Overview. Managers rely on prior beliefs and expectations to make decisions. Typically, IT investment decisions are made by weighing the potential benefits and actual costs of the investment. Hence, establishing an objective understanding of the potential value of such investments is crucial to ensure an effective investment decision making process. The potential benefits of IT investments, however, do not always translate directly to the actual payoffs of investments due to a variety of intervening factors in the value creation process. As such, there often is a gap between potential and realized value of IT investments which needs to be defined and measured (Davern and Kauffman 2000). Most studies in the value of IT literature focus on measuring the realized value of IT investments. Few have explored the issue of the potential value of IT. Moreover, none has developed objective measures for potential value based on explicit statements of theory. As a result, there are a number of modeling and statistical challenges that need to be overcome before we can offer better managerial guidance.

We explore the methodological tools available to measure potential and realized value of e-commerce-related IT investments and address the gap between the potential and realized value by developing a measurement model grounded in production economics. We adopt the Malmquist productivity index to model the potential and realized value of IT and apply data envelopment analysis (DEA) techniques to solve the model. Using this model, we examine the gap between potential and realized value of IT investments in industries within the United States. We also examine the impact of within-industry competition based on the potential and realized value of IT investments.

Analysis Methodology Development. To model the effects of potential and realized value of IT investments, we will conceptualize the creation of IT value as a piece-wise linear production technology where each economic unit, represented by a combination of input and output values, forms the possible technology set. Relying on the axioms of production theory, the production function yields the linear trace of input-output boundary values, which is called the production frontier.

The production frontier represents the upper bound of output for any given mix of input in the production process, and all possible combination of input and output mixes must exist on or below this frontier. Both the potential and realized value of an IT investment can be represented and measured using this non-parametric economic production representation. This representation of the production technology models the frontier to delineate the potential value of the IT investment. The observed output values from the production process map to the realized IT value.

Under this production representation, we modify the Malmquist productivity index (Caves et al. 1982) to model the changes in potential and realized value of IT over time. We mathematically show that overall change in IT efficiency over two time periods, \( M \), depends on two factors: (1) the change in potential value and (2) the ability to realize potential value – both over the same time period. This is expressed in terms of a production mapping, \( D \):

\[
M(x^{t+1}, y^{t+1}, x^t, y^t) = \left( \frac{D^r(x^{t+1}, y^{t+1})}{D^r(x^t, y^t)} \right)^{1/2} \times \frac{D^r(x^{t+1}, y^{t+1})}{D^r(x^t, y^t)}
\]

\[
\Delta \text{ Overall Efficiency} = \frac{\Delta \text{ Potential Value}}{\Delta \text{ Realized Value}}
\]

We apply this model to examine the characteristics of gap between potential and realized value across industries and over time. We also examine the impact of intra-industry firm competition on the potential and realized value of IT investments. We formulated a number of hypotheses based on theoretical knowledge related to IT value conversion effects and industry competition.

Data and Variables. We apply our model on U.S. Bureau of Economic Analysis (BEA) industry-level data from 1992 and 1997 to examine the effects of industry competition on potential and realized IT value. All industries (6-digit codes) that invested in IT are included. Using IT capital, non-IT capital and labor costs as inputs for the production process and gross GDP as the output, we computed the value indices for all represented industries. We used the widely-accepted 4-firm concentration ratio (4FCR) as our industry competitiveness measure (ICM). Based on 1992 ICMs, we separated industries into high/low competition categories. Industries with 4FCRs > 40% are...
highly-competitive; those with $4FCRs < 40\%$ are less-competitive. We use a 40\% cutoff in similar studies; the long-run average of the concentration ratio for all industries in the United States.

**Statistical Challenges.** Although DEA is a fairly well developed technique, there exist some statistical challenges that remain to be addressed. From our work, we identify three challenges. First, there is a need to further explore the techniques available for performing hypothesis testing relating to the shifts in the frontier across time. The Malmquist indices provide only deterministic scores to measure the shift (Fare et al. 1994), resulting in difficulties in testing for statistical significance in frontier movement. Second, unlike econometrics, the technical aspects of endogeneity are not well addressed in DEA techniques. There are no known procedures to test and detect endogeneity in DEA and development in this area is widely called for. Finally, heterogeneity across the utilization of IT suggests inherent differences in distribution of decision making units (DMUs) under the frontier. More work should be done to explore the statistical tools available to examine different sections of the frontier, and understand the possible co-movement of these units around the frontier across time.

**Empirical Estimation and Robustness Testing.** Our measurement model is solved using data envelopment analysis (DEA) techniques (Banker 1993). We test the consistency of the estimation by using statistical procedures developed by Banker and Chang (1995) which involves comparative testing between iterative estimates under different returns-to-scale assumptions. To test our hypotheses, we computed odds ratios for three indices—change in overall efficiency, $\Delta$ realized value and $\Delta$ potential value—based on high/low competition groups. We also used the non-parametric Fisher's exact test to test if there is a non-random relationship between the competition categories and the different value returns measures. This distribution-free test ensures that our results are generalizable to other distributional assumptions made with the DEA analysis. From the tests we found that: (1) Less than half of the industries that we examined realized more than 70\% of their potential value. Over time though, the industries have improved their capacity to realize potential value. (2) Firms in industries that face high levels of competition invest in IT assets that have higher potential value. (3) Industries experiencing low levels of competition in their industries invest in IT assets that have lower potential value. (4) Despite having IT investments with higher potential value, highly competitive industries are less likely to realize potential value compared to industries in less competitive environments. (5) Finally, we find that industry competitiveness does not impact overall IT efficiency gains over time due to countervailing effects.

**Conclusion and Application in E-Commerce Context.** In this study, we have operationalized the constructs of value potential and realized value for use in an industry-level evaluative model, a non-parametric economic measure that builds on the Malmquist productivity index. Using data from the BEA, we found that a gap between potential and realized value exists. We also show that industry competitiveness has a positive impact on the growth of potential value of IT investments. But it has a negative impact on the realized value. E-commerce initiatives entail the investment of substantial IT projects which are crucial for business success. In the dynamic environment of e-commerce, IT investment decisions have to be made promptly. Without an objective measure of the potential value of these investments, investment decisions are often made based on heuristics and subjective judgment that lead to inferior investment choices as seen in the late 1990s. Our proposed measurement tool serves to provide an objective assessment for IT investments to render better decision making processes in e-commerce investments.

**References**


