“Are We There Yet?”
An Exploratory Relationship between National Information Infrastructure Expenditures, Infrastructure Development, and Service-Sector Productivity

Pratim Datta
School of Accounting, Business Law, and Information Systems
Washington State University
Email: pdatta@wsu.edu

Victor Wacham A. Mbarika
Information Systems & Decision Sciences
Louisiana State University
Email: victor@mbarika.com

Abstract
The worldwide scramble for information expenditures in order to gain productive advantage has been an issue of interest for both national policymakers and researchers. Yet little attention has been paid towards the dimensions of the productivity process, including the time lag between investments and returns. This paper illuminates the dimensions by disaggregating information investments into information expenditures and information infrastructure development. Based on past literature, this study uses service-sector productivity as a logical outcome of information expenditures. We contend that productivity follows a path from information expenditures through information infrastructure to service-sector productivity. A conceptual framework is developed and empirically examined using a time-lagged longitudinal dataset of 60 countries equally grouped into 3 income categories is then developed. The empirical examination reveals that information infrastructure development does indeed mediate the path between information investments and service sector productivity—supported by the discriminating evidence in the productivity path between the country categories. We finally discuss the results and implications.

1. The Information Age and the Global Economy

A potentially important factor that has been unequivocally agreed upon but little implemented is the use of a time lag between information expenditures and productivity (Brynjolfsson, 1993; Dutta, 2001). Although both researchers and practitioners confirm that there is indeed a time lag between expending and realizing returns on an information infrastructure, most of past research failed to incorporate the time lag, adding to discrepancies between hypothesized and realized productivity at both the organizational and national levels of analyses.

From organizations to national economies, supply-side economists in the pursuit of productivity have welcomed the information age. The information age has been marked by three distinct phenomena: information expenditures in terms of capital outlay, information infrastructure development, and the growth of the service sector. The relationship between productivity and information expenditures and information infrastructures has been researched across organizations (e.g. Clemons, et al 1989; Broadbent, et al 1996), usually in a piecemeal fashion. Notable exceptions (e.g. Soh & Markus, 1995; Datta, 2002) that have integrated both information expenditures and infrastructure development are both few and far apart, with nearly no evidence of comparative studies conducted on nations on how much productivity was realizable from given amounts of information expenditures.

Another little examined phenomenon is the growth of the service sector as a conduit for productivity in the information age. However, the information infrastructure has been seen to radically impact and improve the growth of the service sectors, especially with information itself being a service. In a recent observation on the impact of the information age on competitive advantages in countries, Kapur and Ramamurti (2001) explicitly evidence the growth of the “knowledge-based tradable services” sectors as constituting the crucial productive link in national economies. A similar observation was also reported by Baily, et al (1994: 29) that although information expenditures substantially promote service sector growth, industries and economies still “understate absolute levels of service productivity by a
substantial margin, individual service industries—like communications, utilities, and wholesale trade—for decades (1948-1973) outperformed manufacturing in measured productivity growth. From 1973 until 1990, individual service industries continued to exceed the productivity gains of non-electrical durable goods and non-durable goods manufacturers, as well as the mining, construction, and total goods producing sectors.”

The proposed conceptual framework is presented in figure 1. In this paper, we develop a preliminary understanding of the time-lagged relationship between information expenditures and productivity in a global context by identifying whether significant differences in information expenditures, information infrastructure, and service sector productivity exist across high-income, median-income, and low-income countries. A comparative study of this nature provides a general understanding of how and whether productivity is realized from information expenditures by nations around the globe. We add to the literature by understanding the lagged relationship between information expenditures, infrastructure, and service sector productivity that can assist government regulators gain insights into the relationship between the scale and scope of information infrastructure and national service sector productivity.

Figure 1

2. Information Expenditures and Infrastructure:

Considering the productivity gains that nations might accrue from the information revolution, nations invest a significant portion of their resources to improve their information infrastructure (King et al., 1994). Yet, researchers have revealed contradictory findings regarding productivity gains from information infrastructure investments (Mbarika, et al., 2001; Dutta, 2001). Much of this ambiguity arose from a misdirected definition of information expenditures as investments. Expenditures are undirected lumpsum monetary allocations while investments are directed capital allocations, both monetary and non-monetary. Because expenditures can only be increased or decreased, it can be viewed only in terms of scale or degree. Information expenditures are thus a necessary but not a sufficient condition for achieving productivity (Soh & Markus, 1996). Yet, supply-side economists have commonly pegged national productivity statistics to mere expenditures, resulting in growing ambiguity.

H1: Information expenditures differ significantly across high-income, median-income, and low-income countries.

The complementing variable that creates both a necessary but not a sufficient condition for productivity is that of creating an information infrastructure. In contrast to information expenditures as representing scale or the “relative size of an outlay” for infrastructure, infrastructure development represents scope in terms of “a distinctive treatment of the outlay” marked by the accessibility and use of the infrastructure. The essence of an information infrastructure lies in its scope. According to McLoughlin (2000: 2), information infrastructure is a “physical system of telecommunications pathways and connections that transmit voice, video, and data, and encompassing a web of telecommunications, information, and computing technologies.” The scope of the information infrastructure rests on two separate but interacting components: (1), the technical component (e.g. telephone lines per capita) that provides access and (2), the users of the technical component (e.g. the number of telephone subscribers/users). In an extensive longitudinal study performed by Wang (1999) concerning the impact of information infrastructure investments on national economic activity in Taiwan, the author posited the need for a having a robust information infrastructure as a precursor to national productivity.

H2: Information infrastructure differs significantly across high-income, median-income, and low-income countries.

3. Economic Productivity and the Service Sector

Previous studies indicate the economic benefits derived from developing robust information infrastructure. Antonelli (1993) asserted that positive externalities derived from robust communications infrastructure yield economic advantages through spillovers that far outnumber the actual marginal monetary revenues. A potential evidence of the spillover benefits can be traced by examining the growth of the service sector.

The structure of an economy comprises of contributions by its three main sectors of agriculture, industry, and services measured in terms of its GDP. In understanding sectoral contributions, Soubbotina & Sheram (2000) highlighted that service sector contributions were positively related to GDP and
more pronounced for high-income economies (Figure 2). The authors contend thereafter that as a country undergoes economic progress, the service sector supplants other sectors to become the leading contributor towards the economy. Through innovations and entrepreneurship, service-sector contribution towards and as a measure of economic activity has been growing (Sikes, 1987; Dowling, et al., 1994). This leads us to the third hypothesis:

\[ H_3: \text{Service-sector productivity differs significantly across high-income, median-income, and low-income countries.} \]

4. Methodology: Data Collection and Analysis

The study design involved the collection and use of secondary data sources across a spectrum of countries for the purposes of a comparative study. In our comparative study, we chose to conduct a time-lagged systematic comparison between countries. For that purpose, the paper randomly sampled 20 countries in each category (N = 60) based on their level of income as a proxy for development. The dataset consisted of low-income, median-income, and high-income countries as designated by the World Bank database. In this paper, economic productivity is examined in terms of the service sector measured by service sector contribution towards GDP. The data on service sector contribution was obtained from tables published the Economist Intelligence Unit (EIU) database while data concerning information expenditure and information infrastructure were obtained from the ITU database. As discussed earlier, information infrastructure involves both technical and human measures. Information infrastructure is operationalized by calculating the interaction between information infrastructure access points (standardized by technology per 100) and users for each of the information infrastructure components of telephones, telex lines, cellular phones, ISDN lines, personal computers, and trained telecommunications personnel. For the purposes of this paper, we assume a time lag of one year between information expenditure, infrastructure development, and service-sector productivity.

In order to test the hypotheses previously presented, the data analysis began by evaluating one-way analysis of variance (ANOVA) to test if the means of two of the three country categories or tiers are significantly different from each other in each of the variables of information expenditure, information infrastructure, and service sector productivity. Moving from the generic to the specific, the reported differences from the F-statistics were then examined more closely through post-hoc analysis using Bonferroni test statistics. Finally, the mediating effect of information infrastructure in achieving productivity is empirically ascertained. All differences are assessed at a 5% level of significance (\( \alpha=0.05 \)).

Confirmatory Analysis for Mediation: Regression

We now concentrate on a confirmatory testing of our hypotheses. As we intend to confirm both mediation and recursiveness among the specified constructs, different statistical techniques are employed to achieve our objectives. Our proposed hypotheses integrate the constructs of information infrastructure scale (expenditures), information infrastructure scope (development), and economic productivity. In the process of integrating the constructs, we borrow and augment the research by Dutta (2001) by including the finer dimensions that contribute towards national economic growth. We borrow his efficacious inclusion of temporal lags and methodology, while augmenting his research by introducing information infrastructure development as a mediating variable (Soh & Markus, 1995), and supplanting the paradigmatic use of GDP with service sector growth (Quinn, et al, 1994).

The proposed mediating relationship of information infrastructure development is tested using a sequential technique proposed and used by Baron & Kenny (1985) in the presence of a lagged dependent variable. In this technique, two separate regression models are utilized to test the mediation: The first including the original predictor variable, in this case, information expenditure (INFEXP); The second regression model expands upon the first by the inclusion of the mediating variable, i.e. information infrastructure development (INFDEV), to the primary predictor, information expenditure. Service sector contribution to GDP (SERGDP), used as a proxy for economic activity, is the response variable in both models. It is also measured as the percentage contribution of the service sector to GDP. Some service sector activities include tourism, transportation, hotels, and restaurants.

The regression models are appended below:

a. Regression model 1 with SERGDP as the predictor and INFEXP as the initial independent variable:

\[ SERGDP_{t+1} = a_1 + b_1INFEXP_t + \epsilon_1 \]

b. Regression model 2 with the mediating variable INFDEV as the predictor and INFEXP as the initial independent variable:

\[ INFDEV_t = a_2 + b_2INFEXP_t + \epsilon_2 \]

c. Regression model 3 with SERGDP as the predictor and INFDEV (mediator) as the independent variable:

\[ SERGDP_{t+1} = a_3 + b_3INFDEV_t + \epsilon_3 \]
5. Results

The results from the one-way ANOVA supported hypotheses H₁, H₂, and H₃, pointing out that the means and the variances of information expenditure (H₁) (F= 151.588, p<0.05), information infrastructure (H₂) (F= 309.365, p<0.05), and service sector productivity (H₃) (F= 246.610, p<0.05) significantly vary by low-income, median-income, and high-income countries (Table 1a). However, while the F-test tells us that country categories are significantly related to information expenditures, information infrastructure, and service sector productivity. Because the p-value is highly significant, one can conclude that national information expenditures, infrastructure, and service-sector productivity do delineate the income-category of countries. However, while the ANOVA provides a generic view on the mean difference across the three tiers of country categories based upon income, it does not mean that information expenditures, information infrastructure, and service-sector productivity makes an equal difference for every country category, thus warranting further investigation for a finer insight into the relationship.

Table 1a

<table>
<thead>
<tr>
<th>Analysis of Variance</th>
<th>Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Infrastructure</td>
<td>Between Groups</td>
<td>15017.669</td>
<td>2</td>
<td>7508.8345</td>
<td>99.99</td>
</tr>
<tr>
<td>Within Groups</td>
<td>70940.705</td>
<td>59</td>
<td>1219.0651</td>
<td>151.588</td>
<td>.000</td>
</tr>
<tr>
<td>Total</td>
<td>4506086897</td>
<td>59</td>
<td>770733.110</td>
<td>309.365</td>
<td>.000</td>
</tr>
<tr>
<td>Information Expenditure</td>
<td>Between Groups</td>
<td>186652.496</td>
<td>2</td>
<td>93326.249</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>1244575.174</td>
<td>59</td>
<td>21085.567</td>
<td>246.610</td>
<td>.000</td>
</tr>
<tr>
<td>Total</td>
<td>448265.694</td>
<td>59</td>
<td>771724.992</td>
<td>309.365</td>
<td>.000</td>
</tr>
<tr>
<td>Service-Sector Productivity</td>
<td>Between Groups</td>
<td>204610.099</td>
<td>2</td>
<td>102305.050</td>
<td>.000</td>
</tr>
<tr>
<td>Within Groups</td>
<td>6189615.24</td>
<td>59</td>
<td>1042806.909</td>
<td>309.365</td>
<td>.000</td>
</tr>
<tr>
<td>Total</td>
<td>406056897</td>
<td>59</td>
<td>640927802</td>
<td>309.365</td>
<td>.000</td>
</tr>
</tbody>
</table>

For understanding the finer grain in the relationships across country categories, a post-hoc analysis was conducted using Bonferroni tests (Table 1b). The post-hoc analysis reveals the structural differences revealed by pairwise multiple comparisons of information expenditures, information infrastructure, and service-sector productivity among the three country categories based on income. The Bonferroni test results from the post hoc analysis provide a finer insight in the differences across each country category. Contrary to the general ANOVA results, the pairwise comparison results partially confirm the hypotheses.

Hypothesis H₄ is partly supported. Results indicate that information expenditures vary significantly between high-income and median-income countries (p<0.05) and also between high-income and low-income countries (p<0.05). However, information expenditures do not seem to
vary significantly between low-income and median-income countries (p>0.05).

Hypothesis H2 is supported. The results indicate that information infrastructure is significantly different between high-income and median-income (p<0.05), high-income and low-income (p<0.05), and low-income and median-income countries (p<0.05).

Hypothesis H3 is partly supported. Results show that while service-sector productivity is significantly different between high-income and median-income countries (p<0.05) and also between high-income and low-income countries (p<0.05), it does not seem to differ between low-income and median-income countries (p>0.05). The results from service-sector productivity seem to closely resemble results obtained for information expenditure.

Table 1b
Post-Hoc Pairwise Multiple Comparisons

<table>
<thead>
<tr>
<th>Dependent Variable</th>
<th>Country Category</th>
<th>Country Category</th>
<th>(1-2)</th>
<th>Std. Error</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Information Infrastructure</td>
<td>High-Income</td>
<td>Median-Income</td>
<td>97.7243</td>
<td>5.13291</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Low-Income</td>
<td></td>
<td>120.0214</td>
<td>5.13291</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Median-Income</td>
<td>Low-Income</td>
<td>-97.7243</td>
<td>5.13291</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Low-Income</td>
<td></td>
<td>22.2971</td>
<td>5.13291</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Low-Income</td>
<td>Median-Income</td>
<td>-120.0214</td>
<td>5.13291</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Median-Income</td>
<td></td>
<td>-22.2971</td>
<td>5.13291</td>
<td>.000</td>
</tr>
<tr>
<td>Information Expenditures</td>
<td>High-Income</td>
<td>Median-Income</td>
<td>159.88671</td>
<td>15.5605</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Low-Income</td>
<td></td>
<td>175.47631</td>
<td>15.5605</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Median-Income</td>
<td>Low-Income</td>
<td>-159.88671</td>
<td>15.5605</td>
<td>.383</td>
</tr>
<tr>
<td></td>
<td>Low-Income</td>
<td></td>
<td>15.5899*</td>
<td>15.5605</td>
<td>.383</td>
</tr>
<tr>
<td></td>
<td>Low-Income</td>
<td>Median-Income</td>
<td>-175.47631</td>
<td>15.5605</td>
<td>.383</td>
</tr>
<tr>
<td></td>
<td>Median-Income</td>
<td></td>
<td>-15.5899*</td>
<td>15.5605</td>
<td>.383</td>
</tr>
<tr>
<td>Service-Sector Productivity</td>
<td>High-Income</td>
<td>Median-Income</td>
<td>16855.324</td>
<td>9.64943</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Low-Income</td>
<td></td>
<td>17907.814</td>
<td>9.64943</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Median-Income</td>
<td>Low-Income</td>
<td>-16855.324</td>
<td>9.64943</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Low-Income</td>
<td></td>
<td>-1052.284</td>
<td>9.64943</td>
<td>.513</td>
</tr>
<tr>
<td></td>
<td>Low-Income</td>
<td>Median-Income</td>
<td>-17907.814</td>
<td>9.64943</td>
<td>.000</td>
</tr>
<tr>
<td></td>
<td>Median-Income</td>
<td></td>
<td>-1052.284</td>
<td>9.64943</td>
<td>.513</td>
</tr>
</tbody>
</table>

* The mean difference is significant at the .05 level.

Table 1c
Empirical Tests for Mediation

<table>
<thead>
<tr>
<th>Country Tier</th>
<th>Regression 1</th>
<th>Regression 2</th>
<th>Regression 3</th>
<th>Sobel Test (Goodman Ver)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>β1</td>
<td>β2</td>
<td>β3</td>
<td>β4</td>
</tr>
<tr>
<td>High</td>
<td>34.935**</td>
<td>4.877*</td>
<td>175.209**</td>
<td>4.806*</td>
</tr>
<tr>
<td>Median</td>
<td>18.95*</td>
<td>3.612*</td>
<td>28.635*</td>
<td>14.73*</td>
</tr>
<tr>
<td>Low</td>
<td>25.277**</td>
<td>1.371**</td>
<td>113.167*</td>
<td>-1.51</td>
</tr>
<tr>
<td>Total</td>
<td>92.452**</td>
<td>1.578**</td>
<td>154.123**</td>
<td>21.387**</td>
</tr>
</tbody>
</table>

Notations for Level of Significance: 0.05(*); Intercept and its significance not considered.

6. Discussion and Conclusion: Are We There Yet?

While we are not there yet, the path is certainly a less dubious. The role of developing an information infrastructure rather than merely expending for it delineates hope and hype. The construct of information infrastructure development does show significant mediation effects. Results show that information infrastructure development (INFODEV) is a statistically significant mediator between information expenditures (INFOEXP) and increased economic activity (SERGDP) among each country tier as well as for the entire data set (High-Income: b4 = 4.81, α<0.05; b5 = 169.93, α<0.01; Median-Income: b4 = 14.73, α<0.05; b5 = 23.68, α<0.01; Low-Income: b4 = -15.1, α<0.05; b5 = 108.74, α<0.01; Entire set: b4 = 21.39, α<0.01; b5 = 123.01, α<0.01). As a minor deviation to the results, the low-income country category results indicate that the influence of infrastructure development as a mediator in the regression equation not only decreased the statistical significance of infrastructure expenditures upon economic activity, but also rendered its influence negative.

While the results from the ANOVA revealing a general difference in information expenditures, information infrastructure, and service-sector productivity, the post-hoc tests provides a finer understanding into each of the categories to highlight interesting insights. The results from the post hoc analyses confirm the complexity of the issue at hand. Datta (2002) and Soh & Markus (1995) have conceptualized the disparity that lies between information expenditures and information infrastructure. As discussed earlier in this paper, much of previous research has assumed an aggregated view of the information infrastructure investments, thus mismatching the dimensions of scale and scope, respectively. Disaggregating the dimensions provide a more detailed understanding of how information expenditures do not necessarily relate to the creation of an information infrastructure. This paper exemplifies the issue by revealing the presence of a bandwagon effect of information expenditures across the globe, especially among median and low-income countries.

The clamor for achieving productivity has fueled the hype towards increased capital outlays. Yet, how much is expended does not always have a direct bearing how it is being expended. The results indicate this phenomenon by pointing out the lack of difference in information expenditure across low-income and median-income countries while revealing significant differences in their information infrastructure. The disparity between expenditures and infrastructure is thus a potential problem in developing economies that need to realize that
information spending does not guarantee a better infrastructure. In conceptualizing technological productivity, Soh & Markus (1995) point out that all expenditures do not add to infrastructure development, necessitating the development of an information infrastructure as a precursor to productivity, a notion also attested by Datta (2002). Economics need to realize that infrastructure is a function of increased access, availability, and support of telecommunications rather than of expenditures. Problems lie in misdirected expenditures or creating clusters accessible by a limited few, thus constraining further prospects of positive spillovers and externalities. Yet, a final concern lies in the results on the difference between service-sector productivity among low-income and high-income countries. The results indicate the following: Given similar levels of information expenditures, while information infrastructure significantly differs among low-income and median-income countries, service-sector productivity does not reveal significant differences. Such a results forces us to reconsider on how much an information infrastructure indeed plays a role on service-sector productivity. However, the answer is not as dismal as it seems. Weill’s (1992) concept of “conversion effectiveness” provides a valuable understanding of the seeming discrepancy. Conversion effectiveness is the ability of a firm or a nation to transform infrastructure investments into productivity, a process reliant upon environment and policy. In the case of median-income countries, information is indeed perceived as a precursor to productivity for which there is an increasing effort towards creating greater access availability and support for existing technology, other factors significantly dampen the information infrastructure efforts. Because countries in the median-income category are generally transitioning economies, most of their infrastructure is too embedded into agriculture and manufacturing, mostly nationalized, thus lacking effective government support and legislation aimed at creating a competitive services industry. Complementing the cause is perhaps the need for increasing the time lag between and information infrastructure and productivity beyond our time frame of one year. However, a burgeoning information infrastructure is gradually transforming business models, evidenced by a proliferation of service industries stimulated indigenously or by foreign direct investments (FDI) in developing countries (Ramamurti & Kapur, 2001). The concern thus nervously hinges upon the low-income countries that have mismanaged their information expenditures and failed to develop a supporting infrastructure for future productivity. Exemplifying the concern, Mbarika, et al. (2001; 2002) has documented the disparity between information expenditures in Sub-Saharan Africa and corresponding growth in information infrastructure in terms of teledensity. With sunk costs in terms of large capital outlays as information expenditures combined with a lack of an information infrastructure, low-income countries face an endemic that is likely to mar attempts to gain service-sector productivity. Evidence from the high-income countries suggests their distinctiveness across all dimensions: from strong information expenditures through a robust information infrastructure leading to venerable service-sector productivity.

Our study is limited in its incorporation of one year of time lag between the constructs of information expenditure, infrastructure development, and service sector productivity. However, this very limitation of our study may provide a window for alternative understanding of the disparate developments across country categories. Anthropological studies suggest that much of the technology designed and produced in developed countries is culturally biased in favor of their own social and cultural systems (Escobar 1994) and notions of infrastructure development and productivity are intricately woven into their cultural and social fabric. Consequently, developing countries encounter individual cultural and social barriers when attempting to achieve productivity of information expenditures. The monochronic versus polychronic cultural and social perspectives may be salient to a country’s particular perspective towards infrastructure and productivity. Monochronic cultures are in contrast to polychronic cultures in that they follow strict time commitments, adhere to plans, and emphasize prompt results. The polychronic view of time is more prevalent across Africa and the Middle East, moderately prevalent in Asia and South America, but changes to a more monochronic view of time across Western Europe and North America. This prevalence of a monochronic versus polychronic view of time could indeed be the discriminating factor in the choice and adoption of time lags. For example, a monochronic society and culture may develop and maintain tight schedules following a critical path from expending to achieving productivity. On the other hand, a polychronic society and culture may imply the need for incorporating a greater time lag in their mode of infrastructure development and achieving productive returns from a specific expenditure. In the sample used for this study, we indeed found that most of the low income countries were in Africa or the Middle East; median income countries in Asia and South America; and high income countries in Western Europe and North America. The finding both implicates and reinforces our assumption that the time lag may indeed be the discriminating candidate in understanding infrastructure development and productivity among the aforesaid country categories. Therefore, in the area of macro-level information
infrastructure productivity low-income countries need to be informed, educated, and “acculturated” on the productive potential of information infrastructure development and its temporal and mission critical impact in their economic well-being.

The study is an attempt to decipher the time-lagged relationship between investments in information expenditures, information infrastructure, and service-sector productivity. It adds to the existing body of knowledge by understanding the need for having a robust information infrastructure as a precursor to economic productivity, within a given time lag, while realizing the factors that can and do influence productivity. The study provides preliminary evidence exploring the relationship between scale, scope, and productivity- bringing into focus a much-needed insight into a comparative study of economic productivity amidst the information revolution.

References


