodensity and Info-use (Sciadas, 2005).

One of the more sophisticated examples of compound measures is the Digital Divide Index (DIDIX) developed within the SIBIS project (Statistical Indicators Benchmarking Information Society), an EU research framework program led by Empirica (2005), which provided comparable 2002–2003 data for 15 EU member states, 10 newly associated states (NAS), and Switzerland and the United

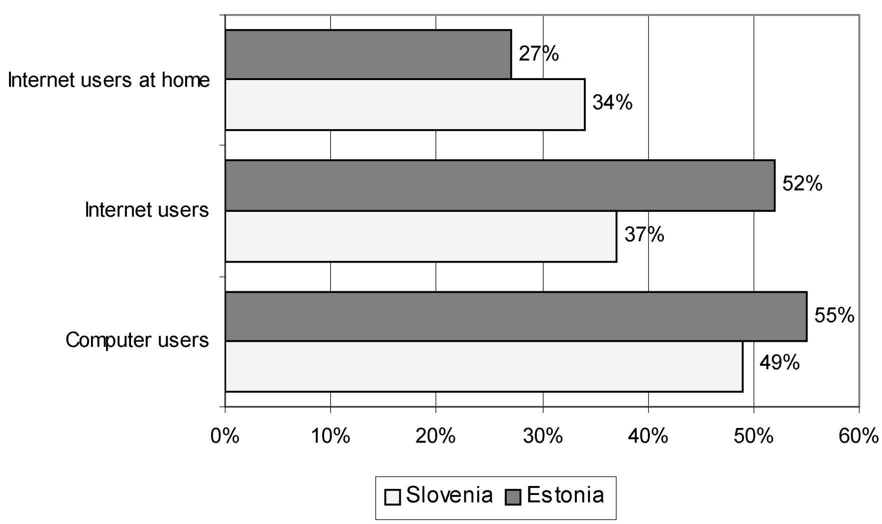

FIG. 1. Percentage shares of Internet and computer users in Estonia and Slovenia (SIBIS, 2003).

States. This index had no scientific pretensions but was initially developed for a policymaker audience. Nevertheless, it has attracted the attention of the scientific community, which indicates the growing need for compound measures.

DIDIX combines the divides with four sociodemographic factors (gender, age, education, and income) in relation to three ICT-related indicators. The initial *compound ICT adoption indicator* is constructed as follows:

- Percentage of computer users[6] (50% weight).
- Percentage of Internet users[7] (30% weight).
- Percentage of Internet users from home[8] (20% weight).

This compound ICT adoption indicator thus expresses the relative adoption of ICTs, which is further observed within the four potentially deprived societal groups (SIBIS, 2003a, pp. 152, 185; SIBIS, 2003b, p. 13):

- Women.
- People aged 50 years and over.
- The low-education group (i.e., people who finished formal school education at the age of 15 years or below).
- The low-income group (i.e., the lowest income quartile of survey respondents).

The *basic DIDIX* values represent the ratio between the compound ICT adoption indicator in a certain risk group and the value of the corresponding indicator in the total population. If the ICT adoption rate of a risk group was equal to that of the population average, then the corresponding basic DIDIX value would be 100 (Selhofer & Hüsing, 2002; Hüsing & Selhofer, 2004).

Figure 2 presents the basic DIDIX values for the four risk groups as well as the *overall DIDIX,* which is calculated as a simple average of basic DIDIX measures across the four segments. The basic educational DIDIX for EU-15 countries is 27 (Figure 2), meaning that this segment (i.e., people who ended their education at age 15 or lower) has adopted ICT only at 27% of the level of the entire population. In NAS countries the education gap is even much sharper (7%). The aggregate comparison shows that in EU-15 countries the risk groups have an overall DIDIX value of 53%, while the corresponding value in NAS countries is much lower (42%).

There is no doubt that DIDIX enables an effective analysis at the aggregate level. Like other compound measures, it has several advantages in comparison to single indicators: We can measure more aspects of relatively complex concepts and consequently we can discriminate between countries on a much higher conceptual level.

However, serious problems arise from the averaging across technologies and across social groups. Selhofer and Hüsing (2002) identified some of the flaws related to the selection and definition of disadvantaged groups as well as regarding the indicators of ICT involvement. In addition to this, we should also warn about the potential interactions among different social groups within countries. In such cases, DIDIX would hide the true status of the digital divide, particularly when a country is not very homogeneous. The assumptions that all three indicators measure the same dimension and that indicator weights reflect the true loadings of the DIDIX indicators can also be problematic. In order to avoid these deficiencies, a measurement model could be tested with confirmatory factor analysis first (however, this analysis could only be applied in the case of at least an interval scale of the variables). In this way, the present arbitrariness of the weights could be overcome by the possibly more adequate figures that would reflect the loadings of the indicators on the factor (for a more elaborated approach for handling weights in the case of information society indices, see Grigorovici et al., 2004a).

The main criticism of compound indicators rests on their oversimplification of complex interrelations, that is, reducing the digital divide to a single number, which may

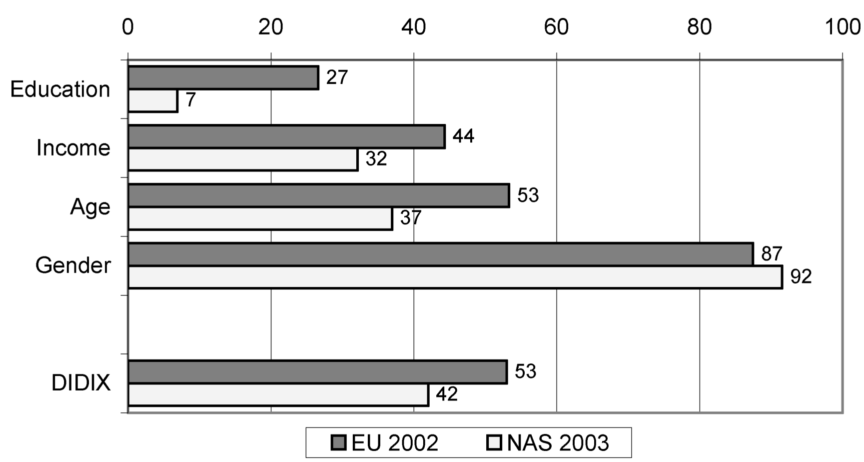

FIG. 2. Basic and overall DIDIX measures for EU-15 and NAS countries (SIBIS, 2003).

be misleading in some instances. However, it should also be recognized that compound indicators can function as important eye openers outside of the scientific community (which does not release the researcher from using adequate and disclosed methodologies). The audience of projects such as SIBIS includes policymakers as well as the public at large.

We could also speculate here about a robust compound digital divide measure, which would identify all key segments and incorporate all relevant ICTs and thus reflect the "true" digital divide. Besides technologies that have already reached saturation (e.g., TV, fixed telephone) or are slowly approaching it (e.g., PC, the Internet), new emerging ICTs (e.g., broadband, videophone) are becoming increasingly important determinants of digital divide measures. In addition, new technologies should be continuously incorporated in the indices. The challenge of constructing such a general (i.e., ultimate) compound indicator of the digital divide seems to be both very fruitful and also very problematic.

Time-Distance Methodology

Digital divide indicators are often presented as static measures. However, static measures of disparities (e.g., percentage difference, ratio, Gini coefficient, Theil index, coefficient of variation, etc.) are insensitive to changes in the corresponding absolute magnitude of the indicator growth rates. In order to overcome this problem, an advanced time-distance methodology was developed at conceptual and applied levels (Sicherl, 1973, 1978, 2003). This is a new statistical measure in dynamic gap analysis (Sicherl, 2004) where the levels of variable(s) are used as identifiers and time is the focus of comparison. This generic idea can be used for numerous additional applications; for example, Granger and Jeon (1997, 2003) further elaborated it for use as a criterion for evaluating forecasting models.

In general, time distance means the difference in time between the occurrences of two events. Sicherl (1973, 1978, 2005) defined a special category of time distance, using an additional perspective by comparing the time series in a horizontal dimension, that is, for a given level of the variable. The corresponding statistical measure *S-time-distance* expresses the distance (or proximity) in time between points in time when the two series compared reach the same specified level of the particular indicator. The observed distance (e.g., the number of years, quarters, months, days etc.) is used as a temporal measure of disparity between the two series in the same way that the observed difference (absolute or relative) at a given point in time is used as a static measure of disparity.

Figure 3 is an example of the simplest form of combining information with respect to time and levels in a single graph. The gender time lag for Internet usage is 5 months, meaning that women reached the specific level of usage by the total population 5 months later (i.e., April 2002 versus November 2001). For the lower education group this time distance is even larger: 4 years (52 months). This example shows that for the same socioeconomic group one can extract new additional insights that are neglected by the usual approaches of comparing penetration rates as they do not fully utilize the information embodied in the existing data.

Figure 4 demonstrates a more advanced application of the time-distance method for the case of a two-dimensional presentation of host density (the number of Internet hosts per 10,000 habitants) for Slovenia and the EU-15 average (1995–2004). In the vertical dimension we expressed the Slovenian relative host density as the ratio to the EU-15 density. The other dimension expresses time distance, that is, how many years earlier was the Slovenian host density reached by the EU-15 average.

In July 1995 Slovenia reached 40% of the EU-15 average and in January 1997 it reached almost 90%, whereas in May 2004 it had returned to around 40% of the EU-15

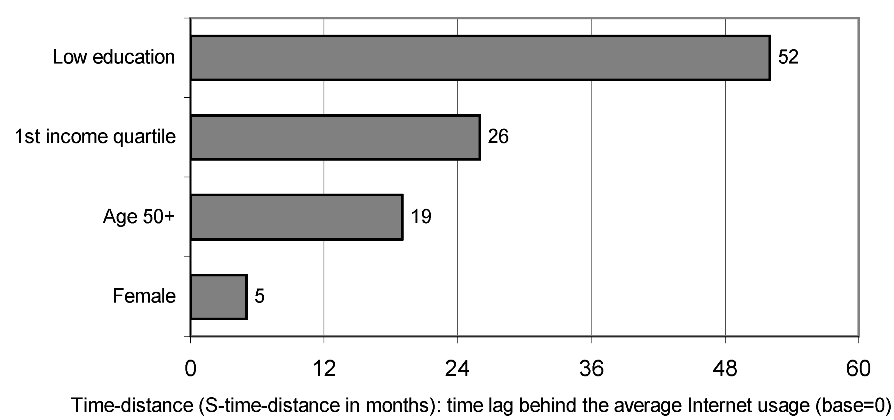

FIG. 3. Digital divide in the EU-15: How many months earlier was the level of Internet penetration of the selected segment (as measured in April 2002) attained by the average Internet user in the total population.

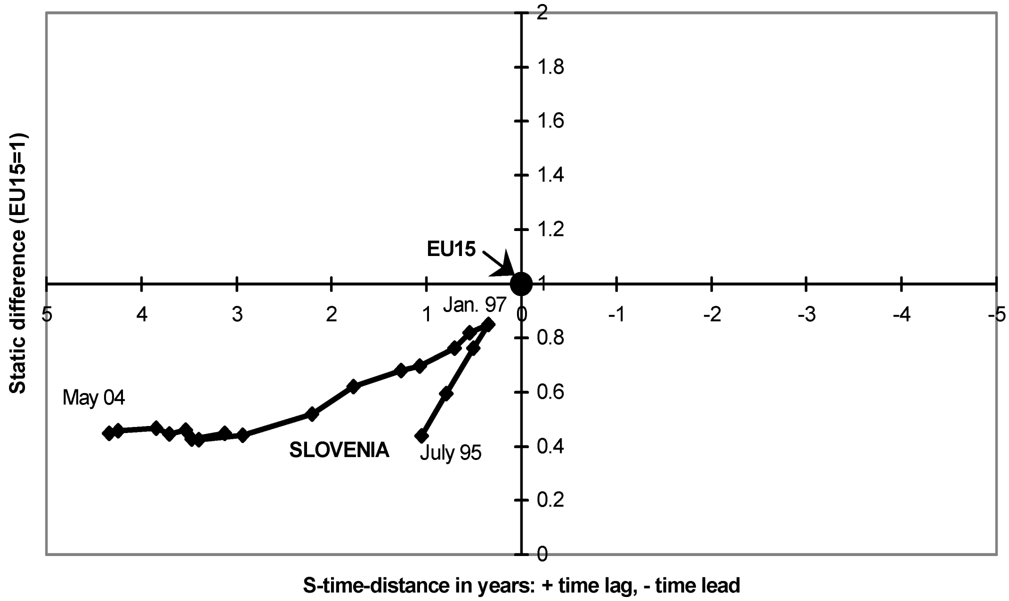

FIG. 4. Host density in the static dimension and in time-distance for Slovenia and the EU-15 (1995–2004).

average. On the other hand, the corresponding time lag was about 1 year in 1995, meaning that the Slovenian host density in July 1995 had been reached by the EU-15 already 1 year earlier, i.e. in July 1994. However, this lag shrank to just 4 months in 1997 and reverted again to 4.4 years in 2004.

After 9 years we thus have the same figures for the relative digital divide (40% in 1995 and in 2004) but a dramatically different interpretation in terms of time-distance (1 year vs. 4 years). This discrepancy can be explained by the fact that it was much easier to expand growth in 1995 when annual growth rates in the hosts' density were around 100%, compared to recent years when growth rates were merely around 10% or have even stagnated.

This example clearly demonstrates that indicators relying only on static comparisons of absolute or relative achievements may not exhaustively explain all digital divide phenomena. In this specific example, the claim that Slovenia maintained the divide at around 40% of the EU level is even directly misleading because the divide actually increased from a 1-year lag to a lag of around 4 years.

At this point we should add that even the inclusion of the time component is not sufficient for a complete analysis of the entire dynamics. The results and interpretation also strongly depend on the specific diffusion patterns of ICT penetration, as well as on the starting delays in the adoption processes. A correct analysis should thus explicitly and carefully address the implicit assumptions for the corresponding distribution models and probability density functions.

Here, further research is needed since one of the most critical questions in digital divide research relates to whether the divide is in fact growing. Obviously, the answer to this simple question requires a very sophisticated methodological approach.

CONCLUSIONS

We can observe and interpret the digital divide from various perspectives. However, to properly understand this complex subject we need a very clear conceptual basis. In principle, we should take into account all relevant technologies (PCs, Internet, mobile technology, etc.), aggregation levels (regional, national, international, global), units of observation (individuals, households, companies, etc.), relations to ICT (access, mode of usage, barriers, attitudes, etc.), and the nature of the study (cross-country comparisons, support for policymaking, observing time trends, testing causal relationships, etc.).

However, regardless of the theoretical approach involved, empirical studies are exposed to certain common methodological problems. Of course, all possible care should be initially taken with standard methodological issues (i.e., operationalization, sampling, nonresponse, measurement, etc.). Nevertheless, this is not enough. Due to its complexity, any digital divide measure must be carefully observed also in a multivariate setting.

Within this context we have discussed three approaches that are highly relevant to digital divide measures: multivariate modeling, compound indices, and time-distance methodology:

- Multivariate (e.g., loglinear) modeling allows us to analyze and control a complex set of variables that constitute a model. By simultaneously examining several variables we may discover that they behave differently compared to bivariate analysis. Even if this seems to be trivial, in digital divide studies this is easily overlooked because it is relatively complicated to implement a proper multivariate analysis.
- Similarly, compound measures offer a more complex insight into the digital divide. Instead of many separated indicators we only deal with one inclusive figure, which simplifies interpretation and communication. Compound measures are particularly relevant in comparative research where only one partial indicator can be directly misleading.
- Another oversimplification in digital divide research occurs when one neglects the specifics of the time dimension. A simplified time analysis based only on absolute or relative differences may offer completely different outcomes compared to the true trends based on proper time-distance observations.

The discrepancies arising from suboptimal methodological approaches may create the room for tailoring research findings to a certain interest group. Luyt (2004), for example, argues that the promotion of the digital divide as a policy issue benefits four major groups: information capital, developing country governments, the development "industry," and global civil society. Along with the national governmental bodies, various international organizations, agencies, and nongovernmental organizations (NGOs; e.g., the World Bank, IMF, UN, UNESCO, ITU, OECD) are also involved in discussions on the digital divide within and across nations. Multinational companies, particularly ICT suppliers, also have very specific interest in the interpretation of digital divide measures. As digital divide trends interfere with complex economic, social, and political issues, it is extremely important to minimize all potential methodological shortcomings.

Of course, all three approaches we presented here have their own disadvantages and limitations, which deserve further research. They also represent only one component within an entire methodological instrument. Other aspects of quantitative social science methodology are equally important. In addition, qualitative research methods should be applied much more often in digital divide studies.

Finally, we should reiterate that due to the methodological profile of our article we have only briefly addressed theoretical problems, the relevance of various types of digital divide, and the importance of conceptual approaches. We are also fully aware that there is a strong need to overcome the technologically deterministic approach in digital divide studies (for more here, see Petrič, this issue; Pruulmann-Vengerfeldt, this issue; Barzilai-Nahon & Rafaeli, this issue). In particular, the substantial questions of *why*, *how,* and *with what benefits and consequences* to individuals using ICTs will have to be addressed more profoundly in future research.

However, to provide a competent answer to substantial questions, empirical analyses have to use the advanced methodological approaches outlined here. A serious warning should thus be directed at simplified indicators, especially bivariate tabulations. This is particularly true when addressing the relationship of the digital divide to the general social divide and when dealing with the question of whether the digital divide is growing or shrinking.

NOTES

1. The Slovenian GSS is a face-to-face probability sample survey and has been regularly conducted since 1968. The response rate in GSS 2000 was 80% and the sample size was $n = 1097$.
2. Internet usage was measured with the question "Do you personally use the Internet?"
3. Loglinear analysis is a relatively sophisticated multivariate technique developed for categorical variables and models the logarithms of cells frequencies. The main advantage of the loglinear models is the ability to analyze three-way and higher interactions. For a complete discussion of loglinear modeling, see, for example, Agresti (1990).
4. If only links (i.e., interactions) that include the Internet usage are presented, the model written in the standard notation of loglinear models is the following: SI/GI/MI/AEI ($p = .12$).
5. All variables have been dichotomized in order to allow a sharper presentation of the conceptual issues.
6. This indicator was operationalized as "Have you used a PC, Mac, or any other computer for work or private purposes in the last four weeks?"
7. This indicator was operationalized as "Have you used the Internet at least once during the last four weeks at home, school, work or in any other place?" ("Internet users" are defined as those who use Internet in at least one of the given locations, e.g. "at work," "at home," etc.).
8. This indicator was operationalized as, "Do you have access to the Internet from your home?"

REFERENCES

Agresti, A. 1990. *Categorical data analysis*. New York: John Wiley & Sons.

Atkinson, A. B., and Hill, J., eds. 1998. *Exclusion, employment and opportunity*. CASE paper 4. London: Centre for the Analysis of Social Exclusion, London School of Economics.

Attewell, P. 2001. The first and the second digital divides. *Sociology of Education* 74:252–259.

Barzilai-Nahon, Karine. 2006. Gaps and bits: Conceptualizing measurements for digital divide/s. *The Information Society* 22(5):269–278.

Bell, P., Reddy, P., and Rainie, L. 2004. *Rural areas and the Internet*. Washington, DC: Pew Internet & American Life Project. http://www.pewinternet.org/pdfs/PIP_Rural_Report.pdf

Blumler, J. G., and Elihu, K. 1974. *The uses of mass communications: Current perspectives on gratifications research*. Beverly Hills, CA: Sage.

Bonfadelli, H. 2002. The Internet and knowledge gaps: A theoretical and empirical investigation. *European Journal of Communication* 17 (1):65–84.

Carvin, A. 2000. *More than just access: Fitting literacy and content into the digital divide equation*. EDUCAUSE Review. http://www.educause.edu/pub/er/erm00/articles006/erm0063.pdf

Cava-Ferreruela, I., and Alabau-Munoz, A. 2004. *Key constraints and drivers for broadband development: A cross-national empirical analysis*. Presented at the 15th European Regional Conference of the International Telecommunications Society (ITS), Berlin, Germany, September. http://userpage.fu-berlin.de/∼jmueller/its/conf/berlin04/Papers/cava-ferreruela_alabau-munoz.pdf

Chen, W., and Wellman, B. 2003. *Charting and bridging digital divides: Comparing socio-economic, gender, life stage and rural-urban internet access and use in eight countries*. AMD Global Consumer Advisory Board. http://www.amd.com/us-en/assets/content_type/DownloadableAssets/FINAL_REPORT_CHARTING_DIGI_DIVIDES.pdf

Cho, J., de Zuniga, H. G., Rojas, H., and Shah, D. V. 2003. Beyond access: The digital divide and Internet uses and gratifications. *IT & Society* 1(4):46–72. http://www.stanford.edu/group/siqss/itandsociety/v01i04/v01i04a04.pdf

Churchill, G. A. 1999. *Marketing research: Methodological foundations*. Fort Worth, TX: Dryden Press.

Cole, J. I., Suman, M., Schramm, P., Lunn, R., Aquino, J.–S., and Lebo, H. (2004). *The digital future report: Surveying the digital future, year four. Ten years, Ten trends*. Los Angeles, CA: USC Annenberg School Center for the Digital Future. http://www.digitalcenter.org/downloads/DigitalFutureReport-Year4-2004.pdf

Compaine, B. M., ed. 2001. *The digital divide: Facing a crisis or creating a myth?* Cambridge, MA: MIT Press.

Corrocher, N., and Ordanini, A. 2002. Measuring the digital divide: A framework for the analysis of cross-country differences. *Journal of Information Technology* 17:9–19.

Cullen, R. 2001. Addressing the digital divide. *Online Information Review* 5:311–320.

Dávila, J. J. 2004. Digital Divide. In *The Internet encyclopaedia*, ed. H. Bidgoli, pp. 468–476. Hoboken, NJ: John Wiley & Sons.

Davis, J. A. 1985. *The logic of causal order.* Beverly Hills, CA: Sage.

DiMaggio, P., and Hargittai, E. 2001. *From the "digital divide" to digital inequality: Studying Internet use as penetration increases.* Working Paper 15. Princeton, NJ: Center for Arts and Cultural Policy Studies, Princeton University.

DiMaggio, P., Hargittai, E., Neuman, W. R., and Robinson, J. P. 2001. Social Implications of the Internet. *Annual Review of Sociology* 27:307–336.

Dolnicar, V., Vukcevic, K., Kronegger, L., and Vehovar, V. 2002. Digitalni razkorak v Sloveniji. *Druzboslovne razprave* 18(40):83–106.

Dutta, S., and Jain, A. 2004. *The Networked Readiness Index 2003–2004: Overview and analysis framework*. http://www.developmentgateway.org/download/222656/Networked_Readiness_Index.pdf

Elliot, G., and Starkings, S. 1997. *Business information technology systems, Theory and practice.* London: Prentice Hall.

Empirica—Communication and Technology Research. 2005. http://www.empirica.biz

European Commission. 2000. *The Lisbon Special European Council (March 2000): Towards a Europe of innovation and knowledge*. Summaries of the Union's legislation. http://europa.eu.int/scadplus/leg/en/cha/c10241.htm

Gartner Group. 2002. *The second digital divide—The "Haves" and the "Have Hads."* The Digital Divide and American Society. www.gartnerweb.com/public/static/techies/digital_d/national/ 6.pdf

Granger, C. W. J., and Jeon, Y. 1997. *Measuring lag structure in forecasting models—The introduction of time distance*. Discussion Paper 97–24. San Diego: University of California.

Granger, C. W. J., and Jeon, Y. 2003. A time-distance criterion for evaluating forecasting models. *International Journal of Forecasting* 19:199–215.

Grigorovici, D. M., Schement, J. R., and Taylor, R. D. 2004a. Weighing the intangible: Towards a theory-based framework for information society indices. In *Global economy and digital society*, eds. E. Bohlin, S. Levin, N. Sung, and C.-H. Yoon, pp. 169–202. Boston: Elsevier Science.

Grigorovici, D. M., Constantin, C., Jayakar, K., Taylor, R. D., and Schement, J. R. 2004b. *InfoMetrics: A structural equation modeling approach to information indicators and "e-readiness" measurement*. Paper presented at the 15th Biennial Conference of the International Telecommunication Society (ITS), Berlin, Germany, September. http://userpage.fhw-berlin.de/∼jmueller/its/conf/berlin04/Papers/Grigorovici_Constantin_Jayakar_Taylor_Schement.pdf

Hargittai, E. 2002. Second-level digital divide: Differences in people's online skills. *First Monday* 7(4). http://www.firstmonday.org/issues/issue7_4/hargittai

Hüsing, T. 2004. *The impact of ICT on social cohesion: Beyond the digital divide.* Paper presented at the 14th Economic Forum, September, Krynica Zdrój, Poland.

Hüsing, T., and Selhofer, H. 2004. DIDIX: A digital divide index for measuring social inequality in IT diffusion. *IT&Society* 1(7): 26–42. http://www.stanford.edu/group/siqss/itandsociety/v01i07/v01i07a02.pdf

IDC. 2001. *The IDC/World Times Information Society Index: The future of the information society*. Framingham, MA: IDC.

International Telecommunication Union. 2003. *World telecommunication development report 2003: Access indicators for the information society (Executive Summary)*. ITU. http://www.itu.int/ITU-D/ict/publications/wtdr_03/material/WTDR2003Sum_e.pdf

International Telecommunication Union. 2005. *Measuring digital opportunity*. Paper presented at the WSIS Thematic Meeting on Multi-Stakeholder Partnerships for Bridging the Digital Divide, Seoul, Republic of Korea, June. http://www.itu.int/itu-wsis/2005/DOI%20V2.pdf

Jung, J.-Y., Qiu, J. L., and Kim, Y.-C. 2001. Internet connectedness and inequality: Beyond the "divide." *Communication Research* 28(4):507–535.

Kalkun, M., and Kalvet, T. 2002. *Digital divide in Estonia and how to bridge it*. Tallinn: Emor and PRAXIS Center for Policy Studies. http://econwpa.wustl.edu:8089/eps/dev/papers/0401/0401004.pdf

Katz, J. E., and Aspden, P. 1997. Motivations for and barriers to Internet usage: Results of a national public opinion survey. *Internet Research—Electronic Networking Applications and Policy* 7(3).

Lawson Mack, R. 2001. *The digital divide: Standing at the intersection of race & technology*. Durham, NC: Carolina Academic Press.

Luyt, B. 2004. Who benefits from the digital divide? *First Monday* 9(8). http://www.firstmonday.org/issues/issue9_8/luyt

Martin, S. P. 2003. Is the digital divide really closing? A critique of inequality measurement in a nation online. *IT&Society* 1(4): 1–13. http://www.stanford.edu/group/siqss/itandsociety/v01i04/v01i04a01.pdf

Menou, M. J. 2001. *Digital and social equity? Opportunities and threats on the road to empowerment*. Paper presented at the LIDA (Libraries in the Digital Age) 2001 Annual Course and Conference, Dubrovnik, Croatia, May. http://www.cnam.fr/instituts/INTD/Menou_intd-er.pdf

Mossberger, K., Tolbert, C. J., and Stansbury, M. 2003. *Virtual inequality: Beyond the digital divide*. Washington, DC: Georgetown University Press.

Muffels, R. J. A., Tsakloglou, P., and Mayes, D. G., eds. 2002. *Social exclusion in European welfare states*. Cheltenham: Edward Elgar.

National Telecommunications and Information Administration. 1995. *Falling through the Net: A survey of the "have nots" in rural and urban America.* Washington, DC: Economics and Statistics Administration, and the National Telecommunications and Information Administration.

National Telecommunications and Information Administration. 1997. *Falling through the Net II: New data on the digital divide*. Washington, DC: Economics and Statistics Administration, and the National Telecommunications and Information Administration.

National Telecommunications and Information Administration. 1999. *Falling through the Net III: Defining the digital divide*. Washington, DC: Economics and Statistics Administration, and the National Telecommunications and Information Administration.

National Telecommunications and Information Administration. 2000. *Falling through the Net: Towards digital inclusion*. Washington, DC: Economics and Statistics Administration, and the National Telecommunications and Information Administration.

National Telecommunications and Information Administration. 2002. *A nation online: How Americans are expanding their use of the Internet*. Washington, DC: Economics and Statistics Administration, and the National Telecommunications and Information Administration.

National Telecommunications and Information Administration. 2004. *A Nation Online: Entering the Broadband Age.* Washington, DC: Economics and Statistics Administration, and the National Telecommunications and Information Administration.

Neuman, W. L. 2003. *Social research methods: Qualitative and quantitative approaches.* Boston: Allyn and Bacon.

Norris, P. 2001. *Digital divide: Civic engagement, information poverty, and the Internet worldwide*. Cambridge, MA: Cambridge University Press.

Nurmela, J., and Viherä, M.-L. 2000. *Communication capability is an intrinsic determinant for the information society.* (Unpublished manuscript). Helsinki.

OECD. 2001. *Understanding the digital divide*. Paris: OECD. http://www.oecd.org/dataoecd/38/57/1888451.pdf

Office of the Vice-President. 1996. Prepared Remarks of Vice-President Al Gore at the White House Conference on Community Empowerment, Washington, DC, February 23. http://wkn.org/gov1.htm

Parayil, G. 2005. Digital divide and increasing returns: Contradictions of informational capitalism. *The Information Society* 21(1):41–51.

Petrič, G. 2006. Conceptualizing and measuring the social uses of the internet: The case of personal web sites. *The Information Society* 22(5):291–301.

Primo Braga, C. A., Kenny, C., Qiang, C., Crisafulli, D., Di Martino, D., Eskinazi, R., Schware, R., and Kerr-Smith, W. 2000. *The networking revolution: Opportunities and challenges for developing countries*. Global Information and Communication Technologies Department, The World Bank Group. http://www.infodev.org/library/WorkingPapers/NetworkingRevolution.pdf

Pruulmann-Vengerfeldt, P. 2006. Exploring social theory as a framework for social and cultural measurements of the Information Society. *The Information Society* 22(5):303–310.

Quibria, M. G., Shamsun, A. N., Tschang, T., and Reyes-Macasaquit, M.-L. 2003. Digital divide: Determinants and policies with special reference to Asia. *Journal of Asian Economics* 13:811–825.

Reddick, A., Boucher, C., and Groseilliers, M. 2000. *The dual digital divide—The information highway in Canada*. Ottawa: Public Interest Advocacy Centre. http://olt-bta.hrdc-drhc.gc.ca/download/oltdualdivide_e.pdf

Rodgers, G., Gore, C., and Figueiredo, J. B., eds. 1995. *Social exclusion: Rhetoric, reality, responses*. Geneva: International Institute for Labour Studies.

Rogers, E. M. 1995. *Diffusion of innovations,* 4th ed. New York: Free Press.

Sciadas, G., ed. 2005. *From the digital divide to digital opportunities: Measuring infostates for development*. Montreal: NRC Press. http://www.orbicom.uqam.ca/projects/ddi2005/index_ict_opp.pdf

Selhofer, H., and Hüsing, T. 2002. *The digital divide index—A measure of the social inequalities in the adoption of ICT.* Paper presented at the IST 2002 Conference, Copenhagen.

Servon, L. J. 2002. *Bridging the digital divide: Technology, community, and public policy*. Malden, MA: Blackwell.

SIBIS. 2003a. *SIBIS pocket book 2002/03: Measuring the information society in the EU, the EU accession countries, Switzerland and the US*. Bonn: SIBIS Project and European Communities. http://www.empirica.biz/sibis/publications/pocketbook.htm

SIBIS. 2003b. *SIBIS synthesis report 2003: Matching up to the information society.* Bonn: SIBIS Project and European Communities. http://www.empirica.biz/sibis/files/SIBIS_Synthesis-Report.pdf

Sicherl, P. 1973. Time-distance as a dynamic measure of disparities in social and economic development. *Kyklos* 26(3):559–575.

Sicherl, P. 1978. S-distance as a measure of time dimension of disparities. In *The social ecology of change*, eds. Z. Mlinar and H. Teune, pp. 237–268. Beverly Hills, CA: Sage.

Sicherl, P. 2003. *Different statistical measures provide different perspectives on digital divide*. Paper presented at the 6th Conference of the European Sociological Association, Murcia. http://www.sicenter.si/pub/Sicherl_Digital_divide_Murcia.pdf

Sicherl, P. 2004. A new generic statistical measure in dynamic gap analysis. *The European e-Business Report*. Luxembourg: European Commission.

Sicherl, P. 2005. Analysis of information society indicators with time distance methodology. *Journal of Computing and Information Technology* 13(4):293–298.

Silver, H. 1994. Social exclusion and social solidarity: Three paradigms. *International Labour Review* 44(2):219–231.

Stanley, L. D. 2003. Beyond access: Psychological barriers to computer literacy. *The Information Society* 19:407–416.

Tichenor, P. J., Donohue, G. A., and Olien, C. N. 1970. Mass media flow and differential growth in knowledge. *Public Opinion Quarterly* 2:159–170.

Tos, N., ed. 2004. *Vrednote v prehodu III. Slovensko javno mnenje 1999–2004*. Ljubljana: Fakulteta za druzbene vede, IDV–CJMMK.

United Nations Development Program. 2001. *Human development report 2001*. New York: Oxford University Press. http://hdr.undp.org/reports/global/2001/en/pdf/techindex.pdf

Van Dijk, J., and Hacker, K. 2003. The digital divide as a complex and dynamic phenomenon. *The Information Society* 19:315–326.

Vehovar, V. 2001. Prospects of small countries in the age of the Internet. In *Cyberimperialism? Global relations in the new electronic frontier*, ed. B. Ebo, pp. 123–138. Westport, CT: Praeger.

Vehovar, V., and Dolnicar, V. 2004. Benchmarking Internet. In *The Internet encyclopaedia*, ed. H. Bidgoli, pp. 57–71. Hoboken, NJ: John Wiley & Sons.

Warschauer, M. 2003a. *Technology and social inclusion: Rethinking the digital divide*. Cambridge, MA: MIT Press.

Warschauer, M. 2003b. Dissecting the "digital divide": A case study in Egypt. *The Information Society* 19:297–304.

Welling, S., and Kubicek, H. 2000. *Measuring and bridging the digital divide in Germany*. Report presented at the International Conference, Stepping-Stones into the Digital World, September, Bremen. http://www.digitale-chancen.de/transfer/downloads/MD35.pdf

Wilhelm, A. G. 2000. *Democracy in the digital age: Challenges to political life in cyberspace.* New York: Routledge.