GLOBAL IT EXPENDITURE GROWTH: AN EMPIRICAL INVESTIGATION ACROSS SOME DEVELOPING NATIONS

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ABSTRACT
Information technology (IT) expenditures in different developing nations of the world have been impressive but controversial lately. Research is needed to know how IT expenditures are growing in these nations. Do stages of IT development or price drops in IT infrastructure influence such growth? We intend to explore these issues with various growth models, using data from 14 nations (constrained by data availability) over a period of time. Our preliminary results show that previous IT expenditure growth models can be improved by including the impact of price and that a price drop in IT keeps the growth unabated. Preliminary evidence also suggests that developing nations are benefiting from a price drop.

Keywords
IT expenditure, diffusion, S-curve, price-adjusted model, IT budget, cross-national study

1. INTRODUCTION
Developing nations often face the dilemma of how much to spend on information technology (IT). Should they spend more than developed nations so that they can bridge the gap in IT or should spending on IT have less priority than spending in other areas such as medical care? The answer to this question cannot be straightforward as there is a debate over the real benefit of IT in terms of increased productivity and strategic use (Wu and Wu, 2002). Empirical studies are needed to verify this fact.

Information technology expenditures across various developing nations around the world have been impressive but controversial lately. According to a report, investment in IT in general decreased by 6.2 per cent in 2002 (U.N. Report, 2002). Argentina had IT expenditures at 3.8% of its GDP in 1999, whereas the same was 8.2% for the U.S, 10.1% for Columbia and 11.9% for New Zealand (World Bank, 2003). Why does Columbia spend more than Argentina or the U.S.? Are the people in Columbia more involved in IT than those in the U.S.? It is known that the U.S. is the acknowledged leader in IT innovations. Do nations with the least IT base spend more on their IT budgets? What determines the amount a nation typically spends on its IT budget? Is price-drop a factor in IT growth? We will try to find answers to some of these questions. In particular, research is needed to know how IT expenditures are growing in different developing nations.

IT expenditure growth over time may reflect the nation’s trend of IT adoption and use and so needs to be studied in detail. The nature of the growth of the IT expenditure of a given nation may yield many insights. Whether a nation’s IT expenditures are growing normally, accelerating or declining depends on the rate of growth over time as well as a nation’s IT level. In order to be able to properly assess a nation’s IT budget growth, the curve has to be looked at carefully. In this way, anomalies can be discovered and a clearer growth picture can emerge.
2. **S-Curve Growth at National Level?**

Computer or IT budgets drive IT expenditures. Nolan and his colleagues in a set of articles postulated that computer budget curve growth follows an S-curve, while studying the computer budgets over a period of time of three companies (Nolan and Gibson, 1974). Per his original theory, there are four stages of development of computer resources in an organization. These are Initiation, Contagion, Control and Integration. The inflection points on this curve divided the curve into these four stages. Later, Nolan added two more stages: Data Administration and Maturity (Nolan, 1979). The theory assumes that an organization’s computer budget over time will have an S-shape. Nolan thus showed a relation between computer budgets and time. However, there are several assumptions in Nolan’s model that restrict its use (Benbasat et al., 1984; King and Kraemer, 1984). In particular, what is missing from this analysis is the impact of price drops in IT products and services (Gurbaxani and Mendelson, 1990).

Some empirical studies have shown that IT budgets don't follow the S-curve, but that budgets grow exponentially or linearly in time. Lucas (1977) examined the growth of the IT budget of California counties over a period of years and came to the conclusion that pure S-curves fail to model the budget growth of various counties. A linear model or even an exponential model can explain the growth better.

However, studies are lacking at a national level that deal with how nations are investing in IT, primarily because of a lack of theory and available data. The growth nature of national IT expenditures is important for research purposes for other reasons. The main study that exists at a national level is that of Gurbaxani and Mendelson’s (1990) on information systems (IS) spending growth in the U.S. They argued that in most cases, IT budget growth has two components. First, IT spending growth over time has peaked and then slowed down. What keeps the IT expenditure growth going is the fact that IT prices are coming down. The reason is primarily because many firms can now afford cost-effective IT-based solutions with an increasing number of IT-automated tasks.

3. **Why Consider Price?**

The importance of price can be looked at from an economic viewpoint. As the price of one good or service (IT expenditures) decreases in relation to other goods and services, more will be demanded of the relatively lower priced good or service. Goods and services are demanded up to the point at which the marginal benefits just exceed the marginal costs. If the marginal costs are lowered in relation to other goods, more will be demanded, as a new gap will have been created between marginal benefits and costs (Samuelson and Marks, 2003).

From an operational standpoint, a chief financial officer or chief information officer would look at the return on investment (ROI) and positive net present value (NPV) of an investment in IT expenditures. The higher the ROI and positive NPV, the more attractive the investment gets. ROI has investment as the denominator; hence a lower cost of investment will lead to a higher ROI and more attractive investment. NPV is likewise affected by the investment, with a lower investment causing a higher NPV. Other measures of investment attractiveness such as the payback period also become more attractive as IT prices come down (Horngren et al., 2000).

Pure diffusion models that capture growth over time may not be able to model IT expenditure growth; the impact of price needs to be considered. However, the Gurbaxani and Mendelson’s price-adjusted model (1990) is based on results from only one nation (the U.S). One needs to test this theory by considering more nations.

4. **The Nature of IT Expenditure Growth**

As mentioned earlier, it would be helpful to gain insight into how the IT expenditure curve of a given nation grows—is it linear or exponential in nature? Linear growth implies that growth
has been flat over the years and nations are not making investments that are unusual. Exponential growth could mean a given nation is making an unusually large amount of investment that calls for explanations. Can pure S-curve models explain such growth at a national level in general? If so, that will mean that growth still follows a traditional diffusion pattern and time is the most important factor in growth. Or do IT budget growth curves demonstrate a price-adjusted growth as postulated by Gurbaxani and Mendelson (1990)? That would imply that price-drop may have an effect on IT budget growth across nations. The present paper attempts to resolve these questions.

Research Question 1: Are traditional growth models (S-curve) adequate to explain IT growth rates in different developing nations?

4.1 IT Spending and IT Infrastructure

Many nations with rich IT infrastructures are forward looking and regard IT spending as a good investment. Rich nations usually spend more on IT budgets than poor nations. It can also be argued that poorer nations in order to grow their IT faster will spend more on IT budgets than their counterparts, i.e., nations with low IT infrastructures may try to spend more to play catch up.

Research Question 2: Are developing nations spending more on IT as a % of GDP than other nations?

5. MODELS AND DATA

5.1 Models

Diffusion studies try to explain and analyze patterns of diffusion of innovations, usually over time and across a population of potential adopters. A typical approach used by diffusion researchers is to define adoption as the purchase of the innovation. Observations of adoption or percentages of adoption are put in the form of a time series, and finally the time series is fitted to some functional form, such as the logistic, Gompertz, modified exponential or mixed models (Mahajan and Peterson, 1987). IT budgets, however, show a different diffusion pattern. The diffusion of many IT budget curves shows no sign of slowing down over the years. This appears to contradict the diffusion theory. One of the reasons could be a price drop in IT products. Gurbaxani and Mendelson’s study (1990) on the development of the IS spending curve for the U.S. shows that the cost of IT has gone down substantially over the years. Therefore, pure diffusion models that overlook the effect of price may not be able to appropriately capture the growth process of IT products in many nations.

An augmented version of diffusion models with price incorporated may act as a better analyzer and predictor of the diffusion process of IT expenditures where price drops have been substantial. It must be mentioned that there could be other indicators, such as social and institutional, that play a role in IT expenditure growth processes (Fichman, 1992; Rogers, 1981).

Previous research has relied on a number of price-adjusted diffusion models (Gurbaxani and Mendelson, 1990; Mahajan and Peterson, 1987). For a price-adjusted diffusion model, assume \( f(t) \) denotes the cumulative adoption of an IT expenditure over a period of time \( t \). The diffusion models are described below. The price-adjusted version of the diffusion model is of the form \( f(t) \cdot \exp(\lambda t) \), where \( f(t) \) is the cumulative adoption curve of IT expenditures of a given nation and \( \lambda \) is the price-effect.

Among the S-curve models, the logistic model turns out as the most used one in the literature (Mahajan and Peterson, 1985). We selected this one over others. The price-adjusted S-curve model considered is a price-adjusted logistic model. Non-S curve models are linear and exponential. The measure of goodness of fit used is \( R^2 \). The fit statistics of all models

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except model (3) are obtained directly from non-linear least square regression. Model (3) is evaluated directly from ordinary least square regression.

The formulations of various models are given below:

(1) Logistic model: Pure S-curve

\[
\frac{1}{IT\text{-Expenditure}(t)} = (K + A \cdot B^t)
\]

Parameters to be estimated: \(A(>0), B\) \((0<B<1)\) and \(K(>0)\). Saturation limit of adoption: \(1/K\).

(2) Price-adjusted logistic model

\[
\frac{1}{IT\text{-Expenditure}(t)} = (K + A \cdot B^t) \cdot \exp(\lambda \cdot \text{time}).
\]

Parameters to be estimated: Same as (1) and \(\lambda(>0)\). \(\lambda\) denotes the price effect.

(3) Linear model:

\[
[IT\text{-Expenditure}(t)] = A + B \cdot t
\]

Parameters to be estimated: A and B.

(4) Exponential model:

\[
[IT\text{-Expenditure}(t)] = b_0 \cdot (e^{b_1 \cdot t}) \text{ or } \ln([IT\text{-Expenditure}(t)]) = \ln(b_0) + (b_1 \cdot t)
\]

Parameters to be estimated: \(b_0\) and \(b_1\).

5.2 Data

To conduct the analysis, we used data obtained from the World Bank WDI data base (World Bank, 2003). The IT expenditure numbers are measured as information and communication technology expenditure per capita in U.S. dollars. The years considered in calculating the growth rate are 1992-1999. The dollar value is adjusted using the 1996 value as the deflator. The data from 1994 and 1995 are used for IT infrastructure measure, as the years are in the middle range and most nations have available data for these years. IT infrastructure index is calculated based on average adoption figures of four types of information technology, measured as per 1000 population (PC, telephone, cell phone and the Internet) for years 1994 and 1995. A principal component analysis was done which extracted a factor from these four technology components. The factor extracted more than 90% from each component. The data from the year 2000 are reserved for forecasting purposes only. A comparison of IT expenditures across various nations requires data from various nations and raises several issues such as how the data were collected, how the calculation of IT spending is done in various nations. A reliable secondary data source such as the World Bank (as used in this study) may alleviate some of these concerns. It may be mentioned that the World Bank data is routinely used in macroeconomic and other studies.

We define developing nations as the set of those nations classified by the World Bank as low income ($765 or less) and lower middle income ($766-$3,035) nations based on 2003 GNI per capita (World Bank, 2003). Altogether 14 nations as shown in Table 1 qualify as developing nations, with data available for analysis. The names of all 49 nations (including developed ones) for which data are available are shown below:

Argentina, Australia, Austria, Belgium, Brazil, Bulgaria, Canada, Chile, China, Colombia, Czech Republic, Denmark, Egypt, Finland, France, Germany, Greece, Hong Kong, Hungary, Iceland, India, Indonesia, Ireland, Italy, Japan, S. Korea, Malaysia, Mexico, Netherlands, New Zealand, Norway, Philippines, Poland, Portugal, Romania, Russian Federation, Singapore, Slovak Republic, Slovenia, S. Africa, Spain, Sweden, Switzerland, Thailand, Turkey, United Kingdom, United States, Venezuela, Vietnam.

The set of all nations is used to test research question 2.
6 RESULTS
The results corresponding to research question 1 are depicted in Tables 1-3. The $R^2$ values from all models are usually very high, indicating a good fit of the model. The $R^2$ values are best for the price-adjusted logistic model (Table 1). For the price-adjusted logistic model, $\lambda$ values (representing the price-effect) are significant for all nations, thus showing a very good and statistically relevant fit. All other coefficients are also significant in this model. Other models, without price adjustments, as shown in Table 2 (exponential, linear and pure logistic (which is an S-curve model)) also show good fits; however, these models provide worse fits when compared to the price-adjusted logistic model. Table 3 summarizes the results and ranks the models in terms of values of $R^2$. The sum of absolute errors was also least for the price-adjusted model for all nations.

<table>
<thead>
<tr>
<th>Country Name</th>
<th>$R^2$</th>
<th>K</th>
<th>A</th>
<th>B</th>
<th>$\lambda$</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRAZIL</td>
<td>0.99</td>
<td>0.0078</td>
<td>0.0339</td>
<td>0.1826</td>
<td>0.2990</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>1.00</td>
<td>0.0156</td>
<td>0.0787</td>
<td>0.3482</td>
<td>0.1892</td>
</tr>
<tr>
<td>CHINA</td>
<td>0.99</td>
<td>0.0933</td>
<td>0.3112</td>
<td>0.3272</td>
<td>0.3455</td>
</tr>
<tr>
<td>COLUMBIA</td>
<td>1.00</td>
<td>0.0108</td>
<td>0.0360</td>
<td>0.2378</td>
<td>0.3024</td>
</tr>
<tr>
<td>EGYPT</td>
<td>0.99</td>
<td>0.0355</td>
<td>0.1435</td>
<td>0.3118</td>
<td>0.2299</td>
</tr>
<tr>
<td>INDIA</td>
<td>0.99</td>
<td>0.4152</td>
<td>0.0918</td>
<td>2.7688</td>
<td>1.2448</td>
</tr>
<tr>
<td>INDONESIA</td>
<td>0.99</td>
<td>0.0193</td>
<td>0.1594</td>
<td>0.3955</td>
<td>0.1311</td>
</tr>
<tr>
<td>PHILIPPINES</td>
<td>0.99</td>
<td>0.1039</td>
<td>0.0214</td>
<td>2.6000</td>
<td>1.1551</td>
</tr>
<tr>
<td>RUMANIA</td>
<td>1.00</td>
<td>0.0442</td>
<td>0.1809</td>
<td>0.3174</td>
<td>0.2329</td>
</tr>
<tr>
<td>RUSSIA</td>
<td>0.99</td>
<td>0.0085</td>
<td>0.0469</td>
<td>0.3237</td>
<td>0.1576</td>
</tr>
<tr>
<td>S. AFRICA</td>
<td>0.99</td>
<td>0.0026</td>
<td>0.0125</td>
<td>0.3445</td>
<td>0.1897</td>
</tr>
<tr>
<td>THAILAND</td>
<td>0.99</td>
<td>0.0061</td>
<td>0.0333</td>
<td>0.3923</td>
<td>0.1536</td>
</tr>
<tr>
<td>TURKEY</td>
<td>0.99</td>
<td>0.0092</td>
<td>0.0460</td>
<td>0.1453</td>
<td>0.2140</td>
</tr>
<tr>
<td>VIETNAM</td>
<td>0.99</td>
<td>0.1712</td>
<td>0.7679</td>
<td>0.3383</td>
<td>0.3673</td>
</tr>
</tbody>
</table>

Table 1. Results from Price-adjusted Logistic Model (t-values are in parenthesis)
Forecasting errors from the price-adjusted models ranged from 9-24% for a sample of nations for a one-year period. For longer forecasts, the error rates will probably be higher. This answers research question 1 in the negative: the price-adjusted model is better suited for explaining IT expenditure growth.

<table>
<thead>
<tr>
<th>Country Name</th>
<th>Exponential $R^2$</th>
<th>Logistic $R^2$</th>
<th>Linear $R^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>BRAZIL</td>
<td>0.966</td>
<td>0.9919</td>
<td>0.968</td>
</tr>
<tr>
<td>BULGARIA</td>
<td>0.9316</td>
<td>0.9953</td>
<td>0.9935</td>
</tr>
<tr>
<td>CHINA</td>
<td>0.9684</td>
<td>0.9967</td>
<td>0.9519</td>
</tr>
<tr>
<td>COLUMBIA</td>
<td>0.9725</td>
<td>0.9935</td>
<td>0.9588</td>
</tr>
<tr>
<td>EGYPT</td>
<td>0.8936</td>
<td>0.9947</td>
<td>0.9883</td>
</tr>
<tr>
<td>INDIA</td>
<td>0.9679</td>
<td>0.9962</td>
<td>0.9737</td>
</tr>
<tr>
<td>INDONESIA</td>
<td>0.9588</td>
<td>0.9985</td>
<td>0.9887</td>
</tr>
<tr>
<td>PHILIPPINES</td>
<td>0.9655</td>
<td>0.9971</td>
<td>0.9964</td>
</tr>
<tr>
<td>RUMANIA</td>
<td>0.9623</td>
<td>0.9946</td>
<td>0.9755</td>
</tr>
<tr>
<td>RUSSIA</td>
<td>0.9347</td>
<td>0.9953</td>
<td>0.9992</td>
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<td>S. AFRICA</td>
<td>0.9535</td>
<td>0.9959</td>
<td>0.9984</td>
</tr>
<tr>
<td>THAILAND</td>
<td>0.9533</td>
<td>0.9974</td>
<td>0.9961</td>
</tr>
<tr>
<td>TURKEY</td>
<td>0.957</td>
<td>0.9846</td>
<td>0.9739</td>
</tr>
<tr>
<td>VIETNAM</td>
<td>0.9878</td>
<td>0.9974</td>
<td>0.956</td>
</tr>
</tbody>
</table>

Table 2. Results from Linear, Exponential and Logistic Models

Table 3. Ranking of Models in Terms of Fit

<table>
<thead>
<tr>
<th>Models</th>
<th>No. of countries</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Rank1</td>
</tr>
<tr>
<td>Price-adjusted</td>
<td>14</td>
</tr>
<tr>
<td>Pure S-curve (logistic)</td>
<td>0</td>
</tr>
<tr>
<td>Exponential</td>
<td>0</td>
</tr>
<tr>
<td>Linear</td>
<td>0</td>
</tr>
</tbody>
</table>
Figure 1. The Linear Fit for Developing Nations

For answering research question 2, we used a correlation analysis to see if there exists a significant relation between the IT expenditure growth rate ($\lambda$) of various nations for the years 1992-1997 with IT infrastructure index (based on availability of data). It was observed that the lower the level of IT infrastructure, the higher was the price effect on IT expenditure growth rate, $\lambda$ (Pearson’s correlation coefficient = -0.284, N=49, significant at 0.05 level), i.e., developing nations (those with low IT infrastructure) are benefiting from a price drop in IT as reflected in their high IT expenditure growth rates ($\lambda$). Considering the set of developing nations only, we also observe the same relationship between IT expenditure growth rate ($\lambda$) of developing nations for the years 1992-1997 with IT infrastructure index as significant (Pearson’s correlation coefficient = -0.498, N=13, significant at 0.08 level). This means that everything else being the same, developing nations will grow their IT investments at higher rates (Barro and Sala-i-Martin, 1998).

The linear fit for developing nations is shown in Figure 1. The x-axis is the IT infrastructure index. The y-axis variables are $\lambda$ (lambda) and its linear fit (Plambda) obtained from the linear regression model: $\lambda = $ IT infrastructure index + constant. Note that dependent variable values are negative, as these are factor values of developing nations. This provided a tentative positive answer to research question 2.

7. CONCLUSION

We examined IT expenditure growth, using a global perspective. This preliminary study shows that pure S-curves are not adequate to model the IT expenditure growth rate of various developing nations. Price has an impact on IT expenditure growth of all nations and is associated with increased growth, independent of diffusion effects. This validates the results obtained earlier by Gurbaxani and Mendelson (1990) for the IS expenditures of the U.S. The
results show that price-adjusted growth curves are well suited for explaining the growth of IT expenditures of various developing nations. The results do not lend credence to pure stage models of IS expenditures of a nation.

It was also observed that developing nations (those with low IT infrastructure) are benefiting from a price drop in IT as reflected in their high IT expenditure growth. What does this tell us? Without the price drop effect, many nations would have slowed down their IT expenditures. However, price drops have helped all nations to increase deployment of IT, as IT expenditures show. Emerging economies can thus potentially gain from more IT deployment. The price drop may benefit the national economy, firms and the individual consumers. Several advantages may result from such a price-drop: it can boost productivity, economic growth and competitiveness (Stiroh, 2001). It can even promote equity and reduce poverty in a nation. The results show that globally, IT expenditures may continue unabated, aided by a continuing drop in IT prices.

There are several limitations to the study. Although the price-adjusted model is a powerful tool that can analyze how the IT expenditures have grown over time, we did not perform rigorous forecasting with this model. Future research may consider several other price-adjusted models and standard forecasting models. Future research may also explore the possibility of a comparison of a price impact between developing and developed nations.

8. REFERENCES


9. ACKNOWLEDGEMENTS
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