International Heterogeneity in Internet Diffusion: Evidence from Global Country-Level Data

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Abstract

Global diffusion of technology products has been a very important but highly underresearched subject. To fill the research gap, we estimate Griliches' diffusion model (GDF), which is nonlinear in parameters, and another model which is linear in parameters both using panel data to analyze the determinants of global diffusion of the Internet in a range of developing and developed countries. The analysis indicates that income and political freedom variables influence the penetration rate and diffusion speed of the Internet. Telecom investment as a proportion of GDP has a significant effect on Internet penetration in the TSCS model linear in parameters. We also found that the random effect TSCS model is more appropriate than the fixed effect model to study the global diffusion of the Internet.

Keywords: TSCS model, Griliches diffusion function, Internet, multicountry, authoritarianism.

Introduction

For firms operating in today’s global environment, an integration of the spatial dimension in diffusion research would help evaluate alternative strategies across geographically dispersed national markets (Mahajan et al. 1990, Putsis et al. 1997). Very few studies on innovation diffusion, however, have focused outside the U.S. and still fewer have considered two or more countries simultaneously (Gatignon et al. 1989). Thus we understand far less about the factors influencing and shaping cross-country diffusion patterns than we do about single-country diffusion patterns (Putsis et al. 1997).

The few available studies on multicountry diffusion are based mainly in the developed OECD countries. Their findings indicate that economic, political and cultural variables such as cosmopolitanism, mobility, and sex roles (Gatignon et al. 1989); media availability (Tellefsen and Takada 1999); adoption time and cross country mixing (Ganesh et al. 1997, Putsis et al. 1997, Takada and Jain 1991); income, education, and availability of related infrastructures (Hargittai 1999); competition and penetration rates of related
technologies (Gruber and Verboven 2001); heterogeneity of social system (Dekimpe, Parker and Sarvary 2000); and type of political regime (Buchner 1988) influence the diffusion patterns of innovations.

There is a considerable gap in the existing literature on diffusion and adoption of innovations. First, recent findings of studies on Internet diffusion patterns in some developing countries have put the implicit assumptions of the “normal process” of development of the Internet to a “severe test” (Mueller 1999). Thus, the generalizability of the studies conducted in OECD countries to developing countries is questionable.

Second, in developing countries, relatively little research exists on consumption patterns in general (Ger and Belk 1996) and diffusion of innovations in particular. Given the importance of the roles developing countries are likely to play in international relations (Andreasen 1990, Shuja 2001) and global e-commerce (Bruce 2000, Mueller 1999) in the future, studies on the relevance of Internet to such countries are needed. Arnold and Quelch (1998) have argued that Internet, as a marketing medium, has a potential to add higher value in developing countries than in developed countries. A focus on the developing world – home to 80% of humanity – is also an antidote to the tendency in the business discipline of becoming “increasingly isolated and of marginal relevance” (Lehmann 1999).

Third, there is little work simultaneously comparing the diffusion and adoption phenomena in developing and developed countries. Only by confronting existing diffusion theories with countries at various stages of economic development can the theories of innovation diffusion be subjected to tests more radical than those feasible with data on more advanced countries only.
Fourth, there is little research that addresses the diffusion of the Internet, the fastest diffusing innovation to date. The Internet’s several unique characteristics – the ability to store information at different virtual locations at very low cost, the availability of powerful and inexpensive means of searching, organizing, and disseminating information; interactivity; the ability to provide excellent perceptual experiences; the ability to serve as a transaction, servicing, support and physical distribution medium; the relatively low entry and establishment costs (Peterson et al. 1997) – make it a unique marketing medium.

This paper attempts to fill these research gaps by analyzing the Internet diffusion data in a range of developing and developed countries. The remainder of the paper: (a) briefly discusses the purpose of our modeling exercise; (b) integrates theories from various perspectives to develop some testable propositions; (c) describes data sources; (d) describes the methodology used; and (e) discusses analysis, findings and limitations.

**Purpose of the modeling exercise**
The primary purpose of modeling in this paper is causal inference rather than prediction.

The hypotheses in the following section are stated in ceteris paribus conditions. Since our objective is causal interference, the ceteris paribus conditions should exclude variables that are likely to transmit the influence of the treatment variables to the dependent variables and should include all confounding variables (Gelman et al. 1995). The dependent variables are the number of Internet hosts per 1000 people and the number of Internet users per 1,000 people.

The treatment variables used in the model include income, political freedom and telecom investment. We excluded variables such as telephone penetration and personal computer penetration in the model because these variables are likely to transmit the
influence of treatment variables (such as income, freedom condition, telecom investment, etc.) on the dependent variables.

**Theory and hypotheses**

In this section, we develop several testable propositions that represent the effects of demand and supply side variables on Internet diffusion, a country being the unit of analysis. The variables of interest are Internet penetration, Internet diffusion speed, and location effect. In fact, Internet penetration is a function of diffusion speed and location effects.

We operationalize Internet penetration with two separate but interrelated variables: the number of Internet users per 1000 people ($IUPK$) and number of Internet hosts ($IHPK$) per 1000 people. Diffusion speed and location effects will be represented by parameters of the Griliches (1957) model (see equation 1 below).

Table 1 presents how theoretical variables are operationalized and table 2 presents the mechanisms by which the operational variables are likely to influence the diffusion of the Internet. Next we discuss the effects of several explanatory variables individually.

**Income**

One of the variables most likely to characterize innovators is high income (Gatignon and Robertson 1985, Rogers 1983). On the supply side, income is a key factor influencing “demand and cost conditions” of technological leadership (Beise 2001). On the demand side, high income arguably allows potential adopters to afford greater economic sacrifice to adopt the innovation (Dekimpe et al. 2000). In an international context, it can be argued that an economy’s standard of living and the level of economic development influence the adoption timing as well as diffusion speed (Antonelli 1993, Gatignon and Robertson 1985, Helson et al. 1993, Dekimpe et al. 2000, Gruber and Verboven 2001). Empirical evidence
also supports this argument (e.g., Dekimpe et al. 2000, Kshetri 2001b, Kshetri and Cheung 2002, Kshetri and Dholakia 2002b). At the aggregate level, we propose that *ceteris paribus*:\n
\[ H_{1a}: \text{The Internet penetration level in an economy is positively related to its income.} \]

\[ H_{1b}: \text{The diffusion speed of the Internet in an economy is positively related to its income.} \]

We also expect a “location effect” of the income variable. We hypothesize that richer economies are likely to introduce an advanced technology such as the Internet earlier than poorer countries. Since telephone and PCs have reached virtually all countries in the world, the incremental cost to connect to the Internet is relatively low. Income level determines the types of economic activities that require Internet use as well as the existence of critical mass of users required for Internet service providers.

Some other variables discussed later in this section, such as political freedom status, influence Internet penetration and diffusion speed, they are likely to have relatively minor effect on the time of first introduction. Authoritarian regimes, for instance, are not necessarily slow in introducing the Internet but they are less willing to open the Internet to the public. Thus we propose that:

\[ H_{1c}: \text{The income variable has a positive “location effect” (that is countries with higher income are likely to introduce the Internet sooner than countries with lower income).} \]

**Compatibility with the social system (freedom condition)**
Drawing on past research (e.g., Rogers 1983), Gatignon and Robertson (1985) propose that the diffusion rate of an innovation is positively related to the innovation’s compatibility with social system values. The Internet – “the greatest democratizer the world has ever
seen” (Pitroda 1993) – is more compatible with countries having democratic political structures than authoritarian ones.

Theoretical and empirical evidence suggests that authoritarian governments have distastes and unfavorable attitude towards interpersonal means of communications such as telephone and the Internet (e.g., Groth and Hunt 1985; Kshetri 2001a, b; Kshetri and Dholakia 2001). Groth and Hunt (1985) argue that Marxist governments allocate relatively smaller proportion of resources for the development of interpersonal communications means. For instance, Stalin vetoed Trotsky’s proposal to develop modern telephone system in Russia commenting that:

It will unmake our work. No greater instrument for counterrevolution and conspiracy can be imagined (Boettinger 1977, p.206).

Likewise, Buchner (1988), in a comparison of the diffusion of telephone and television in Marxist and non-Marxist European nations, found that the penetration rates of telephones in comparison to television were much lower in the former than in the latter. The highest of the ratios of the number of telephones to number of televisions among Marxist nations was smaller than the lowest of the ratios among non-Marxist nations.

To take an example specific to the Internet, an official of the Zhejiang Provincial government in China commented that Internet ads contain “distorted, misleading and even illegal information” and have “greatly endangered customers' interests” (Chinese Education and Research Network 2001). Chinese Ministry of Information Industry (MII) and the State Press and Publication Administration issued new set of regulations in July, 2002, which threaten to fine or close down Internet publishers and portals disobeying content guidelines. Portals and search engines not following the guidelines such as Google and Altavista have been banned in China since 2002 (Singer 2002).
Apart from controls on Internet ads and portals, there are also broader measures of Internet control in authoritarian regimes. The Chinese government in 2002, for instance, closed 150,000 Internet cafes and required the remaining cafes to install software that prevents access to up to 500,000 banned sites (BBC News 2002). Likewise, a Harvard Law School study found that government sponsored proxy servers in Saudi Arabia filter and block sexually explicit contents (Hermida 2002). Internet control measures in authoritarian regimes have reduced the attractiveness of Internet use.

One of the dimensions of the social value system indicative of compatibility with the interpersonal means of communications, such as the Internet, is, thus, the political rights or freedom status in the country. Thus,

\[ H_{2a}: \text{Internet penetration is positively related to the political rights or freedom.} \]
\[ H_{2b}: \text{Internet diffusion speed is positively related to the political rights or freedom.} \]

**Priority setting**

The diffusion pattern of telecom-related products such as the Internet is also a function of the level of priority set for the telecom sector (National Academy of Science 1985) and focus of national industrial and technological policies on fostering and strengthening this sector (Beise 2001, p. 263).

The proportion of GDP spent in the telecom sector can be taken as a proxy of the level of priority. Put differently, relatively higher investment in the telecom sector is an indication of the higher level of priority set for this sector. Moreover, whereas most other supply related variables are highly correlated with income, telecom investment as a proportion of GDP has no significant correlation with the income variable (Table 8).
Table 1: Definitions and explanations of theoretical and operational variables

<table>
<thead>
<tr>
<th>Theoretical variable</th>
<th>Definition</th>
<th>Operational variable</th>
<th>Explanation of operational variable</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income level</td>
<td>Total value at market prices of goods and services produced in an economy.</td>
<td>Per capita Gross National Product (GNPPC)</td>
<td>Sum of the total value of consumption expenditure, total value of investment expenditure, government purchases of goods and services and net exports of goods and services divided by the population.</td>
</tr>
<tr>
<td>Freedom condition</td>
<td>“Rights to free expression, to organize or demonstrate, as well as rights to a degree of autonomy such as is provided by freedom of religion, education, travel, and other personal rights” (Gastil 1986–87, p. 7).</td>
<td>Political freedom condition (PFD)</td>
<td>The average of political right index and civil liberty index from Freedom House (2001).</td>
</tr>
<tr>
<td>Priority set for telecom sector</td>
<td>The degree of attention and consideration given to telecom sector compared to other sectors in an economy.</td>
<td>Telecom investment (TELINV)</td>
<td>Percentage of GDP invested in telecom sector in an economy.</td>
</tr>
<tr>
<td>Population size</td>
<td>The degree of bigness or smallness of an economy measured by the population.</td>
<td>Population (POP)</td>
<td>The number of people living in an economy.</td>
</tr>
<tr>
<td>Population density</td>
<td>The quality of being dense of the population in an economy.</td>
<td>Population density (PODE)</td>
<td>Number of people per unit area in an economy.</td>
</tr>
</tbody>
</table>


The supply condition resulted from the level of priority set for the telecom sector is likely to influence the penetration of a technology as well as its diffusion speed by influencing the characteristics of the technology, its price structure as well as the allocation of resources (Robertson and Gatignon 1986). First, economic theory suggests that higher supply leads to lower price. The lower price, in turn, accelerates the diffusion rate. For example, Jain and Rao (1990) found that lower price positively influenced purchasing decision of consumer durables. Second, suppliers influence the diffusion pattern by making an innovation more or less attractive (Robertson and Gatignon 1986).
Third, supply conditions influence the shape of diffusion curves. For instance, Simon and Sebastian (1987) argue that the diffusion curve experiences slow growing and fast declining (that is, negatively skewed) pattern under conditions of supply restriction. In an empirical study of the diffusion of the telephone in Israel under the condition of supply restriction, Jain et al. (1991) found negatively skewed diffusion pattern. The next propositions are:

\[ H_{3a}: \text{Internet penetration level is positively related to the level of priority set for the telecom sector.} \]

\[ H_{3b}: \text{Internet diffusion speed is positively related to the level of priority set for the telecom sector.} \]

**Population size**
Population size influences the diffusion of a technology in several ways. First, the market size, which is an important factor technology suppliers take into account in assessing the profitability of a market, is positively related to the population size. Second, network externality effects of technologies, such as the Internet, are likely to be higher for more populous economies. The discussion in this paragraph is summarized as:

\[ H_{4a}: \text{Internet penetration level is positively related to the population size.} \]

\[ H_{4b}: \text{Internet diffusion speed is positively related to the population size.} \]

\[ H_{4c}: \text{The location effect is positively related to the population size.} \]

**Population density**
Population density influences the diffusion of innovations and more so for communications technologies such as the Internet. First, higher population density results in lower costs to wire a country. For instance, high population density is one of the important factors contributing to Hong Kong’s rapid Internet development (Kshetri and Dholakia 2002a). Second, higher population density facilitates interaction between adopters and potential
adopters thereby influencing diffusion process positively. Such interaction results in a higher coefficient of imitation or the “coefficient of external influence” (Bass 1969). Therefore, we propose:

\[ H_{5a}: \text{Internet penetration level is positively related to population density.} \]

\[ H_{5b}: \text{Internet diffusion speed is positively related to population density.} \]

**Table 2: Effect of various operational variables on Internet diffusion and adoption**

<table>
<thead>
<tr>
<th>Operational variable</th>
<th>Effect on diffusion and adoption of the Internet</th>
</tr>
</thead>
<tbody>
<tr>
<td>Income level (GNPPC)</td>
<td>Higher income means greater ability to afford economic sacrifice to adopt the Internet.</td>
</tr>
<tr>
<td>Political freedom condition (PFD)</td>
<td>Internet is more compatible with greater freedom.</td>
</tr>
<tr>
<td>Priority or Telecom investment (TELINV)</td>
<td>Influences availability, price structure and quality of Internet services and indicates priority setting.</td>
</tr>
<tr>
<td>Population size (POP)</td>
<td>Influences the economies of scale and market size.</td>
</tr>
<tr>
<td>Population density (PODE)</td>
<td>Influences the level of interaction between adopters and potential adopters and suppliers’ cost to provide Internet services.</td>
</tr>
</tbody>
</table>

**Data sources**

Data related to the dependent and explanatory variables were collected from various sources discussed below.

**Euromonitor Publications**

The data related to GNP, telephone penetration, telephone investment, exchange rate, Internet hosts and Internet users and populations for the year 1992-99 were obtained from Euromonitor (2001a, b). GNPPC (GNP per capita) figures for 1992-99 were obtained by dividing GNP by the populations for the corresponding years. Euromonitor obtains most of these data from market research firms, national government and various organizations under the United Nations (UN) systems.

**UN System and the World Bank**

Telephone penetration, Internet hosts and Internet user data for 1999 to 2001 were obtained from International Telecommunications Union, an agency in the United Nations system.
Statistical data related to telecommunications are collected and processed by the Telecommunication Development Bureau (BDT) from replies received to ITU questionnaires sent to telecommunication ministries, regulators and operating companies. As such the data provided by ITU are considered to be the most authoritative source of data about the evolution of the public telecommunications sector available anywhere (ITU 2001).

GNPPC for the year 2000 were obtained from the World Bank. Euromonitor (2001a, b) had some observations missing on the income variable. The income data for some economies for different subsets of the period 1992-99 are obtained from UNCTAD (1999) and UNDP (2001).

**Freedom House**
Data related to political freedom (PFD) were obtained from Freedom House (2000). PFD is taken as the average of two variables: political rights (PR) and civil liberty (CL). Both PR and CL vary from 1 to 7, the higher values indicating lower freedom.

Political Rights (PR) index takes into account factors such as the existence of the provision of free and fair elections; people’s right to organize in different political parties or other competitive political groupings of their choice; freedom from domination by the military, foreign powers, totalitarian parties, religious hierarchies, economic oligarchies, or any other powerful group; ability of cultural, ethnic, religious, and other minority groups to have reasonable self-determination, etc.

Civil Liberties (CL) index takes into account such factors as the existence of the Freedom of Expression and Belief; Association and Organizational Rights; Rule of Law and Human Rights; Personal Autonomy and Economic Rights; etc.
Central Intelligence Agency (CIA)
Data related to area, number of Internet users for the year 2000 and the number of Internet service providers were obtained from the World Fact Book 2001 of the CIA (2001).

Table 3: Applying Jocelyn’s go/no go framework to evaluate the data and the sources used in this study

<table>
<thead>
<tr>
<th>Question</th>
<th>Euromonitor</th>
<th>UN System</th>
<th>Freedom house</th>
<th>CIA</th>
<th>Other sources</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do the data help to answer the questions set out in the problem definition?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Do the data apply to the population of interest?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Do the data apply to the time period of interest?</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Can the units and classifications presented apply?</td>
<td>Yes, for most of the data. For others (e.g., telecom investment) some transformations were applied.</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes, for most of the data. For others some transformations were applied.</td>
<td>Yes</td>
</tr>
<tr>
<td>If possible, go to the original source of the data</td>
<td>Some of the data were verified from original sources.</td>
<td>Too costly and time consuming to verify all UN data from original sources (national governments). Freely available online.</td>
<td>This is the original source for political freedom data.</td>
<td>Too costly and time consuming to verify all data from original sources. Freely available online.</td>
<td>Too costly and time consuming to verify from original sources. Freely available online.</td>
</tr>
<tr>
<td>Is the cost of data acquisition worth it?</td>
<td>The publications are available in university libraries.</td>
<td>Freely available online.</td>
<td>Freely available online.</td>
<td>Freely available online.</td>
<td>Freely available online.</td>
</tr>
<tr>
<td>Is there a possibility of bias?</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Can the accuracy of the data collection be verified?</td>
<td>Gives reference to the original sources.</td>
<td>Collected from national governments.</td>
<td>Partly</td>
<td>Partly</td>
<td>No</td>
</tr>
</tbody>
</table>

Source: Joselyn (1977) and author’s research

Other sources
Data on the first introduction of the Internet were obtained from Goldstein (2000) and various other sources. Data for some of the economies on several variables for different
subsets of the period 1992-2000\textsuperscript{5}, which were missing from the sources mentioned above were also obtained from Statistical Abstracts of the U.S. (1997, 1998, 1999, 2000, 2001).

There are five major constraints related to international secondary data: *accuracy, age, reliability, lumping and comparability* (Kotabe and Helsen 2001). Kotabe (2002) argues that Euromonitor, despite its reliance on various sources, addresses most of the constraints. Other dataset used in this study have also been used in past studies and are considered to be reliable. For instance, data from the publications of the UN system have been used by Hill and Dhanda (1999), Tellefsen and Takada (1999), etc. Similarly, political freedom data from Freedom House have been used in past studies (e.g., Barro 1999, Diamond 1992, and Goldsmith 1999).

Qualitative and quantitative assessment suggested by Malhotra et al. (1998) and go/no-go framework suggested by Joselyn (1977) were used to evaluate the data from various sources (Table 3).

**Methodology**

We estimate Griliches' diffusion model (GDF), which is nonlinear in parameters, and another model which is linear in parameters (say, linear time-series cross section (LTSCS) model), both using panel data.

**Griliches Diffusion Function**

Griliches diffusion function tests the effects of several explanatory variables on “*diffusion speed*” (Gruber and Verboven 2001) and *location effect* for the period 1994-99.

To test the effects of the explanatory variables on diffusion speed and location effect, a version of Griliches (1957) logistic model (1) was estimated by using nonlinear
least square (NLS) technique. Let $y_{it}$ denote the total number of adopters and $y^*_{it}$ the total number of potential adopters of the Internet in the country $i$ at time $t$. Then,

$$y_{it} = \frac{y^*_{it}}{1 + \exp(-a_{it} - b_{it})}$$  \hspace{1cm} (1),

where $a_{it}$ is the location or timing variable that shifts the S-shaped diffusion function forwards or backwards and $b_{it}$ is a measure of diffusion speed. For an economy, $t$ measures the number of years the Internet is being used. It is clear from equation (1) that as $t \to \infty$, $y_{it} \to y^*_{it}$. Furthermore, the proportion of potential adopters that have adopted the Internet at a point of time, $\frac{y_{it}}{y^*_{it}}$, is positively related to location effect ($a_{it}$) and diffusion speed ($b_{it}$). $a_{it}$ and $b_{it}$ in equation (1) are specified as linear functions of several demand and supply variables as given below:

$$a_{it} = \alpha_0 + \alpha_1 \text{GNPPC} + \alpha_4 \text{POP}$$ \hspace{1cm} (2)

$$b_{it} = \beta_0 + \beta_1 \text{GNPPC} + \beta_2 \text{PFD} + \beta_3 \text{TELNV} + \beta_4 \text{POP} + \beta_5 \text{PODE}$$ \hspace{1cm} (3)

Equation (1) is then estimated by adding error term (Gruber and Verboven 2001). For the number of Internet hosts per thousand people (IHPK) as the dependent variable, $y^*_{it}$ was taken as a constant proportion ($\lambda$) of the number of telephones per 1000 people. Telephone penetration was taken as the saturation level of potential adopters for various reasons. First, a telephone is almost a prerequisite to be connected to the Internet and hence the number of telephone represents the maximum number of computer systems connected to the Internet. Second, although PC penetration seems to be a more obvious saturation level for IHPK, time-series data on PC penetration are not available for most of the economies for the given period. Third, although the number of Internet users per 1000
people \((IUPK)\) has a more obvious saturation level, namely 1000, the model with \(IUPK\) as the dependent variable failed to converge for all combinations of explanatory variables.

**Time-series cross-section models linear in parameters (LTSCS Models)**

The Griliches model, however, has some limitations in the context of global data on Internet diffusion. First, because of the unavailability of relevant data on explanatory and dependent variables (mainly the time of introduction of the Internet in a country) we could include only 21 countries in this model. Second, because of the lack of relevant data many developing countries could not be included in the model. Third, the non-linear least square (NLS) technique used to estimate the parameters of the model does not guarantee convergence and hence does not ensure the estimation of best values of the parameters (Greene 1999, SAS Institute 1999).

To overcome some of the limitations of Griliches diffusion function, we estimated LTSCS models for the same period, that is, 1994-99. We take Internet penetration level as measured by the number of Internet hosts per 1000 people and the number of Internet users per 1000 people as the dependent variables in the LTSCS models. Complete data were available for 51 economies to estimate the LTSCS models. Although Internet penetration is a function of diffusion speed and location effect (estimated by the Griliches diffusion function), the outcomes of the two models may slightly differ for various reasons. First, we have included 51 economies (Table 4) in the LTSCS models as compared to 21 economies in the Griliches function. Second, the LTSCS models do not consider the time of introduction of the Internet. Third, there is no problem of convergence in LTSCS models and hence we have included additional variables that could not be included in the Griliches function.
### Table 4: List of economies used in LTSCS and Griliches models

<table>
<thead>
<tr>
<th>Country</th>
<th>Country</th>
<th>Country</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Algeria</td>
<td>*18</td>
<td>Greece</td>
<td>35</td>
</tr>
<tr>
<td>*2 Argentina</td>
<td>*19</td>
<td>India</td>
<td>36</td>
</tr>
<tr>
<td>*3 Australia</td>
<td>20</td>
<td>Indonesia</td>
<td>37</td>
</tr>
<tr>
<td>*4 Austria</td>
<td>21</td>
<td>Iran</td>
<td>*38</td>
</tr>
<tr>
<td>*5 Belgium</td>
<td>*22</td>
<td>Ireland</td>
<td>*39</td>
</tr>
<tr>
<td>*6 Brazil</td>
<td>*23</td>
<td>Israel</td>
<td>*40</td>
</tr>
<tr>
<td>7 Bulgaria</td>
<td>*24</td>
<td>Italy</td>
<td>41</td>
</tr>
<tr>
<td>*8 Canada</td>
<td>25</td>
<td>Jamaica</td>
<td>*42</td>
</tr>
<tr>
<td>*9 Chile</td>
<td>26</td>
<td>Jordan</td>
<td>43</td>
</tr>
<tr>
<td>10 China</td>
<td>27</td>
<td>Kenya</td>
<td>44</td>
</tr>
<tr>
<td>11 Costa Rica</td>
<td>28</td>
<td>Malaysia</td>
<td>*45</td>
</tr>
<tr>
<td>12 Denmark</td>
<td>*29</td>
<td>Morocco</td>
<td>*46</td>
</tr>
<tr>
<td>13 Ecuador</td>
<td>30</td>
<td>Namibia</td>
<td>47</td>
</tr>
<tr>
<td>14 Egypt</td>
<td>*31</td>
<td>Netherlands</td>
<td>*48</td>
</tr>
<tr>
<td>15 El Salvador</td>
<td>32</td>
<td>New Zealand</td>
<td>49</td>
</tr>
<tr>
<td>16 France</td>
<td>33</td>
<td>Norway</td>
<td>50</td>
</tr>
<tr>
<td>*17 Germany</td>
<td>34</td>
<td>Pakistan</td>
<td>51</td>
</tr>
</tbody>
</table>

Note: All countries (51) used in the linear TSCS models. * indicates economies used in Griliches models (21 countries).

LTSCS models are designed to overcome the limitations of usual linear models. When pooling data, it is highly likely that one or more assumptions of the usual linear model may be violated. Fomby et al. (1984, p. 337) point out several such possibilities.

First, the error terms in a pooled model may be “heteroskedastic, autocorrelated and may exhibit contemporaneous correlation” which make generalized least square technique inappropriate. Second, the parameters of the data generating process may differ from observation to observation. The reactions of different individuals may be different to changes in explanatory variables and the reactions may also change over time. LTSCS models allow for differences in behavior over cross sectional units as well as the differences in behavior over time for a given cross section. In this way, such models are likely to be consistent with the way the data were generated (Fomby et al. 1984). Problems related to such models include the selection of the most efficient estimation procedures and testing of hypotheses about the parameters.
The following LTSCS models were employed:

\[
\frac{IHPKit}{1000 - IHPKit} = \beta_{1it} + \sum_{k=2}^{K} \beta_{k \times it} x_{ik} + \varepsilon_i \quad (4),
\]
\[
\frac{IUPKit}{1000 - IUPKit} = \beta_{1it} + \sum_{k=2}^{K} \beta_{k \times it} x_{ik} + \varepsilon_i \quad (5),
\]

where, \( IHPKit \) is the number of Internet hosts per 1000 people, \( IUPKit \) is the number of Internet users per 1000 people, \( \beta_{1it} \) is the dummy variable for the \( i \)th country for the \( t \)th time period and \( \beta_{kit} \) (\( k \geq 2 \)) are the slopes. \( X_{kit} \) (\( k \geq 2 \)) is the value of the factor \( X_k \) for the \( i \)th country in time \( t \).

Several factors need to be taken into account in selecting the appropriate model. The first is the choice between fixed and random effect models. For the fixed effect (or dummy variable) model, the intercept term \( \beta_{1it} \) in (4) and (5) above can be written as

\[
\beta_{1it} = \alpha_i + \tau_t \quad (6),
\]

where \( \alpha_i \) are the country “dummies” and \( \tau_t \) are the time “dummies”. The dummy variable model, however, eliminates a major portion of the variation among explained as well as explanatory variables if the between-country and between-time period variation is large (Maddala 1971), a likely occurrence in Internet diffusion data. Additional problems include a loss in a substantial number of degrees of freedom and a lack of meaningful interpretation of the dummy variables (Maddala 1971).

These problems can be overcome by treating \( \alpha_i \) and \( \tau_t \) as random in which case only two parameters, the mean and the variance of the \( \alpha \)'s (and similarly for \( \tau \)'s), are estimated instead of \( N+T \) parameters in dummy variable models, where \( N \) is the number of cross-sections and \( T \) is the number of time periods. The procedure of treating \( \alpha_i \) and \( \tau_t \) as random can be rationalized by arguing that the dummy variables do in effect represent
some ignorance – just like $\varepsilon_{it}$. Maddala argues that this type of ignorance, or “specific ignorance,” can be treated in the same manner as $\varepsilon_{it}$. Then the residual can be written as:

$$u_{it} = \alpha_i + \tau_t + \varepsilon_{it}$$  \hspace{1cm} (7).

In TSCS models, two considerations, *logical and statistical*, may determine the choice of specification—fixed vs. random (Hausman 1978). The *logical* consideration is whether $\beta_{1it}$ can be considered random and drawn from an independently and identically distributed (IID) distribution (Hausman 1978, p. 1263). The statistical consideration is whether the $\beta_{1it}$’s satisfy “di Finetti’s exchangeability criterion” (p. 1263), a necessary and sufficient condition for random sampling. If these conditions are satisfied, then the random model can be more appropriate than the fixed model. To empirically test the *statistical* consideration, we estimated the fixed effect model for 51 cross-sections for which “complete” data for the period 1994-99 were available. Then we calculated the correlation between the country specific fixed effects and time specific fixed effects with other country-specific factors or regressors (Table 5).

**Table 5: Pearsonian correlations between country and time specific fixed effects with regressors**

<table>
<thead>
<tr>
<th>Variable</th>
<th>Pearsonian correlation coefficient with country specific fixed effect (p-value)</th>
<th>Pearsonian correlation coefficient with time specific fixed effect (p-value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Population (POP)</td>
<td>0.087 (0.546)</td>
<td>0.518 (0.371)</td>
</tr>
<tr>
<td>Per capita GNP (GNPPC)</td>
<td>0.281 (0.048)</td>
<td>-0.334 (0.582)</td>
</tr>
<tr>
<td>Telecom investment</td>
<td>-0.051 (0.726)</td>
<td>0.985 (0.002)</td>
</tr>
<tr>
<td>(TELINV)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Political freedom</td>
<td>-0.151 (0.295)</td>
<td>-0.891 (0.042)</td>
</tr>
<tr>
<td>(PFD)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Population density</td>
<td>0.052 (0.719)</td>
<td></td>
</tr>
<tr>
<td>(PODE)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
As table 5 indicates, of the 9 Pearsonian correlation coefficients, only one is significant at 1% level. Since most of the Pearsonian correlation coefficients were insignificant, it became clear that random effect LTCS models are more appropriate for the given data set than fixed effect LTCS models.

After knowing the appropriateness of the random effect LTCS models over fixed effect ones, the next step is to select the most appropriate random effect model. In the pooled data on Internet diffusion, it is reasonable to expect heteroskedasticity \([i.e. \ E(u_{it}^2) = \sigma_{it}]\), contemporaneous correlation or spatial heterogeneity \([i.e. \ E(u_{it}u_{jt}) = \sigma_{ij}]\) (Anselin 1987), and autoregression \([i.e. \ u_{it} = \rho_i u_{i,t-1} + \epsilon_{it}]\). The three most commonly used estimation procedures for random effect TSCS models are Fuller-Battese, Da Silva and Parks. The Fuller-Battese (Fuller and Battese 1974) takes only heteroskedasticity into account while Da Silva (1975) considers heteroskedasticity and autoregression. The Parks (1967) method, on the other hand, takes heteroskedasticity, autoregression as well as contemporaneous correlation into account (See Appendix 1).

**Data Analysis, Discussion and Limitations**

We estimated the following models for the global country-level data:

1. GDF (Dependent variable: Diffusion speed and location effect)
2. LTCS models for the period 1994-99 (Dependent variable: Penetration rate)

**Estimation of Griliches Logistic Model**

The dependent variable for this analysis was Internet hosts per 1000 \((IHPK)\). Twenty one countries (table 4) were considered covering the years 1994 to 1999. Table 6 provides the results of the estimation of Griliches diffusion function for 21 developing and developed economies. We have presented the results only for the combinations of variables for which the model converged.
Table 6: Estimation of Griliches model (Dependent variable IHPK)

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\lambda$</td>
<td>0.269</td>
<td>0.347</td>
<td>0.326</td>
</tr>
<tr>
<td></td>
<td>(6.25)$^a$</td>
<td>(5.1)$^a$</td>
<td>(5.38)$^a$</td>
</tr>
<tr>
<td>GNPPC ($\alpha_1$)</td>
<td>-0.265</td>
<td>-0.236</td>
<td>-0.239</td>
</tr>
<tr>
<td></td>
<td>(13.25)$^a$</td>
<td>(16.52)$^a$</td>
<td>(15.93)$^a$</td>
</tr>
<tr>
<td>Intercept ($\beta_0$)</td>
<td>-0.338</td>
<td>-0.088</td>
<td>-0.104</td>
</tr>
<tr>
<td></td>
<td>(11.44)$^a$</td>
<td>(1.83)$^c$</td>
<td>(2.18)$^a$</td>
</tr>
<tr>
<td>GNPPC ($\beta_1$)</td>
<td>0.0375</td>
<td>0.031</td>
<td>0.031</td>
</tr>
<tr>
<td></td>
<td>(13.99)$^a$</td>
<td>(15.85)$^a$</td>
<td>(14.90)$^a$</td>
</tr>
<tr>
<td>PFD ($\beta_2$)</td>
<td>-0.179</td>
<td>-0.155</td>
<td>-0.82</td>
</tr>
<tr>
<td></td>
<td>(5.99)$^a$</td>
<td>(4.93)$^a$</td>
<td>(1.25)</td>
</tr>
<tr>
<td>TELINV ($\beta_3$)</td>
<td>-0.82</td>
<td>-0.82</td>
<td>-0.82</td>
</tr>
<tr>
<td></td>
<td>(1.25)</td>
<td>(1.25)</td>
<td>(1.25)</td>
</tr>
<tr>
<td>$F$</td>
<td>135.88$^a$</td>
<td>142.87$^a$</td>
<td>148.04$^a$</td>
</tr>
</tbody>
</table>

The numbers in the parentheses are the t-values.
a. Significant at 0.01 level, b. Significant at 0.05 level, c. Significant at 0.10 level

The model could not be estimated by including population size and population density as explanatory variables. For diffusion speed as the dependent variable, the hypotheses regarding the influence of GNPPC and PFD were supported. There was no support regarding the impact of priority variable (TELINV).

For location effect as the dependent variable, it is somewhat surprising that GNPPC has negative effect. A closer examination of the dataset indicates that the economies used in the GDF may not be a representative sample of economies in the world. Some economies used in the GDF introduced the Internet later than economies at lower income levels. For instance, in Canada and the U.S., the Internet was available to the public since 1988. Germany, Netherlands and the U.K. introduced the Internet in 1989 and Switzerland in 1990. Switzerland’s income during 1994-99 was about 50% higher than that of U.S. and almost over twice of Canada. Similarly, Germany, Netherlands, the U.K. had much higher income than Canada during 1994-99.
**LTSCS Analyses**

The dependent variable for this analysis was Internet Penetration rate, and the period covered was 1994 to 1999. In the TSCS model, we used per capita GNP (GNPPC), population density (PODE), population size (POP), political freedom (PFD) and telecom investment as a proportion of GDP (TELINV) as the explanatory variables.

**Table 7a: TSCS analysis (Dependent variable: \( \ln \left( \frac{IHPK_{it}}{1000 - IHPK_{it}} \right) \) for 51 economies (1994-99)**

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
<th>Model 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.40 (-0.10)</td>
<td>-1.26 (-0.36)</td>
<td>0.13 (0.03)</td>
<td>0.79 (0.20)</td>
</tr>
<tr>
<td>GNPPC</td>
<td>1.42 (4.32)</td>
<td>1.56 (6.24)</td>
<td>1.12 (4.61)</td>
<td>1.32 (4.78)</td>
</tr>
<tr>
<td>PFD</td>
<td></td>
<td>-1.33 (-6.39)</td>
<td>-1.21 (-4.76)</td>
<td></td>
</tr>
<tr>
<td>TELINV</td>
<td>0.256 (6.53)</td>
<td></td>
<td>0.17 (2.39)</td>
<td></td>
</tr>
<tr>
<td>POP</td>
<td>-0.19 (-0.54)</td>
<td>0.02 (0.01)</td>
<td>-0.06 (-0.18)</td>
<td>-0.08 (-0.22)</td>
</tr>
<tr>
<td>PODE</td>
<td>0.21 (1.51)</td>
<td>0.22 (1.83)</td>
<td>0.19 (0.13)</td>
<td>0.09 (0.52)</td>
</tr>
<tr>
<td>R²</td>
<td>0.72</td>
<td>0.85</td>
<td>0.83</td>
<td>0.79</td>
</tr>
</tbody>
</table>

The numbers in the parentheses are the t-values.

a. Significant at 0.01 level
b. Significant at 0.05 level
c. Significant at 0.10 level

(Note: All regressors are the natural logarithmic transformations of the original variables).

**Table 7b: TSCS analysis (Dependent variable: \( \ln \left( \frac{IUPK_{it}}{1000 - IUPK_{it}} \right) \) for 51 economies (1994-99)**

<table>
<thead>
<tr>
<th></th>
<th>Model 1</th>
<th>Model 2</th>
<th>Model 3</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-4.08 (-1.90)</td>
<td>-3.90 (-2.64)</td>
<td>-3.13 (-1.96)</td>
</tr>
<tr>
<td>GNPPC</td>
<td>1.69 (10.17)</td>
<td>1.89 (25.6)</td>
<td>1.31 (13.39)</td>
</tr>
<tr>
<td>PFD</td>
<td></td>
<td>-1.95 (-15.91)</td>
<td></td>
</tr>
<tr>
<td>TELINV</td>
<td>0.19 (7.61)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>POP</td>
<td>-0.07 (-0.38)</td>
<td>0.02 (2.15)</td>
<td>0.12 (0.79)</td>
</tr>
<tr>
<td>PODE</td>
<td>0.24 (1.90)</td>
<td>0.16 (1.39)</td>
<td>0.11 (3.24)</td>
</tr>
<tr>
<td>R²</td>
<td>0.98</td>
<td>0.99</td>
<td>0.98</td>
</tr>
</tbody>
</table>

**Table 7a and table 7b present the results of LTSCS models with IUPK and IHPK as the dependent variables. As tables 6; 7a and 7b indicate income and political freedom variables influence the penetration rate and diffusion speed of the Internet.**
investment as a proportion of GDP has a significant effect on Internet penetration in the LTSCS model but not in the GDF. Population and population density, on the other hand, gave mixed results. We also found that the random effect LTSCS model is more appropriate than the fixed effect model to study the global diffusion of the Internet.

Table 8: Correlation Matrix for 1999 data

<table>
<thead>
<tr>
<th></th>
<th>PFD</th>
<th>TELINV</th>
<th>POP</th>
<th>PODE</th>
</tr>
</thead>
<tbody>
<tr>
<td>GNPPC</td>
<td>-0.73&lt;sup&gt;a&lt;/sup&gt;</td>
<td>-0.03</td>
<td>0.01</td>
<td>0.18&lt;sup&gt;b&lt;/sup&gt;</td>
</tr>
<tr>
<td>PFD</td>
<td>-0.12</td>
<td>0.30&lt;sup&gt;b&lt;/sup&gt;</td>
<td>-0.10</td>
<td></td>
</tr>
<tr>
<td>TELINV</td>
<td></td>
<td>-0.25&lt;sup&gt;c&lt;/sup&gt;</td>
<td>-0.02</td>
<td></td>
</tr>
<tr>
<td>POP</td>
<td></td>
<td></td>
<td>-0.03</td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup>. Significant at 0.01 level  
<sup>b</sup>. Significant at 0.05 level  
<sup>c</sup>. Significant at 0.10 level

Although the data set used in this paper has a distinct advantage in the sense that it represents real “action” rather than attitude or intention as used in most studies, there are some limitations as well. First, the accuracy of the data on Internet users, which were obtained by government surveys, may vary widely across economies.

Second, despite our attempt to include more developing countries, we could include only a few especially in the Griliches diffusion function indicating a possible bias of the findings towards developed countries. Third, it is difficult to find country specific explanatory variables that have significant effect on Internet diffusion and at the same time not correlated with the income variable.

In this paper, we mainly focused on the factors influencing the diffusion of the Internet. When data on e-commerce transactions become available for several economies, TSCS models with e-commerce transactions as the dependent variable would provide valuable insights into the factors that are likely to influence the commercial uses of the Internet.
Finally, international agencies concerned with the diffusion of information and communications technologies (ICTs) should place higher emphasis on collecting relevant time series data on various factors that are related to the diffusion dynamics.
Appendix 1: Parks Method

\[ E(u_{it}^2) = \sigma_{ii} \text{ (heteroskedasticity)} \]

\[ E(u_{it}u_{jt}) = \sigma_{ij} \text{ (contemporaneous correlation)} \]

\[ u_{it} = \rho_i u_{i,t-1} + \epsilon_{it} \text{ (autoregression)} \]

where,

\[ E(\epsilon_{it}) = 0 \]

\[ E(u_{i,t-1}\epsilon_{jt}) = 0 \]

\[ E(\epsilon_{it}\epsilon_{jt}) = \phi_{ij} \]

\[ E(\epsilon_{it}\epsilon_{js}) = 0 \quad (s \neq t) \]

\[ E(u_{i0}) = 0 \]

\[ E(u_{i0}u_{j0}) = \sigma_{ij} = \frac{\phi_{ij}}{1-\rho_i\rho_j} \]

The model assumed first order autoregressive with contemporaneous correlation between cross sections. The covariance matrix of \( u \) is

\[ E(uu') = \Sigma = \begin{bmatrix} 
\sigma_{11}P_{11} & \sigma_{12}P_{12} & \ldots & \sigma_{1N}P_{1N} \\
\sigma_{21}P_{21} & \sigma_{22}P_{22} & \ldots & \sigma_{2N}P_{2N} \\
\vdots & \vdots & \ddots & \vdots \\
\sigma_{N1}P_{N1} & \sigma_{N2}P_{N2} & \ldots & \sigma_{NN}P_{NN} 
\end{bmatrix} \]

Where,
\[ P_{ij} = \begin{bmatrix} 1 & \rho_j & \rho_j^2 & \ldots & \rho_j^{T-1} \\
\rho_j & 1 & \rho_j & \ldots & \rho_j^{T-2} \\
\rho_j^2 & \rho_j & 1 & \ldots & \rho_j^{T-3} \\
\vdots & \vdots & \vdots & \ddots & \vdots \\
\rho_i^{T-1} & \rho_i^{T-2} & \rho_i^{T-3} & \ldots & 1 \end{bmatrix} \]

\( V \) is estimated by using two-stage procedure, and \( \beta \) is then estimated by using generalized least square (GLS). The first step in estimating \( V \) entails the use of ordinary least square (OLS) and then obtain the fitted residuals, as follows:

\[ \hat{\mathbf{u}} = \mathbf{y} - \mathbf{X} \hat{\beta}_{OLS} \]

**Estimation of \( \hat{\rho}_i \)**

A consistent estimator of the first-order autoregressive parameter is obtained as follows:

\[ \hat{\rho}_i = \left( \frac{\sum_{t=2}^T \hat{u}_{i,t} \hat{u}_{i,t-1}}{\sum_{t=2}^T (\hat{u}_{i,t-1})^2} \right) i = 1, 2, \ldots, N. \]

The autoregressive character of the data can be removed (asymptotically) by the usual transformation of taking weighted differences. That is for \( i = 1, \ldots, N. \)

\[ y_{i1} \sqrt{1 - \hat{\rho}_i^2} = \sum_{k=1}^p X_{i1,k} \sqrt{1 - \hat{\rho}_i^2} + u_{i1} \sqrt{1 - \hat{\rho}_i^2} \]

\[ y_{i1} - \hat{\rho}_i y_{i1,t-1} = \sum_{k=1}^p (X_{i,t,k} - \hat{\rho}_i X_{i,t-1,k}) \beta_k + u_{i1} - u_{i1,t-1}, t = 2, \ldots, T \]

which can be written as

\[ y_{i,t}^* = \sum_{k=1}^p X_{i,t,k}^* \beta_k + u_{i,t}^* \quad i = 1, 2, \ldots, N; t = 1, 2, \ldots, T. \]

It should be noted that the transformed model has not lost any observation.
Estimation of \( \mathbf{V} \)

\[
\hat{\mathbf{u}}^* = \mathbf{y} - \mathbf{X} \hat{\beta}_{OLS}^*
\]

from which the consistent estimator of \( \sigma_{ij} \) is calculated.

\[
s_{ij} = \frac{\hat{\phi}_{ij}}{(1 - \hat{\rho}_i \hat{\rho}_j)}
\]

where,

\[
\hat{\phi}_{ij} = \frac{1}{T-p} \sum_{t=1}^{T} u_t^* u_{jt}^*
\]

EGLS then proceeds in the usual manner:

\[
\hat{\beta}_p = \left( \mathbf{X}' \hat{\mathbf{V}}^{-1} \mathbf{X} \right)^{-1} \mathbf{X}' \hat{\mathbf{V}}^{-1} \mathbf{y}
\]

where \( \hat{\mathbf{V}} \) is the derived consistent estimator of \( \mathbf{V} \). For computational purposes, \( \hat{\beta}_p \) is obtained directly from the transformed model,

\[
\hat{\beta}_p = \left( \mathbf{X}^* \left( \hat{\phi}^{-1} \otimes I_T \right) \mathbf{X}^* \right)^{-1} \mathbf{X}^* \left( \hat{\phi}^{-1} \otimes I_T \right) \mathbf{y}^*
\]

The procedure is equivalent to Zellner’s two-stage methodology applied to the transformed model (Zellner 1962).

Parks demonstrates that his estimator is consistent and asymptotically, normally distributed with

\[
\text{Var} \left( \hat{\beta}_p \right) = \left( \mathbf{X}' \hat{\mathbf{V}}^{-1} \mathbf{X} \right)^{-1}
\]
References


**Endnotes**

1 OECD stands for the Organization for Economic Cooperation and Development, the body that represents about 30 advanced, democratically governed economies of the world. The work by Dekimpe, Parker and Sarvary (2000) is an exception. They consider the diffusion of digital mobile technology in 162 countries. However, the study focuses only on the introduction of the mobile technology and not on the penetration level in individual countries.
These variables influence Internet diffusion by shifting the Internet demand curve forward or backward, thereby producing income effect, compatibility effect, skill effect, distance effect, etc.

An Internet host is “a computer system connected to the Internet—either a single terminal directly connected or a computer that allows multiple users to access network services through it” (UNDP 2001).

All the hypotheses are stated on a ceteris paribus – other things being equal – basis. The phrase “Ceteris paribus” is implicit at the beginning of each hypothesis statement, and has not been explicitly stated.

We used only the period 1994-99 in the estimation TSCS models and the GDF because of the unavailability of data on explanatory and/or dependent variables for several economies.

Gruber and Verboven (2001) used equation (1) to estimate mobile telecom diffusion in the European Union countries.

We could not estimate $\beta_4$, $\beta_5$, and $\alpha_4$ because of convergence problems in the Griliches model.

Although a significant proportion of users these days access the Internet via non-dial up channels such as broadband, such means were very limited until 1999. So we used, telephone penetration as the upper limit for Internet penetration.

Even if random effects specification is found more appropriate on logical ground, one may still estimate fixed effects models. The fixed effect estimators are based on a particular sample which treats them as fixed in the sample (Hausman 1978).
Founded in 1892, the University of Rhode Island is one of eight land, urban, and sea grant universities in the United States. The 1,200-acre rural campus is less than ten miles from Narragansett Bay and highlights its traditions of natural resource, marine and urban related research. There are over 14,000 undergraduate and graduate students enrolled in seven degree-granting colleges representing 48 states and the District of Columbia. More than 500 international students represent 59 different countries. Eighteen percent of the freshman class graduated in the top ten percent of their high school classes. The teaching and research faculty numbers over 600 and the University offers 101 undergraduate programs and 86 advanced degree programs. URI students have received Rhodes, Fulbright, Truman, Goldwater, and Udall scholarships. There are over 80,000 active alumnae.

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The creation of this working paper series has been funded by an endowment established by William A. Orme, URI College of Business Administration, Class of 1949 and former head of the General Electric Foundation. This working paper series is intended to permit faculty members to obtain feedback on research activities before the research is submitted to academic and professional journals and professional associations for presentations.

An award is presented annually for the most outstanding paper submitted.