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MULTINATIONAL DIFFUSION THEORY:
A MACRO LEVEL ANALYSIS

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ELIF SONMEZ

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Major Professor's Signature

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MULTINATIONAL DIFFUSION THEORY:
A MACRO LEVEL ANALYSIS

By

Elif Sonmez

A DISSERTATION

Submitted to
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ABSTRACT

MULTINATIONAL DIFFUSION THEORY: A MACRO LEVEL ANALYSIS

By

Elif Sonmez

Multinational diffusion of innovations is an increasingly important topic from both theoretical and managerial perspectives. From the theoretical perspective, a limited number of studies have focused on multinational diffusion of innovations, and these mostly concentrated on developed rather than developing countries. From the managerial perspective, as firms become more involved in global business, understanding how innovations are accepted in new markets becomes imperative. The purpose in this dissertation is to examine the impact of macro level globalization drivers (trade volume, foreign direct investment and income) on the diffusion of consumer durable products in both developed and developing countries. The model is based on the Generalized Bass Model, where the covariates are the globalization drives. Data for four consumer durable products (compact disc player, home computer, mobile phone and video camera) in twenty-two developed and twenty-one developing countries are analyzed using the Augmented Kalman Filter with Continuous State and Discrete Observations methodology. The results suggest that the macro level globalization drivers effect the diffusion of innovations process in a similar manner in developed and developing countries. Yet, significantly different diffusion parameters in developed and developing countries suggest that the diffusion patterns in developed and developing countries are not similar. It should also be noted that diffusion of innovations happens faster in both developed and developing countries due to increasing coefficient of innovation over time.

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CHAPTER 1

INTRODUCTION

Diffusion of new products research has advanced a great deal in the recent decades. Researchers have succeeded in shedding light on what shapes and influences within-country diffusion patterns. Issues regarding multinational (cross-country) diffusion of new products, however, have received limited attention. Due to recent economic trends such as the removal of political and trade barriers, increased foreign competition, and saturated home markets, firms have increasingly been seeking to establish global presence and compete effectively in the global marketplace. With rapid globalization of the world economy, cross-country diffusion has become a central issue for firms launching new products in foreign countries.

The crucial role of new products for a firm's viability as well as its competitive performance is well documented in the literature (e.g., Day and Wensley 1988). Firms must create and sustain competitive advantage (Porter 1985). The ability to develop and launch new products successfully is a major determinant of a firm's competitive advantage. Such firms are more likely to increase their market shares and profits. To ensure success in introducing their products in foreign markets, firms need a solid understanding of their target markets. Part of this understanding comes from the knowledge of how their products diffuse in different countries, and why there are similarities or differences in the diffusion process between countries.

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Although countries differ from each other significantly, there is still considerable/increasing convergence in the markets due to globalization in the recent decades (Levitt 1983, and Ohmae 1985). The world economy has been moving toward a global system in which national economies are increasingly becoming interdependent. The decline trends in trade and investment barriers are among the main drivers of this globalization process. After the experience of the Great Depression of the 1930s, the post World War II era is characterized by the commitment of the advanced industrial nations to removing barriers to free flow of goods, services, and capital between nations. As a result of the rounds of negotiations under the umbrella of GATT (General Agreement on Tariffs and Trade) and the WTO (World Trade Organization), there have been progressive reductions in trade barriers such as tariffs. Average tariff rates on manufactured products in countries such as France, Germany, Italy, United Kingdom, and United States declined from 15-25 percent in 1950 to 5-6 percent in 1990 and further down to 3.9 percent in 2000. Many countries have also been progressively removing restrictions to foreign direct investment (FDI). For example, between 1991 and 1999, more than one hundred countries made 1,035 changes in legislation governing FDI, and ninety-four percent of these changes involved liberalizing foreign investment regulations to make it easier for foreign companies to enter their markets (United Nations, World Investment Report 2000).

Declines in trade and investment barriers facilitate globalization of markets where the consumer characteristics such as tastes and preferences have been converging. One reflection of the globalization of markets can naturally be expected on the diffusion rates of new products in

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of new products in different markets. The convergence of market trends in terms of diffusion rates has been examined by Ganesh (1998) in the context of the European Union. This study empirically examined EU convergence/divergence trends and their implications for international marketing through time-series analysis of the diffusion patterns of consumer durable goods in individual EU countries. In fact, the objective of the Ganesh (1998) study was to reconcile the conflicting results of the Craig, Douglas, and Grein (1992) and Leeflang and van Raaij (1995) studies that examined the macro level trends in several developed countries.

Craig, Douglas and Grein (1992) examined similarities in the macro level characteristics of eighteen developed countries (sixteen European countries, United States and Japan) from 1960 to 1988 to assess the effect of these characteristics on the evolution of these countries over time. The macro level variables included in the analysis were infant mortality, men's life expectancy, cost of living, real per capita income, inhabitants per physician, population density, electrical production, rail passengers per kilometer, passenger motor vehicles, aviation passengers per kilometer, telephones in use, student population, book production, daily newspaper circulation, and radios in use. They concluded that, contrary to their initial hypotheses, countries are becoming more divergent.

Leeflang and van Raaij's (1995) study is a meta-analysis of several studies published in International Journal of Research in Marketing on changing consumer behavior (consumption patterns, credit usage, time allocation, information processing etc.) in

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Europe. The macro level variables examined in these studies were economic environment (income, unemployment, inflation etc.), social/demographic environment (population, age and sex distribution, household size and composition, degree of urbanization etc.), and cultural environment (education, liberalization, health consciousness, ecological awareness, materialism etc.). Leeflang and van Raaij (1995) compared the main findings of the individual studies and concluded that, despite interesting and often substantial divergence, the EU nations are converging toward a similar macromarketing environment.

Ganesh (1998) aimed at resolving the contradictory findings of these two previous studies regarding macro level convergence in the EU by examining variations in the diffusion parameters over time. He used sales data for ten products. Five of these products (car radios, lawn mowers, color televisions, deep freezers, dishwashers) were introduced before 1970; the other five products (VCRs, microwave ovens, home computers, cellular phones, and CD players) were introduced after 1970. 1970 was chosen as the midpoint of the unification process in Europe, which expanded from May 1950 to January 1993.

Ganesh (1998) hypothesized that "convergence of macroenvironmental variables (economic, sociocultural, and demographic) among EU member nations will reflect in a relatively similar pattern of innovation diffusion among those countries" and "will accelerate innovation diffusion rates in those countries" (p.37). The examination of various comparisons of diffusion parameters for pre- and post-1970 data showed support for the first hypothesis while no support was found for faster diffusion rates in the EU ountries due to unif

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countries due to unification. This unexpected result regarding the speed of diffusion in EU countries was attributed to the increased perceived risk associated with buying a new product immediately after introduction due to high inflation and high unemployment rates in Europe in the early1980s, and recession in the early 1990s. Ganesh (1998) noted that as the economy improved and consumer confidence increased, the diffusion rates in Europe would be faster as already evidenced by the penetration of more recent innovations such as cellular phones and CD players. This argument is in line with the results of an earlier study by Mahajan and Muller (1994). They simulated the effect of unification in Europe on new product diffusion and concluded that an integrated European market would result in faster penetration of new ideas, products and technologies.

The unification of Europe is certainly a component of the globalization trend that has been continuing increasingly in the recent decades. Mahajan and Muller (1994) and Ganesh (1998) have provided valuable insight for understanding how globalization trend may impact the diffusion of new products in a multinational setting. However, these studies have not explicitly examined the impact of specific drivers of globalization on the diffusion processes in various countries. The phenomenon of globalization drivers has been identified by Yip (1992). There are four groups of globalization drivers that cover all the critical industry conditions affecting the potential for globalization, and the need for competing with a global strategy. These are market globalization drivers, cost globalization drivers, government globalization drivers, and competitive globalization drivers. *Market globalization drivers* include common customer needs, global customers, channels. tra

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global channels, transferable marketing strategies, and existence of lead countries in terms of innovativeness, which require participation in these markets for exposure to latest innovations. *Cost globalization drivers* include global economies of scale and scope, steep experience curve effect, sourcing efficiencies, favorable logistics, differences in country costs including exchange rates, high product development costs, and fast changing technology. *Government globalization drivers* include favorable trade policies including trade incentives, compatible technical standards, common marketing regulations, government-owned competitors and customers, and host government concerns related to tax issues, weakening of national decision centers etc. Finally, *competitive globalization drivers* include high exports and imports, competitors from different continents, interdependence of countries due to sharing of business activities, and globalized competitors. Some of the recent trends in the globalization drivers include convergence in per capita income among industrialized nations, convergence of lifestyle and tastes, accelerating technological innovations, increasing cost of product development relative to market life, reduction of tariff and non-tariff barriers, shift to open market economies from closed communist systems in eastern Europe and the former Soviet Union, continuing increase in the level of world trade (Yip 2002)

In this dissertation the main objective is to analyze the diffusion process of new products by incorporating certain macro level globalization drivers, specifically, foreign direct investment inflows, trade volume, and income (GDP) into the model. These most crucial components of the globalization phenomenon are easily observed macroeconomic phenomena that managers can monitor. The declines in trade and investment barriers are among the main fact

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among the main factors that contribute the integration of economies across the globe (Yip 1992). Further, these globalization drivers are closely related to the economic and social well being of the countries. The openness of an economy due to market deregulation, and thus, increased international trade, and foreign direct investments lead to greater market efficiency with larger and more variety of products to consumers. It is expected that the globalization phenomenon reflected as increases in income levels and the foreign direct investment inflows as well as the overall trade volume have resulted in convergence of as well as faster diffusion rates (higher coefficients of external influence and coefficients of internal influence) for new products in developed and developing countries.

The approach in this dissertation will allow quantifying the impact of specific globalization drivers on the diffusion parameters (coefficient of innovation and coefficient of imitation). This will also enable assessing whether the countries that exhibit similar characteristics in terms of globalization drivers are also similar in diffusion patterns. If they do, this may have significant impact on the global marketing strategies of the firms. For example, if any two countries have similar diffusion patterns for the same product (class), and if the firm has experience with the product in either country, the manager may successfully predict the market size as well as the time and magnitude of the peak sales for the product in the other market. If, on the other hand, countries with similar characteristics of globalization drivers do not have similar diffusion patterns, the contribution in the knowledge base in terms of which globalization driver impacts the fusion parameters

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Firms that seek to establish or continue to have presence in the global business arena need to engage in the dynamic evolutionary process of global strategy making (Douglas and Craig 1995). Initial market entry and expansion are among the most critical aspects of this process. International entry decisions include the identification and selection of potential markets along with the timing and order of entry (Ayal and Zif 1979).

Decisions regarding identification and selection of markets have traditionally been based on macro level market characteristics such as market size, growth rate, attractiveness based on perceived risks (e.g., Cavusgil 1985). Timing of entry studies (e.g., Davidson and Harrigan 1977, Kalish, Mahajan, and Muller 1995), on the other hand, suggest that firms can adopt either the sprinkler strategy, or the waterfall strategy when entering international markets. In the sprinkler strategy, firms adopt a simultaneous approach in which they enter multiple foreign markets at the same time. Firms that adopt the waterfall strategy enter initially one or more lead markets, and subsequently expand to other foreign markets in a sequential manner.

Managers of multinational firms are faced with critical questions regarding the choice of the entry strategy. Should the firm adopt the sprinkler strategy or the waterfall strategy? If the firm adopts the waterfall strategy, which foreign markets should it enter first? What is the global market potential for a given new product? What should the order of expansion to oth

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expansion to other foreign markets be for the realization of the market potential? These strategic issues facing the international managers can be addressed from the perspective of multinational diffusion of new products. More specifically, to capitalize effectively on the opportunities presented by globalization, managers need to fully comprehend the impact of globalization on market trends such as the diffusion of new products. Convergence in the diffusion rates of new products due to the impact of globalization drivers would not only mean the possibility of using a standardized global approach through global brands and marketing strategies but also have implications for the timing and order of entry in the global markets. Similarities in diffusion rates of new products among different countries may suggest that firms adopt a sprinkler approach (Kalish, Mahajan, and Muller 1995), whereas dissimilarities in diffusion rates would suggest a more prudent waterfall strategy.

The development and application of the quantitative diffusion model in this dissertation will provide guidance in new product planning and decision-making. Quantitative diffusion models specify mathematical relationships between quantifiable variables and include parameters that allow the model to be customized for a specific application. The focus will be on aggregate diffusion models representing the market penetration of new products. It is aimed that the model results generate actionable information by a decision maker/policy maker. In this respect, the models may be used to describe the rate of diffusion and to provide a better understanding of the drivers of adoption, to predict the future penetration trajectory so that growth may be planned for, and to control the future penetration trajectory to provide inputs for strategy making decisions. The foundation of the model is the basic

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the model is the basic framework of the Bass (1969) model (Bass model will be described in Chapter 2 in detail). The concentration will be on the dynamics of the macro (market) level diffusion process of new products in a multinational setting.

Data and Sources of Data

In the literature on multinational diffusion of new products, certain issues regarding data are brought up by researchers repeatedly. These issues (see for example, Heeler and Hustad 1980, Gatignon, Eliashberg, and Robertson 1989, Takada and Jain 1991, Helsen, Jedidi, and Desarbo 1993, Putsis, Balasubramanian, Kaplan, and Sen 1997, Van de Bulte and Lilien 1997, Xie et al. 1997, Putsis et al. 1997, Kumar, Ganesh, and Echambadi 1998, Talukdar, Sudhir, and Ainslie 2002) can be summarized as follows:

1) The performance of an estimation procedure is determined not only by its formulation and algorithm but also by its data sources.

2) The number of the products and countries in the multinational diffusion studies are limited. More products and countries (particularly countries with drastic differences in cultures or level of development) should be included in future analyses.

3) The number of data points, that is, the length and/or frequency of time series data should be increased and observations from the tail end of the diffusion process should be included in the series.

4) More comprehensive set of covariates should be incorporated in the diffusion models.

The database to be used for this dissertation research aims at addressing these issues. Data for forty-three countries on annual sales or possession of goods, exports, mports. foreign dire

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imports, foreign direct investment inflows, and GDP are collected. The products included in this research are all consumer durables (Video camera, compact disc (CD) player, home computer, cellular phone). The main data sources are the Global Market Information Database, European Marketing Data and Statistics, and International Marketing Data and Statistics by Euromonitor. The list of countries is as follows: *Argentina*, Australia, Austria, Belgium, *Brazil*, Canada, *Chile*, *China*, Denmark, *Egypt*, Finland, France, Germany, Greece, *Hong Kong (China)*, *Hungary*, *India*, *Indonesia*, Ireland, Israel, Italy, Japan, *Malaysia*, *Mexico*, the Netherlands, New Zealand, Norway, *Pakistan*, Portugal, *Poland*, *Russia*, *Singapore*, *South Africa*, *South Korea*, Spain, Sweden, Switzerland, *Taiwan*, *Thailand*, *Tunisia*, *Turkey*, the United Kingdom, the United States of America (the countries written in *italic* are the developing countries).

It is worth noting two issues here:

1. Only four consumer durables are included because these are the products that are consistently available across the forty-three countries in the study.
2. Twenty-one out of the forty-three countries are developing countries while the rest are the developed countries. This will enable us to examine the differences in the diffusion parameters between developed and developing countries in addition to the analysis of the diffusion of new products phenomenon in each country.

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Estimation Methodology

The methodology to be used in this dissertation is the Augmented Kalman Filter with Continuous State and Discrete Observations (AKF(C-D)) methodology developed by Xie et al. (1997). Although the details of this methodology and model development are to be addressed in Chapter 2 and Chapter 3, respectively, there are certain issues that can be settled right away in the light of the advantages of the AKF(C-D) procedure and the characteristics of the data set.

The model will contain a differential diffusion model, theoretical underpinnings of which is the Bass model. The parameters will be estimated in a time-varying manner due to the characteristics of the AKF(C-D) methodology. The information regarding prior distribution of the parameters will be incorporated in the estimation procedure. Given the scope of the products and countries, it is expected that in some cases strong priors will be available, in others little information about priors will be known. Employing a Bayesian approach that can make use of already available information and also can update the estimates as new data comes in is also crucial for this reason.

The advantages of the AKF(C-D) methodology developed by Xie at al.(1997) include not only its superior predictive performance compared to other procedures but also other desirable characteristics. First, it is a general estimation approach that is not restricted by the model structure or by the nature of the unknown parameters. It can be applied directly to a differential diffusion model without requiring the diffusion model to be replaced by a discrete analog or requiring that the diffusion model have an analytical solution. It can be sed to estimate par

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used to estimate parameters changing over time (both deterministic and stochastic changes). Also, AKF(C-D) is a Bayesian estimation procedure. It can provide better forecasts from the early stages of the diffusion process by incorporating any information on the prior distributions of the parameters in the estimation process and updating the estimates adaptively. Third, AKF(C-D) is capable of estimating time-varying parameters with or without a prior knowledge of how the parameters change over time. Further, uncertainty about parameter estimates can be built into the estimation. Hence, the model is useful in situations where strong priors on the parameter estimates are present as well as in situations where little information is known about the parameter estimates.

The formulation of the AKF(C-D) model is as follows:

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\begin{aligned}
\frac{dx(t)}{d(t)} &= f_x[x(t), \phi(t), \beta, t] + w_x \\
\frac{d\beta}{dt} &= f_\beta[\beta, x(t), t] + w_\beta \qquad (1.1) \\
z_k &= x_k + v_k
\end{aligned}
$$

where $x(t)$ is the cumulative number of adopters, $\phi(t)$ is a vector of covariates (for example, marketing mix variables or globalization drivers), β is the unknown parameter vector, w_x and w_β are the process noise, x_k and z_k are the true and observed cumulative number of adopters at time t_k and v_k is the observation noise. It is assumed that $x(0) \sim (x_0, \sigma_{x0})$ and $\beta(0) \sim (\beta_0, P_{\beta 0})$, $\{w_x, w_\beta\}$ and $\{v_k\}$ are white noises. $\{w_x, w_\beta\} \sim$ (0,Q) and $\{v_k\} \sim$ (0, R), and $\{w_x, w_\beta\}$ and $\{v_k\}$ are not correlated to one another. The process noise, w_x, includes model specification errors (due to omitted

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$$z_k = x_k + v_k$$

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variables and/or misspecification), and sampling errors which can occur when using the model to describe the diffusion process of a sampled group instead of the entire population. The measurement error, v_k, includes random errors in the data collection.

Without loss of generality, an augmented state vector (y) that consists of the original state vector (x) and the unknown parameter vector (β) can be formed. Then the general AKF(C-D) model becomes:

$$\frac{dy(t)}{d(t)} = f_y\left[y(t), \phi(t), t\right] + w_y \qquad (1.2)$$
$$z_k = x_k + v_k$$

where $f_y = (f_x, f_\beta)^T$

The specific model to be used in the dissertation will be an extension of the Bass model where the augmented state vector (y) includes the cumulative adoption rate (x), the coefficient of innovation (p), the coefficient of imitation (q) and the number of potential adopters (m), and the vector of covariates ($\phi(t)$) includes the globalization drivers (FDI inflows, trade volume and GDP).

Contributions

There are two levels that this dissertation will contribute to the multinational diffusion theory. On the theoretical level, the covariates used will provide knowledge about how specific globalization drivers affect the diffusion of new products in various countries. The covariates used, specifically FDI inflows, trade volume and GDP are macroeconomic variables that hav

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variables that have direct impact on the well-being of a country's overall economic climate. Although Ganesh (1998) provided insights with his study on the impact of regional integration (European Union) on the convergence of diffusion rates in European countries, there are no studies that have investigated the exact quantitative effect of specific macroeconomic variables on diffusion rates.

Two issues add to the importance of the study at the theoretical level: Economic risk has to be evaluated when doing business globally, and FDI inflows, trade volume and GDP are very much part of the general economic picture in a country. Second, these macroeconomic variables are also among the main drivers of globalization (Yip 1992), and the globalization phenomenon and its impact on business have to be understood to the best extent for both theoretical and practical purposes. Quantifying the impact of specific globalization drivers on the diffusion parameters (coefficient of innovation and coefficient of imitation) will be a step in achieving these purposes. It will help assessing whether the countries that exhibit similar characteristics in terms of globalization drivers are also similar in diffusion patterns. The results are likely to have significant impact on the global marketing strategies of the firms, which brings forth the managerial contributions of this dissertation.

Global strategy making is a multifaceted task in which initial market entry and expansion (identification and selection of potential markets along with the timing and order of entry) are among the most critical aspects. If there is convergence in the diffusion rates of new products in different countries as hypothesized in this study, this would mean the possibility of using a

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possibility of using a standardized global approach through global brands and marketing strategies as well as have implications for the timing and order of entry in the global markets. Similarities in diffusion rates of new products among different countries may suggest that firms adopt a sprinkler approach (Kalish, Mahajan, and Muller 1995), whereas dissimilarities in diffusion rates would suggest a waterfall strategy.

Further, due to the methodology and the nature of the database that will be used in this dissertation, the estimated values for the diffusion parameters will be more reliable as well as the forecasts of future diffusion trajectories. These are significant contributions to multinational diffusion theory, since previous studies repeatedly called for more advanced techniques using more extensive data sets. Particularly better prediction of how diffusion will take place in the future provide a powerful tool for managers.

Plan of the Dissertation

The format of the dissertation manuscript is as follows: Chapter 1 is the Introduction chapter where the overview of the dissertation is given. Chapter 2 (Literature Review) contains the detailed review of the relevant diffusion literature. In Chapter 3 (Methodology), the details of the AKF (C-D) methodology and the model specification are described. Chapter 4 is Data and Analysis. Finally, the results of the data analysis are discussed in Ch.5 along with the theoretical and managerial contributions and the limitations of the dissertation.

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CHAPTER 2

LITERATURE REVIEW

New product diffusion has been the subject matter of many studies since early 1960s. Most of these studies center around the seminal work of Bass (1969). The Bass model is a good starting point for forecasting the long-term diffusion of new products when the firm has recently introduced the product and has observed the diffusion of for a few time periods, or the firm has not yet introduced the product but it is similar in some way to existing products whose diffusion history is known.

The framework originally proposed by Bass (1969) constitutes a single-equation model of first purchase with parameters that remain constant over time. The model can be stated as follows:

$$s(t) = \frac{dx(t)}{dt} = \left[p + \left\{q\frac{x(t)}{m}\right\}\right]\left[m - x(t)\right] = pm + \left[(q-p)x(t)\right] - \left[\left(\frac{q}{m}\right)x(t)^2\right] \qquad (2.1)$$

where $s(t)$ is the sales rate at time t, $x(t)$ is the cumulative number of adopters at time t (with $x(0) = 0$), and m is the maximum number of potential adopters. The parameter p is the coefficient of innovation or the coefficient of external influence. It reflects the tendency to adopt at time 0. Note that $s(0) = pm$. The parameter q is the coefficient of imitation or the coefficient of internal influence. It reflects word-of–mouth communication.

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$$\frac{f(t)}{1-F(t)} = p + qF(t)$$

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$$f(t) = \frac{\frac{(p+q)^2}{p}e^{-(p}}{1+\frac{q}{p}e^{-(p+}}$$

The point of inflection

penetration rate.

$$F(t^*) = \frac{1}{2} - \frac{p}{2q}$$

$$t^* = -\frac{1}{(p+q)}\ln\left(\frac{p}{q}\right)$$

$$f(t^*) = \frac{q}{4} + \frac{p}{2} + \frac{p^2}{4q}$$

Defining $f(t)$ as the density function describing the time of adoption for a population, and $F(t)$ as the cumulative density, the hazard function describing the probability of adoption at time t is given by

$$\frac{f(t)}{1-F(t)} = p + qF(t) \tag{2.2}$$

Assuming $F(0) = 0$,

$$F(t) = \left[\frac{1-e^{-(p+q)t}}{1+\frac{q}{p}e^{-(p+q)t}}\right] \tag{2.3}$$

Assuming that each adopter only buys one unit, the sales rate, $s(t) = mf(t)$, where $f(t)$ is given by

$$f(t) = \left[\frac{\frac{(p+q)^2}{p}e^{-(p+q)t}}{\left(1+\frac{q}{p}e^{-(p+q)t}\right)^2}\right] \tag{2.4}$$

The point of inflection in $F(t)$ occurs at time t^*, which corresponds to the maximum penetration rate.

$$F(t^*) = \frac{1}{2} - \frac{p}{2q} \tag{2.5}$$

$$t^* = -\left[\frac{1}{(p+q)}\right]\ln\left(\frac{p}{q}\right) \tag{2.6}$$

$$f(t^*) = \frac{q}{4} + \frac{p}{2} + \frac{p^2}{4q} \tag{2.7}$$

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Note that the Bass model is framed in terms of number of adopters (diffusion, penetration) and not number of units sold (sales). When adopters acquire multiple units of the product, or replace the existing units, diffusion and sales series may differ significantly.

The original Bass (1969) model has been the foundation model of almost all diffusion studies in the following years. It has been modified to include the effects of various covariates such as marketing mix variables or macro level country characteristics. One very influential extension of the original Bass (1969) model, for example, is the Generalized Bass Model. Bass, Krishnan, and Jain (1994) have proposed a generalized form of the Bass model that incorporates the effects of marketing mix variables on the likelihood of adoption of the new product. They added a multiplicative factor $Z(t)$ to the original model given by Equation (2.1):

$$s(t) = \frac{dx(t)}{dt} = \left[p + \left\{q\frac{x(t)}{m}\right\}\right][m - x(t)]Z(t) \tag{2.8}$$

where

$$Z(t) = 1 + \alpha\left[\frac{P(t) - P(t-1)}{P(t-1)}\right] + \beta \max\left\{0, \left[\frac{A(t) - A(t-1)}{A(t-1)}\right]\right\} \tag{2.9}$$

The percentage increase in diffusion speed due to a 1 percent decrease in price P(t) is captured by the coefficient α. The percentage increase in diffusion speed due to a 1 percent increase in advertising A(t) is captured by the coefficient β. Note that in this formulation diffusion speed is insensitive to cuts in advertising.

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Another extension, which can be made to both the original (Equation (2.1)) and the generalized Bass model (Equation (2.8)), is to allow the number of potential adopters (*m*) to change over time. The number of adopters in a market may change because the overall population increases or decreases. It is also possible that an improvement in the product's distribution infrastructure may make the product physically available to an increasing number of consumers. Further, the availability of complementary products may affect the number of potential adopters. If the potential population is related to the price of the product, the number of potential adopters can be expressed as:

$$m(t) = m(1)(1+r)^{t-1}\left[\frac{P(t)}{P(1)}\right]^{-\eta} \tag{2.10}$$

where $m(t)$ is the number of eventual adopters in period t, r is the market growth rate (apart from price effects), $P(t)$ is price in period t, and η is elasticity of the number of eventual adopters with respect to the innovation's price.

There are numerous other examples of the extensions and modifications of the original Bass (1969) model. Given the purpose of analyzing how globalization drivers (trade volume, FDI inflows, and GDP) impact the diffusion of new products, these studies are interesting from mainly a methodological point of view. Hence, further discussion of the manner covariates are incorporated in the Bass (1969) model is deferred until Chapter 3. In the remaining of this chapter, first a review of the multinational diffusion literature will be presented. Then, the methodological overview of the diffusion research with respect to the different techniques used to analyze the diffusion phenomena will be given.

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Key Studies in the Multinational Diffusion of New Products Literature

Despite the importance of understanding the dynamics of multinational diffusion of new products for international strategy making, very few empirical studies have been undertaken in this area. These (Gatignon, Eliashberg, and Robertson 1989, Takada and Jain 1991, Helsen, Jedidi, and Desarbo 1993, Ganesh, Kumar, and Subramaniam 1997, Putsis, Balasubramanian, Kaplan, and Sen 1997, Kumar, Ganesh, and Echambadi 1998, and Talukdar, Sudhir, and Ainslie 2002) are the key studies that have attempted to explain the difference in diffusion patterns across several countries. In all of these studies, the Bass model is the starting point of the models developed and estimated using various techniques. These key studies, focusing exclusively on consumer durable goods, have shown that the diffusion of a new product is a country/culture specific phenomenon and certain economic, social, and cultural factors are useful in explaining the cross-country differences in the diffusion patterns of new products.

It should be noted that there are other studies such as Heeler and Hustad (1980), and Lindberg (1982) that have assessed the Bass model in an international setting. These studies, however, focused on predicting future demand rather than analyzing the nature of the diffusion process in different countries. The Gatignon, Eliashberg, and Robertson 1989, Takada and Jain 1991, Helsen, Jedidi, and Desarbo 1993, Ganesh, Kumar, and Subramaniam 1997, Putsis, Balasubramanian, Kaplan, and Sen 1997, Kumar, Ganesh, and Echambadi 1998, and Talukdar, Sudhir, and Ainslie 2002 studies, on the other hand, exclusively aim at explaining the diffusion process of new products in a multinational setting. Hence, the knowledge base created by these studies will be the basic framework for this dissertation rese

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for this dissertation research. In the following subsections a summary/review of these key studies will be provided.

Gatignon, Eliashberg, and Robertson (1989)

Gatignon, Eliashberg, and Robertson (1989) is one of the early studies that provide an application of the diffusion paradigm in a global market setting. A statistically efficient methodology for analyzing and predicting multinational diffusion patterns is presented in this study. It allows for the estimation of the parameters of the diffusion model even in cases where these parameters cannot be estimated for separate product/country models. The complete set of diffusion parameters can be estimated due to the larger degrees of freedom resulting from pooling all observations for one product across all countries, and the constraints imposed concerning differences in diffusion parameters across countries. Consequently, this methodology enables the prediction of the diffusion rate of a product in a country before the product is introduced in that country, and the estimation of the diffusion parameters for countries where data are not readily available, which occurs commonly in international marketing research. Using their proposed methodology, Gatignon, Eliashberg, and Robertson (1989) modeled the heterogeneity among different countries in terms of their propensity to innovate and imitate within the diffusion process. The country characteristics they used to explain the diffusion pattern across countries were cosmopolitanism, mobility, and sex roles.

Cosmopolitanism refers to the degree that the individuals of a society are oriented beyond their immediate social system (Gouldner 1957). The relationship between cosmopolitanism and ten

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cosmopolitanism and tendency to innovate has been established in rural psychology (Rogers 1995), organizational behavior (Kimberly and Evanisko 1981), and consumer behavior/marketing (Robertson 1971). Gatignon, Eliashberg, and Robertson (1989) proposed "countries with a higher degree of cosmopolitanism show a greater propensity to innovate and a smaller propensity to imitate" (p.234). The second variable, *mobility* of the population, is a key underlying dimension of any spatial theory of diffusion (e.g., Hagerstrand 1953, Brown 1981), since the lack of mobility constitutes a barrier to interpersonal communication. Therefore, Gatignon, Eliashberg, and Robertson (1989) proposed "mobility will be positively associated with propensity to imitate, since it increases the opportunity for social interaction" (p.234). They did not have a proposition regarding the effect of mobility on propensity to innovate, as they appeared to be theoretically unrelated. The third variable Gatignon, Eliashberg, and Robertson (1989) used to model the heterogeneity across countries is related to the role of women in the society. They related the *sex roles* to the transmission of influence in terms of heterophily (information transfer across dissimilar individuals) within a social system, and proposed that "the percentage of women in the labor force is negatively related to the propensity to innovate for time-consuming innovations and positively related to the propensity to imitate when the work context provides a level of heterophilus influence" (p.235). Data regarding cosmopolitanism, mobility, and sex roles were cross-sectional.

The model developed by Gatignon, Eliashberg, and Robertson (1989) extended the single time series based model of Bass (1969) to multiple time series with a simultaneous estimation of the effects of the determinants of the diffusion parameters across countries.

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It is a discrete-time econometric data-generating model that consists of the discrete version of the Bass model (with notation that allows for simultaneous diffusion of an innovation in multiple countries), and the equations that link the diffusion parameters and the country characteristics (cosmopolitanism, mobility, and sex roles). The model is estimated employing a generalized least squares (GLS) estimation procedure on all three equations simultaneously. Data for consumer durables (dishwashers, deep freezers, lawnmowers, pocket calculators, car radios, and color televisions) for fourteen European countries (Austria, Belgium, Denmark, Finland, France, West Germany, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, United Kingdom) between 1965 and 1980 were used.

The results generally provided support for the importance of incorporating internal social communication factors in the diffusion model. Hence, a country's cosmopolitanism, mobility level, and sex roles account for systematic pattern differences in the diffusion of new consumer durables in an international context. One should view the general results of this study with caution though due to the limited number of products and countries analyzed. Further, the country characteristics used are not fully representative of the variety of development levels and cultures in the world. Gatignon, Eliashberg, and Robertson (1989) themselves called for possible modification of predictor variables as well as inclusion of countries with drastic differences in level of development or in cultures to refine the theory of multinational diffusion of new products.

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Takada and Jain (1991)

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Takada and Jain (1991)

Takada and Jain (1991) applied the Bass model to analyze the diffusion process of consumer durables in four Pacific Rim countries (United States, Japan, South Korea and Taiwan) that represent a variety in terms of socioeconomic and cultural characteristics. They developed hypotheses regarding country effect and time effect on the coefficient of imitation. They did not consider the coefficient of innovation since innovators are a very small segment in the market and their role in diffusing the innovation to other segments is very limited (Rogers 1995). The *country effect* refers to the uncontrollable factors (e.g., cultural, economic, geographic, legal, and political environments) that directly or indirectly affect the diffusion processes of new products in different countries. Based on Hall 1976, 1987) and Rogers (1995), Takada and Jain (1991) hypothesized that "the rate of adoption in countries characterized by high context culture and homophilous communication (such as Japan, South Korea, Taiwan, parenthesis added) is faster (higher value for the imitation coefficient, i.e., word-of-mouth effect) than that in countries characterized by low context culture and heterophilous communication (such as US, parenthesis added)" (p.50). The *time effect* refers to the lead and lag relationship of diffusion processes in different countries. According to Takada and Jain (1991) "the later a product is introduced in a market, the faster will be the rate of adoption. Consequently, the imitation coefficient will have a larger value for the country in which the product is introduced later than for the country in which the product is first introduced" (p.50). The framework for this argument is provided by Rogers (1995), which suggests that four perceived attributes of innovations accelerate their rate of adoption. These attributes are the relative advantag

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Takada and Jain (1991) estimated the coefficient of innovation, coefficient of imitation, and market potential by applying nonlinear least squares (NLS) estimation to the Jain and Rao (1990) formulation of the Bass model. Data consisted of sales data for black and white televisions, electric washing machines, room air conditioners, passenger cars, electric refrigerators, calculators, vacuum cleaners, and radios during different time periods for U.S., Japan, South Korea and Taiwan. In cases where sales data were not readily available, data were derived by subtracting the export unit sales and adding the import unit sales to unit production, which gives apparent consumption data. Takada and Jain (1989) found support for both of their hypotheses. Their empirical results suggested the positive influence of cultural/communication system, and time on the diffusion of new products in the four Pacific Rim countries.

Helsen, Jedidi, and DeSarbo (1993)

Helsen, Jedidi, and DeSarbo (1993) study is an attempt to understand the merits of country segmentation schemes based on multinational diffusion parameters. They analyzed the extent to which countries belonging to the same (different) grouping reveal similar (dissimilar) diffusion patterns. The research questions Helsen, Jedidi, and DeSarbo (1993) sought answer for were stated as follows (p.62):

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1. To what extent the country segments derived from traditional analyses of macro-level data correspond to segments derived from multinational, product-class specific diffusion parameters?

2. How well do variables that are typically used in macro-level country segmentation studies perform when used to profile diffusion-based country groups?

3. How stable are diffusion-based country segmentation schemes estimated across different innovations?

The methodology Helsen, Jedidi, and DeSarbo (1993) used to segment the set of countries on the basis of observed diffusion patterns is a latent class structure methodology for regression models (for applicability to the Bass model). It is a modification of the methodology developed by DeSarbo et al. (1992). This technique offered several advantages. First, short time series data were not a problem because the sales data was pooled across countries. Second, the country segments were derived without imposing any a priori segmentation scheme. Another benefit was that the country segments and parameter estimates were determined simultaneously. Also, the technique relied on statistical criteria to evaluate appropriate number of country segments. Finally, the method allowed each country to belong to fractionally more than one grouping.

Data consisted of annual sales data for color television sets, VCRs, and CD players for twelve countries (Austria, Belgium, Denmark, France, Finland, Japan, the Netherlands, Norway, Sweden, Switzerland, U.K. and U.S.). Twenty-three macro level variables grouped into six constructs (mobility, health, trade, lifestyle, cosmopolitanism, and miscellaneous) were

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miscellaneous) were also used to segment the same countries in addition to diffusion-based segmentation. The results of the study showed little agreement between the segment composition based on macro level variables and the segment composition based on diffusion parameters. Further, segmentation comparisons showed no stability of diffusion-based segments across new product introductions. These results suggest that traditional country segmentation schemes based on macro level socioeconomic, political, and/or cultural criteria may provide little guidance as to the success of specific new product introductions. Also, cross-country diffusion process differences are not explained well using these macro level characteristics. Finally, the same country may exhibit substantially different diffusion patterns for different new product introductions even if these products share similar characteristics just like in the Helsen, Jedidi, and DeSarbo (1993) study (all three products were consumer entertainment electronics).

Ganesh, Kumar, and Subramaniam (1997)

Ganesh, Kumar, and Subramaniam (1997) study investigates the existence of a systematic learning effect between pairs of lead and lag countries in the case of consumer durables. They proposed a theoretical framework that identifies the factors that influence the learning process, and empirically examine the relationship between these factors and the learning effect. The learning effect is defined as the phenomenon contributing to an accelerated diffusion of a product in the lag countries due to the success of the product in the lead country (Ganesh and Kumar 1996). It is critical to note that the learning effect examined in the Ganesh, Kumar, and Subramaniam (1997) study is not organizational learning, or changes to the marketing mix decisions based on prior experience in the lead market. Rather, it ref

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market. Rather, it refers to the behavioral response of potential adopters in the lag markets toward the new product based on their observation of the experiences of the adopters in the lead market.

Drawing from past research in international marketing, and multinational diffusion, Ganesh, Kumar, and Subramaniam (1997) identify six factors that potentially influence the learning process between a pair of lead and lag markets. These are geographical proximity, cultural similarity, economic similarity, time lag, type of innovation, and technical standard. *Geographical proximity* is measured as the distance between capital cities of the lag countries and the lead country. *Cultural similarity* is measured as a negative index of the sum of absolute differences in each of the four Hofstede (1980) dimensions between the corresponding lead and lag countries. The cultural dimensions Hofstede (1980) identifies are individualism, power distance, masculinity/femininity, and uncertainty avoidance. *Economic similarity* is measured as a negative index of the sum of absolute differences in the standardized values (due to differences in the unit of measurement) of GDP per capita, level of urbanization, and unemployment rate between the corresponding lead and lag countries. *Time lag* is measured as the difference in the years of introduction of the product between the lead and the lag countries. *Type of innovation* refers to whether the innovation is a continuous or a discontinuous one. And finally, *technical standard* refers to whether there were conflicting technologies when the product was first introduced in the marketplace (for example, VCRs) or not. Ganesh, Kumar, and Subramaniam (1997) hypothesized that the learning effect will be stronger if the lead and the lag countries are more similar geographically, culturally, and economically, the time

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economically, the time lag is longer, the innovation is a continuous innovation rather than a discontinuous one, and a technical standard for the product already exists.

The data used in this study includes annual sales of VCRs, microwave ovens, home computers, and cellular phones for sixteen (eleven in the case of cellular phones) European countries (Austria, Belgium, Denmark, Finland, France, Germany, Greece, Italy, Ireland, The Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom). The starting point of data for each product is its first introduction year in each of the countries. The country in which a product was first introduced in the region is categorized as the lead country for that product category.

Ganesh, Kumar, and Subramaniam (1997) estimated the classical Bass (1969) model in order to capture the diffusion process of each of the products in the individual countries using the non-linear least squares (NLS) procedure recommended by Srinivasan and Mason (1986). They also estimated a learning model that captures the influence of the adopters in the lead country on the potential adopters in the lag country. This learning model is similar to the independent product model developed by Peterson and Mahajan (1978), which allows for a one-way interaction between a pair of products. The learning model includes the coefficient of learning for the lag country, which is modeled as a function of the four (geographical proximity, cultural similarity, economic similarity, time lag) of the six factors described above. The other two factors (type of innovation, and technical standard) are tested with a dummy variable regression model where the values of the learning

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values of the learning coefficient are regressed with the dummy variables representing the type of innovation, and the presence of technical standard.

The empirical findings of the Ganesh, Kumar, and Subramaniam (1997) study suggest that the learning effect exists systematically across all product categories, and that the learning model explains most of the variations in the sales data (adjusted R^2 ranging from 87% to 97%). Further, five of the six factors examined (cultural similarity, economic similarity, time lag, type of innovation, and the existence of a technical standard) are strongly related to the learning process. Although the main focus of the study is on the learning effect rather than the parameters of the basic Bass model, it is worth noting that the estimates of the coefficient of innovation, and coefficient of imitation as well as the market potential are plausible. Also the basic diffusion model explains 80% to 99% of the variance in annual sales.

Ganesh, Kumar, and Subramaniam (1997) evaluated the forecasting performance of the learning model in comparison to the basic Bass model as well. Data from several countries were used as holdout samples. Based on the mean absolute deviations (MAD) and the mean squared errors (MSE) of the two models for all of the countries and each product category, they found that the forecasting performance of the learning model is better than that of the basic Bass model in 12 of the 17 cases. This result underscores the robustness of the learning model and the role of the learning coefficient in explaining the diffusion process in the lag markets.

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Putsis, Balasubramanian, Kaplan, and Sen (1997)

Putsis et al.(1997) study addresses the extent to which prior adoption of a new product in one country affects adoption in other countries. They investigated the importance and effect of *mixing* (the pattern of communication within and across countries) in the context of a new product diffusion model. In their model, mixing is viewed as occurring across a continuum with segregation (no mixing) at one end, and random mixing at the other. Intermediate forms of mixing that lie along this continuum are called Bernoulli mixing.

Data consisted of annual sales data for VCRs (1977-1990), microwave ovens (1975-90), CD players (1984-1993), and home computers (1981-1991) for ten European Community nations (Austria, Belgium, Denmark, France, Italy, Germany, Great Britain, the Netherlands, Spain, and Sweden). A diffusion model that incorporates cross-country prior adoption, cross-country mixing patterns, and individual country covariates (television set ownership as a proxy for non-word-of-mouth effects, and gross domestic product per capita as a proxy for information-seeking behavior and susceptibility to word-of-mouth influence; the parameters of these covariates correspond the coefficients of innovation and imitation in the Bass model) was estimated simultaneously across all countries for each of the products.

The results provide preliminary evidence of the importance of considering cross-country interactions when estimating diffusion models. The mean absolute percentage error (MAPE) declined when the random mixing assumption was relaxed and Bernoulli mixing was allowed for all of the products, and increased dramatically as segregation which is the most common f

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the most common form of cross-country diffusion pattern previously addressed in the literature (e.g., Gatignon, Eliashberg, and Robinson 1989, Takada and Jain 1991) was approached. The patterns MAPE followed for videocassette recorders, microwave ovens and compact disc players was similar with mixing parameters around 0.5 while the mixing parameter for home computers was around 0.7. Further, results showed that country covariates matter in determining the diffusion patterns in different countries, and the value of their parameters differ across countries and products.

Dekimpe, Parker, and Sarvary (1998)

The primary contribution of the Dekimpe, Parker, and Sarvary (1998) study is methodological. Their estimation procedure is based on the premise that samples should be matched on external criteria before valid comparisons can be made among them. According to Dekimpe, Parker, and Sarvary (1998) the four components of a diffusion pattern that require matching are the social system size, the long-run penetration ceiling, the first year acceptance level (the intercept of the penetration curve), and the speed of diffusion or the growth rate between the intercept and the ceiling. The secondary contribution of this study is with respect to the scope of cross-cultural variation considered. Dekimpe, Parker, and Sarvary (1998) used data on the adoption of cellular phones in 184 countries (55 from Africa, 37 from Asia, 32 from Europe, 15 from the Americas, and 15 from other regions, mostly island countries) between 1979 and 1992.

Using the matching criteria and incorporating several macro level covariates in the model, Dekimpe, Parker, and Sarvary (1998) estimated their model using a staged estimation procedure w

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estimation procedure with the following sequence: 1) external estimation and validation of the social system sizes, and long run adoption ceilings across countries; 2) calculation of the intercept term which is exogenous to the subsequent growth process; and 3) internal estimation of each countries' growth parameter which is endogenous to the social system, the ceiling, and the time-origin (intercept) concept. More details about the model and the estimation procedure used in this study will be given in the methodological overview section. The covariates included in the model are such factors as average annual population growth rate, number of major population centers, GNP per capita, crude death rate, number of competitors, political environment (communism or not), number of ethnic groups, and number of countries that adopted cellular phones previously.

The results of the Dekimpe, Parker, and Sarvary (1998) study suggest that poverty (approximated by crude death rates), and ethnic heterogeneity are negatively related to both initial penetration level and the speed of diffusion. The number of major population centers is negatively related to the initial penetration level (because it is difficult to provide coverage service for cellular phones in all areas at once), and positively related to the growth rate of diffusion. Factors that are positively related to the initial penetration level are population growth rate and number of competitors. All other factors such as GNP per capita, state control of the economy, and number of previous countries that adopted cellular phone service previously do not have any impact on either the penetration levels or the growth rates.

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Kumar, Ganesh, and Echambadi (1998)

Kumar, Ganesh, and Echambadi (1998) study replicated and extended the findings of Gatignon, Eliashberg, and Robertson (1989), Takada and Jain (1991), and Helsen, Jedidi, and DeSarbo (1993) studies using a common set of product categories (VCRs, microwave ovens, cellular phones, home computers, and CD players) and countries (Austria, Belgium, Denmark, Finland, France, Germany, Italy, the Netherlands, Norway, Portugal, Spain, Sweden, Switzerland, and UK). Its objectives were to empirically verify (a) the role of country-specific effects in explaining the differences in diffusion parameters, (b) the presence of a lead-lag effect, (c) the use of cultural variables to explain systematically the diffusion patterns across countries, and (d) the merit of country segmentation schemes based on diffusion parameters.

The general result that came out of the Kumar, Ganesh, and Echambadi (1998) study is that diffusion parameters across countries are influenced by certain country-specific characteristics related to social communication (cosmopolitanism, mobility, sex roles) and time lag effects. This is in accordance with Gatignon, Eliashberg, and Robertson (1989) and Takada and Jain (1991). Another result of the Kumar, Ganesh, and Echambadi (1998) study is that although the relative influences of country-specific and time lag variables differ across product categories, different products, on the average, have similar diffusion parameters, and hence, the average of the coefficient of these variables across existing products can be used to generate forecasts for a new product.

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Kumar, Ganesh, and Echambadi (1998) did not find corresponding results to Helsen, Jedidi, and DeSarbo's (1993) country segmentation composition based on macro level variables. The country segments they formed based on the similarities of diffusion model parameters for each product category suggested that countries seem to group together in terms of the time of introduction. Second, given similar time periods of introduction, geographical proximity appeared to influence the formation of segments (note that this result provides support for the argument/result regarding the importance of mixing in Putsis et al. (1997)). Further, cultural and economic similarity also seemed to influence the segmentation scheme.

Kumar, Ganesh, and Echambadi (1998) did also an extension study where the model contained both country-specific characteristics (cosmopolitanism, mobility, sex roles), which are cross-sectional data as well as the time lag variable. This cross-sectional time series model was estimated using GLS, and the results supported the influence of these variables on the cross-country diffusion parameters. Further, the comparison of the forecasting performance of this extended model to the forecasting performance of Gatignon, Eliashberg, and Robertson (1989) model, which is the cross-sectional model, suggested that the cross-sectional time series model has superior forecasting accuracy.

Talukdar, Sudhir, and Ainslie (2002)

Talukdar, Sudhir, and Ainslie (2002) is the most recent study that recognizes the increasing importance of global marketing, and multinational diffusion of new products. They contribute to the multinational diffusion research by addressing three important gaps in the lite

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gaps in the literature. The first one is related to the scope of the countries. Unlike previous studies, Talukdar, Sudhir, and Ainslie (2002) included developing as well as developed countries in their analysis. Second, they investigated the impact of a larger set of covariates on the diffusion process than any other single multinational diffusion study. Third, they used Hierarchical Bayesian estimation procedure that allows combining information about past diffusion patterns across products and countries with the aim of improving the predictive power of the Bass (1969) model.

The data set Talukdar, Sudhir, and Ainslie (2002) used consists of 6 consumer durable products (camcorders, cellular phones, CD players, fax machines, microwave ovens, and VCRs) for 31 countries from Europe, Asia, North America, and South America. The base model of the study is the discrete time version of the Bass (1969) diffusion model. They used per capita sales in order to correct for the influence of scale in countries with respect to varying populations, and to account for population growth over the time period of analysis. They modified the basic Bass model by incorporating the error term on the demand in a multiplicative fashion, as done in Van den Bulte and Lilien (1997), in order to reduce the effects of heteroscedasticity, and to prevent the possibility of support for negative demand. They also allowed for autocorrelated errors in order to account for any serial correlation in errors between successive periods.

After estimating the modified (nonlinear) Bass model using non-linear least squares estimation (Srinivasan and Mason 1986), Talukdar, Sudhir, and Ainslie (2002) transformed the parameters of the model (market penetration potential, coefficient of external influ

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external influence, and coefficient of internal influence) using an exponential, non-linear transformation to restrict the actual parameters to be positive, while allowing their transformed values to lie along the full real line to allow estimation of the variance decomposition using the normal distribution. Next, they modeled the heterogeneity structure of the transformed parameters by separating each parameter into a component that is common across all countries for a particular product, a component that is common across all products for a particular country, and a component that is unique to the particular product-country combination. It is worth noting that Talukdar, Sudhir, and Ainslie (2002) assumed the parameters of the diffusion model are time-invariant. Therefore, the country specific covariates are included in the model as time-invariant. The product specific component is modeled as a random effects model (i.e., without any hierarchical regressors). More details will be given about the model Talukdar, Sudhir, and Ainslie (2002) used in the methodological overview section.

The heterogeneity structure of the diffusion parameters across products and countries are analyzed using Hierarchical Bayes estimation methodology. In doing so, Talukdar, Sudhir, and Ainslie (2002) draw strongly on two previous diffusion studies, Gatignon, Eliashberg, and Robertson (1989), and Lenk and Rao (1990), although there are considerable differences that are worth noting. Unlike the Gatignon, Eliashberg, and Robertson (1989) study, Talukdar, Sudhir, and Ainslie (2002) focused on explaining not only the coefficients of external and internal influence but also the penetration potential. They also considered heterogeneity of the diffusion parameters across products and countries, whereas Gatignon, Eliashberg, and Robertson (1989) pooled the data only across countries, a

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across countries, and estimate the model one product at a time. Lastly, Gatignon, Eliashberg, and Robertson (1989) used an estimation methodology that can be applied to only linear models; Talukdar, Sudhir, and Ainslie (2002) estimated a nonlinear diffusion model. With respect to the Lenk and Rao (1990) study, Talukdar, Sudhir, and Ainslie (2002) present a more through analysis as well. Although Lenk and Rao (1990) too used a Hierarchical Bayesian approach, their analysis contained no hierarchical regressors and a simpler error structure, and they pooled the data only across products rather than across both products and countries as Talukdar, Sudhir, and Ainslie (2002) did.

Talukdar, Sudhir, and Ainslie (2002) included an extensive collection of covariates in their model. These covariates and their expected impacts on the diffusion parameters are as follows: 1) The factors that affect the penetration potential (*m*) are consumers' ability to pay (purchasing power parity (+), Gini index (-), proportion of dependents in the population (-)), willingness to pay (percentage of customers waitlisted for terrestrial lines for cellular phones (+), TV penetration level for VCRs (+), per capita installed base of telephones for fax machines (+)), and access to the product (urbanization (+), and percentage of exports and imports in GDP (+)). 2) The factors that affect the coefficient of external influence (*p*) are consumers' access to product related information (external contact in terms of number of minutes of incoming and outgoing international phone calls (+), access to mass media in terms of TV and newspaper penetration levels (+), and years of lag in product introduction (+)), inclination and ability to process non-word-of-mouth information (illiteracy level in a country (-)). 3) The factors that affect the coefficient of internal influence (*q*) are population homogeneity (Gini index (-), number of distinct ethnic groups (

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The estimation results for the diffusion model support almost all of the expected impacts of the covariates on the diffusion parameters. One surprising result was the negative impact of time lag on the coefficient of external influence. The hypothesis regarding this relationship was that as the number of years of lag increased, there would be an increase in the amount of information about the product externally which in turn would lead to an increase in the coefficient of external influence. Talukdar, Sudhir, and Ainslie (2002) explain this unexpected result by reversing the direction of causality given that timing of entry in a market is in control of the managers unlike other factor such as illiteracy rate. According to this explanation, the introductory lag might really be a proxy for firm information about the relative take-off times for different products in different countries, and there are unobservable characteristics of a country that reduce the coefficient of external influence and slow the take-off time which in turn delay the entry to that country.

Other interesting, although not unexpected, results of the Talukdar, Sudhir, and Ainslie (2002) study include that developing countries have lower coefficients of innovation and higher coefficient of imitation than developed countries. With respect to the variance decomposition of the diffusion parameters, Talukdar, Sudhir, and Ainslie (2002) found that while country effects (past experiences of other products in a country) are relatively more useful to explain the penetration level or cumulative sales, product effects (past experiences i

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experiences in other countries where the product was introduced earlier) are more useful to explain the coefficient of external influence and the coefficient of internal influence, or the speed of diffusion.

In order to evaluate the performance of their model, Talukdar, Sudhir, and Ainslie (2002) compared it against two simpler benchmarks. The first one modeled all countries for a particular product (in line with Gatignon, Eliashberg, and Robertson (1989)), and the second one modeled all products for a particular country (in line with Lenk and Rao (1990)). The percentage improvements in the forecasts (measured by improvements in mean square errors) when the full model (the model that accounts for both country and product effects) is used ranged from 17% to 36%. The comparisons were based on improvements in one period and two period ahead forecasts of the three types of models (full model, country model, and product model).

An overall summary of the multinational diffusion studies reviewed in this section is given in Table 1.1. With respect to the individual results one needs to be aware of the idiosyncrasies of each study in terms of the data characteristics, model specifications and the methodology used to analyze the diffusion process. Still, collectively, these studies provide the knowledge base in the multinational diffusion literature. They point to the importance of several macro environmental variables along with the interdependence of the diffusion process across countries. Further each and every one of them emphasize the crucial impact of the globalization phenomenon on the diffusion of new products.

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The approach we adopt in this dissertation follows directly from this perspective. The main argument we make is that the drivers of globalization have a direct impact on the diffusion patterns of new products across countries. We expect that the speed of diffusion (reflected in the coefficient of innovation and the coefficient of imitation) has increased over time, and that there are identifiable diffusion patterns across countries based on their involvement in globalization at the macro level as well as their level of development (developed versus developing). In order to investigate these issues we will use the Augmented Kalman Filter with Continuous State and Discrete Observations (AKF (C-D)) methodology developed by Xie et al. (1997). This is a methodology that has not been applied in the multinational diffusion literature before, and has very appealing advantages over the previously used methodologies in this area. These advantages are mainly due to the Bayesian nature of the AKF (C-D) procedure, which also yields time-variant parameter estimates.

In the next section, we will present a methodological overview of the diffusion of new products research. The AKF (C-D) methodology will be explained in more detail along with the other methodologies commonly used in previous studies. The specific model and the algorithm to be used in this dissertation, however, will be explained in Chapter 3.

Methodological Overview of the Diffusion of New Products Literature

Accurate prediction of the diffusion of new products requires the specification of the diffusion model and the estimation of the model parameters. A variety of methods for estimating diffusion models have been proposed (for extensive reviews of the estimation techniques see

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techniques see Mahajan, Muller, and Bass 1990, Putsis and Srinivasan 2000). These estimation procedures can be grouped under three subheadings.

Single-equation time-invariant estimation procedures

Most of the work on estimation of diffusion models has focused on the estimation of single-equation time-invariant models. Time-invariant estimation procedures include the conventional estimation methods such as ordinary least squares (OLS) (Bass 1969), maximum likelihood estimation (MLE) (Schmittlein and Mahajan 1982), and nonlinear least squares (NLS) (Srinivasan and Mason 1986). These estimation procedures suffer some common limitations. First, to obtain stable and robust parameter estimates, time-invariant procedures often require data to include peak sales (Mahajan, Muller and Bass 1990). Time-invariant procedures are not helpful in forecasting a new product diffusion process because by the time sufficient data have been collected, it is too late to use the estimates for forecasting or planning marketing strategies.

Second, though diffusion models often are expressed by a continuous differential equation, the time-invariant procedures can be applied only to the discrete form of the diffusion model or to the solution of the diffusion model. It becomes necessary to estimate a continuous model using data across discrete time intervals because sales, and cumulative sales are not observed continuously. The discrete form used to estimate diffusion models often results in biased and high variance estimates. Requiring a diffusion model to be analytically solvable limits the applicability of the estimation procedures (Putsis and Srinivasan 2000).

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Bass (1969) originally suggested the OLS estimation of the parameters *m*, *p*, and *q* using the discrete analog of Equation (2.1). The discrete analog of Equation (2.1) can be expressed as:

$$s_t = a + bx_{t-1} + cx_{t-1}^2 + e_t \tag{2.11}$$

Where s_t is sales over the t^{th} time interval, and x_{t-1} is cumulative sales at the end of period t-1. Further, $m = \frac{-b-(b^2-4ac)^{1/2}}{2c}$, $p = \frac{a}{m}$, and $q = -mc$.

Using OLS to estimate the Bass (1969) model attracts many inherent problems (e.g., Schmittlein and Mahajan 1982, Srinivasan and Mason 1986, Putsis 1996, Van de Bulte and Lilien 1997). First, parameter estimates can be extremely unstable when there are only a few data points. Second, the standard errors of the parameter estimates of p, q, and *m* are not readily available since they are nonlinear functions of *a*, *b*, and *c*. Third, there is a time interval bias due to estimating Equation (2.1) using discrete time-series data. This bias results from attempting to estimate a continuous time model using $s_t = x(t) - x(t-1)$ on the left-hand side of Equation (2.1), where, to be consistent with the right-hand side, it should represent the derivative of *x* at t-1. As a result, the application of OLS will overestimate sales when cumulative sales are growing quickly (such as before peak sales), and underestimate when cumulative sales are growing slowly (such as after peak sales). In theory, the shorter the data interval used the smaller the time interval bias under OLS (Putsis 1996).

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MLE and NLS are the other two estimation approaches that have been used frequently in estimating single-equation time-invariant diffusion models. These two approaches are not subject to the time interval bias. Further, they have the added benefit of providing standard errors for the estimated parameters. Schmittlein and Mahajan (1982) proposed a MLE approach that provided significant improvement over OLS by appropriately aggregating the continuous time model over the time intervals in the data. Note that Equation (2.3) can be rewritten as $F(t) = (1 - e^{-\gamma t})/(1 + \lambda e^{-\gamma t})$ where $\lambda = q / p$ and $\gamma = (p + q)$. Also note that in a sample of size *M*, if the eventual probability of adopting is μ, then the expected number of eventual adopters is μM and $E[x(t)] = \mu M F(t)$. Schmittlein and Mahajan (1982) first generate maximum likelihood estimates of γ, λ, and μ, which determine the estimates of *p*, *q*, and *m*. Formulae for approximate standard errors of the estimates for *p*, *q*, and *m* are also derived. MLE is consistent, asymptotically normal, and asymptotically efficient.

In the NLS approach proposed by Srinivasan and Mason (1986), an expression for the right-hand side of Equation (2.1) is derived such that the right-hand side equals the same difference on the left-hand side. That is, there is a continuous form expression for the difference $x(t) - x(t-1)$ and the parameters *p*, *q*, and *m* can be estimated directly via this difference. Specifically, *p*, *q*, and *m* can be estimated via NLS using

$$s_t = m[F(t) - F(t-1)] + u_t$$

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where u_t is an additive error term.

The formulation suggested by Jain and Rao (1990) is slightly different. Their alternative to Equation (2.11) is

$$s_t = [m - x(t-1)]\left[\frac{[F(t)-F(t-1)]}{[1-F(t-1)]}\right]+\varepsilon_t \tag{2.13}$$

where $\left[\frac{[F(t)-F(t-1)]}{[1-F(t-1)]}\right]$ is the probability that an individual who has not purchased the product up till period t-1 will purchase in the t^{th} time interval. NLS estimators obtained by both Srinivasan and Mason (1986) and Jain and Rao (1990) are consistent but not unbiased (Van den Bulte and Lilien 1997). Consequently, NLS parameter estimates obtained from data sets with few and noisy observations should be viewed with caution.

Although both the MLE and the NLS procedures eliminate the time interval bias, there are some important differences between the two estimation procedures. For example, since the MLE approach of Schmittlein and Mahajan (1982) focuses on the sampling errors and ignores all other sources of errors (such as omitted variables), it seriously underestimates the standard errors of the estimated parameters (Srinivasan and Mason 1986). On the other hand, the error term under NLS includes both sampling errors, and errors due to omitted variables and functional form misspecification. Hence, NLS may have an advar

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have an advantage in instances where nonsampling errors are substantial (Putsis and Srinivasan 2000). Still, it is useful to note Srinivasan and Mason (1986) report that the downward biases in the MLE standard error estimates are negligible when the adoption data were based on sample sizes of 200 or fewer customers.

Both the MLE and the NLS approaches suffer similar limitations. They are only directly applicable to diffusion models for which $F(t)$ can be expressed as an explicit function of time. Further, both procedures require specifying starting values for each of the parameters that are used in the estimation algorithm. Although we have a somewhat good sense of what the parameters in applications of the Bass model are likely to be (e.g., Sultan, Farley, and Lehmann 1990), this may not be true for more complex specifications or for simultaneous equations models that are particularly suitable for multinational diffusion research. Since the estimated parameters in both the MLE and the NLS procedures are sensitive to the starting values, this issue may become of major importance.

Overall, the main advantages of MLE and NLS techniques are that they overcome the time interval bias and that they provide direct estimated of the diffusion parameters and their standard errors. In the context of a single equation Bass model applied to consumer durables, the noncumulative form of NLS (Equation (2.11)) will do well in most settings and may be preferred to MLE (Putsis and Srinivasan 2000), especially since there might be serious downward bias in standard error estimates when MLE is used (Srinivasan and Mason 1986).

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Conceptually there are numerous reasons why it is important to address parameter variation in diffusion models over time. First, a diffusion model's parameters may vary over time due to competitive activity, changes in the advertising quality, or changes in the product itself (Eliashberg and Chatterjee 1986) as well as due to perfection in technology and associated increases in product quality, increased benefits that result from an expanding installed base, and changing consumer expectations (Horsky 1990). Second, different segments of the market are likely to adopt at different points in time. This can cause variation in the estimated diffusion parameters over time. For example, early adopters may have different coefficients of external and internal influence than late adopters, high-income households are likely to have different parameter values than low-income households (e.g., Horsky 1990) and so on. Third, specification and measurement errors can result in parameters that vary over time. For example, "contamination" of first purchase data with repeat purchases can lead to the appearance of varying parameters (Putsis 1998). Finally, aggregation, use of proxy variables, nonlinearity and omitted variables can also result in varying estimators (Sarris 1973, Judge et al. 1985).

Understanding parameter variation in diffusion models over time is important for various reasons. First, the form of the variation can provide insight into the nature of the diffusion process. Second, it provides information on the appropriate estimation technique or theoretical model to use to estimate the relevant parameters that vary over time. Finally, it allows to relatively easily improve the within sample fit and forecasting ability of diffusion mode

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diffusion models (Putsis 1998). In fact, time-varying parameter specifications can substantially lower forecast errors (Putsis 1998, Xie et al. 1997)

Time-varying parameter models can be grouped into three groups:

1) Systematic (nonstochastic) variation models:

In these models, the form of transition is prespecified by the researcher, and transition from period to period is not allowed to vary stochastically. Although more restrictive than stochastic variation models, these models offer added flexibility over time-invariant NLS method. The estimated parameters can change over the time span covered by the data set and allow theory to guide the transition. Further, the rigidity in the Bass model is reduced since the specification in systematic variation models allow for nonsymmetric diffusion curves and flexible inflection points.

These models are not free of limitations however. The requirement to specify the form of transition a priori is often difficult, especially in the case of weak priors. The application of these models is problematic also when $F(t)$ is not known or when solution to the differential equation does not exist. In these cases stochastic or Bayesian specifications may be preferred. Stochastic parameter models allow the parameters in a diffusion model to vary stochastically over time according to either a stationary or a nonstationary process. Although stochastic parameter models have received limited attention to date, evidence shows that models allowing for flexible forms or parameter variation can provide a very good fit to diffusion data and have better predictive validity (e.g., Bretschneider and Mahajan 1980, Easingwood 1987, 1988, Putsis 1988).

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2) Stochastic stationary processes

Feedback filters and Bayesian approaches have been used in a variety of ways to update parameter estimates. The basic approach of adaptive models is to use the information provided by the forecast error *e*(*t*) to update the estimated coefficients $\alpha_i(t)$. For example, Bretschneider and Mahajan (1980) express the discrete analog of the Bass model as $s(t) = \alpha_1(t) + \alpha_2(t)x(t-1) + \alpha_3(t)x^2(t-1)$, and sales $s(t)$ are predicted based on the time-varying coefficients, which are defined by $\alpha_i(t) = \alpha_i(t-1) + A_i(e(t))$. $A_i(e(t))$ is called the feedback filter, which is a function of the one-step ahead forecast errors. It can also be specified as any weighted average of past errors. The objective is to determine the magnitude and direction by which the previously estimated coefficients need to be adjusted. This can be prespecified and imposed on the system, or estimated directly.

Although the application by Bretschneider and Mahajan (1980) is based on the discrete analog of the Bass model, this need not be the case. Another application of feedback filters can also be found in adaptive estimation procedure introduced by Carbone and Longini (1977).

An alternative stochastic stationary process is the Kalman filter (Kalman 1960, Kalman and Bucy 1961) estimation technique designed to estimate state variables in a dynamic system in an optimal way. It is based on a probabilistic treatment of process and measurement noises. It can also be used, often in the form of a feedback filter, to update the parameter estimates when new observations become available. The basic form of the discrete Kalma

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discrete Kalman filter consists of two sets of equations. System (or transition) equations describe the evolution of the state variable y_k. Measurement equations describe how the observations are related to the state of the system.

System equations are $y_{k+1} = f_k\left[y_k, \beta, u_k, t_k\right] + G_k w_k$ (2.14)

where $y_0 \sim (\bar{y}_0, P_0)$, $w_k \sim (0, Q)$.

Measurement equations are $z_k = H_k y_k + v_k$ (2.15)

where $v_k \sim (0, R)$.

y_k is the state vector, z_k is the observation vector. w_k and v_k are stationary white noise processes uncorrelated with y_k and with each other. f_k is a vector function of state (y_k), parameter vector (β), control vector u_k and time t_k. G_k and H_k are known matrices, and Q and R are covariance matrices of the process and measurement noises, respectively.

Together the set of system and measurement equations represents a *state space model.* Once a state space model is specified, the Kalman filter can be used to estimate and trace out or smooth the parameter estimates across time periods. Harvey and Phillips (1982), Judge et al. (1985) and Putsis (1998) are other studies that provide applications of the Kalman filter estimation technique.

Xie, Song, Sirbu, and Wang (1997) proposed a new approach to diffusion model estimation: the Augmented Kalman Filter with Continuous State and Discrete

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Observations (AKF(C-D)). This technique is built based on the extended Kalman filter which uses discrete observations to estimate the state of a continuous system with known parameters, and augmented Kalman filter which estimates unknown parameters in a continuous Kalman filter model. The reviews of these methods can be found in Lewis (1986) and Stengel (1986)). The limitations of the standard Kalman filter method applied in a diffusion setting are addressed by the AKF(C-D) approach. These limitations are:

1) In a standard Kalman filter, both the system and the measurement equations are either discrete or continuous. Because diffusion models often are expressed by a continuous differential equation whereas sales data are obtained in discrete time intervals, neither the discrete nor the continuous Kalman filter is directly applicable to diffusion model estimation.

2) When the discrete version of the Bass model is used as the system equation, the standard Kalman filter method is subject to the same time interval bias as is OLS. (e.g., Bretschneider and Mahajan 1980).

3) The standard Kalman filter can only be applied in situations where the differential equation has an analytic solution (e.g., Lenk and Rao 1990, Sultan, Farley, and Lehmann 1990).

It is desirable for a diffusion model to facilitate forecasts early in the product cycle, when there are only a few observations are available. In order to do so, the estimation method should provide a systematic way of incorporating prior information about the likely values of model parameters and an updating formula to upgrade the initial estimates as additional data become available. Further, the estimation method should be directly applicable to dif

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applicable to diffusion models expressed as a differential equation for cumulative sales/ apparent consumption. It should require neither a discrete analog nor an analytical solution to the equation. A discrete analog would require that a continuous differential equation be rewritten as a discrete time equation in a way that introduces a time interval bias. An analytic solution would require that cumulative sales/apparent consumption be written as an analytic function of t. AKF(C-D) method Xie et al. (1997) proposed addresses these issues. It is superior to the previous estimation procedures (e.g., Adaptive Filter developed by Bretschneider and Mahajan (1980), the meta-analysis conducted by Sultan, Farley, and Lehmann (1990), and the Hierarchical Bayesian introduced by Lenk and Rao (1990)) because it does not introduce a time interval bias due to discretizing the differential equation, and does not require the differential equation to have an analytical solution. Second, it can be used to estimate parameters that change over time (deterministic or stochastic). Third, it explicitly incorporates observation error in the estimation process. Another advantage of AKF(C-D) is that its algorithm is straightforward and easy to implement. Furthermore, a parallel AKF(C-D) procedure can be used to overcome the uncertainty in choosing diffusion model structure and/or prior distributions of unknown parameters.

The formulation of the AKF(C-D) model is as follows:

$$\begin{aligned}
\frac{dx(t)}{d(t)} &= f_x\left[x(t),\phi(t),\beta,t\right]+w_x \\
\frac{d\beta}{dt} &= f_\beta\left[\beta,x(t),t\right]+w_\beta \\
z_k &= x_k+v_k
\end{aligned} \qquad (2.16)$$

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where $x(t)$ is the cumulative number of adopters, $\phi(t)$ is a vector of covariates (for example, marketing mix variables), β is the unknown parameter vector, w_x and w_β are the process noise, x_k and z_k are the true and observed cumulative number of adopters at time t_k, and v_k is the observation noise. It is assumed that $x(0) \sim (x_0, \sigma_{x0})$ and $\beta(0) \sim (\beta_0, P_{\beta 0})$, $\{w_x, w_\beta\}$ and $\{v_k\}$ are white noises. $\{w_x, w_\beta\} \sim (0,Q)$ and $\{v_k\} \sim (0, R)$, and $\{w_x, w_\beta\}$ and $\{v_k\}$ are not correlated to one another. The process noise, w_x, includes model specification errors (due to omitted variables and/or misspecification), and sampling errors which can occur when using the model to describe the diffusion process of a sampled group instead of the entire population. The measurement error, v_k, includes random errors in the data collection.

The AKF(C-D) algorithm is essentially a Bayesian updating procedure. Using prior experience and knowledge, one gives the initial estimates for the unknown parameters. AKF(C-D) updates the parameter estimates of the diffusion model as new data become available. It estimates parameters and updates the state variables through a time updating process and a measurement updating process. The details of the AKF(C-D) algorithm will be presented in Chapter 3.

Xie et al. (1997), using diffusion data for seven products (room air conditioner, color TV, clothes dryer, ultrasound, mammography, foreign language education, and accelerated educational program) compared four time-invariant procedures, namely OLS (Bass 1969), MLE (Schmittlein and Mahajan 1982), NLS (Srinivasan and Mason 1986), and algebrai

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algebraic estimation (AE) (Mahajan and Sharma 1986), one time-varying model, namely Adaptive Filter (AF) (Bretschneider and Mahajan 1980), and their AKF(C-D) model. Based on three criteria (mean absolute deviation, mean squared error, and mean absolute percentage deviation (Mahajan, Mason, and Srinivasan 1986)) for comparing one-step-ahead forecasts of the different methods, Xie et al. (1997) found that AKF(C-D) performs better than each of the estimation procedures considered. Further, they extended the AKF(C-D) estimation to the situation in which there is uncertainty in choosing model structure and prior distributions of unknown parameters.

There are several advantages of the AKF(C-D) estimation approach that should be considered along with its superior predictive performance. First, it is a general estimation approach that is not restricted by the model structure or by the nature of the unknown parameters. It can be applied directly to a differential diffusion model without requiring the diffusion model to be replaced by a discrete analog or requiring that the diffusion model have an analytical solution. It can be used to estimate both constant parameters and parameters changing over time (both deterministic and stochastic changes). Second, AKF(C-D) is a Bayesian estimation procedure. It can provide better forecasts from the early stages of the diffusion process by incorporating any information on the prior distributions of the parameters in the estimation process and updating the estimates adaptively. Third, AKF(C-D) is a better estimator compared to other methods because it avoids the time-interval bias problem, it is capable of estimating time-varying parameters with or without a prior knowledge of how the parameters change over time, and it accounts explicitly for possible noise during the data collection process. Fourth, the

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AKF(C-D) algorithm is straightforward and easy to implement. Fifth, when multiple model structures or prior distributions are considered, the parallel AKF(C-D) procedure can be employed to deal with the uncertainty. Thus, the model is useful in situations where strong parameters on the parameter estimates are present as well as in situations where little information is known about the parameter estimates. It should be noted that in the latter case nonstationary stochastic processes may have some advantages in developing the priors when prior adoption data are available (Putsis and Srinivasan 2000).

3) Stochastic nonstationary processes

Putsis (1998) applied the nonstationary stochastic Cooley and Prescott (1973, 1976) model, which divides each parameter vector in to a permanent component (which persists from one period to the next) and a transitory component (which dissipates at the end of each period). Examples of the changes that persist from one period to the next, and hence would be incorporated into the permanent component of the parameter vector include changes in price elasticity due to improvements in product quality, the impact of increased product familiarity over time, increased benefits due to a larger installed base, and the effect of replacement sales (Eliashberg and Chatterjee 1986, Kamakura and Balasubramanian 1987, Horsky 1990). The effect of changes in transitory income, sale price changes, short-term advertising expenditures are likely to be included in the transitory component of the parameter vector.

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The details of the Cooley-Prescott procedure can be found in Cooley and Prescott (1973, 1976), Judge et al. (1985), and Hanssens et al. (1990).

Simultaneous equation estimation

There are situations, for example successive-generation models (Norton and Bass 1987, Islam and Meade 1997) and multinational diffusion of new products (Putsis et al. 1997, Dekimpe, Parker, Sarvary 1998; please note that these studies are also reviewed in the previous section), where estimation techniques designed to address single-equation settings may not be appropriate to use, but methods like full information maximum likelihood (FIML), seemingly unrelated regression (SUR) or three-stage least squares (3SLS) are necessary.

The Dekimpe, Parker, and Sarvary (1998) study provides an illustration for adoption of (cellular phones) based on previous research on multinational diffusion of new products (e.g., Gatignon, Eliashberg, and Robertson 1989, Takada and Jain 1991). They reported parameter estimates for the Bass model using NLS applied separately to data on cellular phones service between 1979 and 1992 for 184 countries. However, there are significant issues that resulted in implausible parameter estimates in almost all of the cases. Since service started at different dates in each country, the available degrees of freedom ranged from 1 to 13. Further, the diffusion processes across all 184 countries are certainly not independent. Putsis et al. (1997) point out significant interaction across countries in a multinational setting. Also, network externalities (Dekimpe, Parker, and Sarvary 2000) as well as supply-side relationships such as production economies (Jain, Mahajan, and

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Muller 1991) make it highly unlikely that diffusion in multiple countries are independent. Finally, it is also likely that omitted variables such as price and income are correlated across countries, implying that, at a minimum, SUR estimation is required. Given the considerations regarding the system's specification and parameter identification issues as well, FIML, 3SLS, or nonlinear 3SLS are more than likely choices for estimation.

Dekimpe, Parker, and Sarvary (1998) proposed a three-stage estimation process that they suggested is temporally consistent with the evolutionary nature of the diffusion process. For a given country *i*, they defined the following adoption function over time:

$$s_{i,t} = \left[\left(\frac{s_i(1)}{C_i SZ_i}\right) + \left(\frac{B_i x_i(t-1)}{C_i SZ_i}\right)\right]\left[C_i SZ_i - x_i(t-1)\right] \qquad (2.17)$$

where $s_{i,t}$ is sales in country i over the t^{th} time interval, and $x_i(t-1)$ is cumulative sales (adoptions) through the end of period t-1. The term $s_i(1)$ represents the penetration level at the end of the first period, SZ_i denotes the social system size (population), and C_i $(0 \le C_i \le 1)$ captures the long-run adoption ceiling. $A_{i1} = \left(\frac{s_i(1)}{C_i SZ_i}\right)$ denotes the intercept of the penetration curve, which is specified as endogenous to the social system. The parameter B_i is defined as the growth-rate parameter that captures the growth that occurs between the intercept and the adoption ceiling. Country-specific covariates are incorporated using logistic transformations $A_{it} = \left[1 + e^{-d_1 X_i}\right]^{-1}$ and $B_i = \left[1 + e^{-d_2 X_i}\right]^{-1}$ where X_i denotes a country-specific set of covariates.

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The first stage of the three-stage estimation procedure Dekimpe, Parker, and Sarvary (1998) used consists of external estimation of the social system sizes and long-run adoption ceilings across countries. These are specified as exogenous. In the second stage, the intercepts for each country, which are exogenous to the next stage are calculated. In third stage, internal estimation of each country's growth parameter, specified as endogenous to the social system is undertaken using data pooled across countries. The estimation procedure requires sample matching, which entails matching countries based on external criteria. Dekimpe, Parker, and Sarvary (1998) suggested that four components of the diffusion process (the social system size, the adoption ceiling, the time intercept origin, and the growth rate) require matching. Once the countries are matched according to these criteria, the diffusion process based on similar sets of countries can be understood better. Since the diffusion process is temporally sequential in nature (for example, social infrastructure is established before the product launch), the matched samples can be used to estimate diffusion parameters sequentially, rather than simultaneously.

The advantages of the staged estimation procedure include sufficient flexibility to explain cross-country variation using either endogenous or exogenous covariates as well as provision of a reasonable basis for testing hypotheses when only the earliest adoption figures are available. This procedure also allows for estimation when products are launched at different times across countries. However, there are also limitations. For example, estimated parameters for the intercept, the long-run adoption ceiling, and the social system size for each country are fixed in the third stage while the ceiling and the population size may change over time. Sequential rather than simultaneous estimation may make parameter estimates inconsistent (Anderson 1970). Accordingly, the estimation procedure employed needs to consider that diffusion of the product may be related across countries after launch in a simultaneous manner (see e.g., Putsis et al.1997).

Putsis et al. (1997) developed a model that empirically addresses cross-country relationships. Each country's adoption equation was specified not only as a function of its own prior adoption but also as a function of prior adoption in the other countries. A mixing parameter and country covariates were also incorporated in the model. Ten individual-country adoption equations were estimated simultaneously with the aim of measuring the individual-country diffusion parameters and the mixing parameter. It should be noted that the technique Putsis et al.(1997) resulted in plausible estimates because the product launches for the products studied had occurred at approximately the same time. Otherwise, Bayesian or unbalanced panel methods would have been more appropriate techniques.

There are serious methodological issues that make use of nonlinear methods such as nonlinear SUR, nonlinear 3SLS, or FIML problematic. Convergence issues and concerns about parameter instability are such examples as the models get complex and nonlinear. Also, in 3SLS and FIML, misspecification in a single equation can seriously affect parameter estimates in all of the equations of the system. Further, the solutions of complex nonlinear systems are highly sensitive to the starting values of the parameters and great care should be given to ensure that a global solution is obtained (Putsis et al. 1997). It should also be considered that convergence and identification problems may arise once covariates are incorporated in the model, but not necessarily before.

Given the pros and cons of using the different methodologies that are reviewed in this section, we have decided that the most appropriate method to use for the purposes of this dissertation is the Augmented Kalman Filter with Continuous State and Discrete Observations (Xie et al. 1997). The main reasons for this decision are the ability of the AKF (C-D) methodology to do Bayesian updating of the parameter estimates as new data becomes available, and the time-varying nature of the parameter estimates that will enable us to examine the impact of our covariates on the diffusion process over time.

Table 2.1
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Table 2.1
Summary of International Diffusion of Consumer Durables Research

Study	Countries	Product Categories	Time Period	Covariates	Method	Major Findings
Talukdar, Sudhir, and Ainsley (2002)	31 developed and developing countries in Europe, Asia, North America, and South America	Camcorders, CD players, cellular phones, fax machines, microwave ovens, VCRs	First 9 years after product introduction in a each country	For *m*: ability to pay, willingness to pay, access to the product For *p*: access to product related information, inclination and ability to process non-word-of-mouth information For *q*: population homophily, persuasiveness of existing adopters	Hierarchical Bayes	Ability to pay, willingness to pay, access to the product have a positive effect on *m*. Access to product related information, inclination and ability to process non-word-of-mouth information have a positive effect on *p*. Population homophily, persuasiveness of existing adopters have a positive effect on *q*. Country effects are relatively more useful to explain the penetration level, and product effects are relatively more useful to explain the speed of diffusion (*p* and *q*).

Average annual	Staged Estimation	Poverty and ethnic heterogeneity have a	

Table 2.1 Cont'd.

Dekimpe, Parker, and Sarvary (1998)	184 countries in Africa (55), Asia (37), the Americas (45), Europe (32), and others (15)	Cellular phones	1979-1992	Average annual population growth rate, number of major population centers, GNP per capita, crude death rate, number of competitors, political disposition, number of ethnic groups, and number of countries that adopted cellular phones previously.	Staged Estimation	Poverty and ethnic heterogeneity have a negative effect on both initial penetration level (A_i) and the speed of diffusion (B_i). The number of major population centers has a negative effect on A_i, and a positive effect on B_i. Population growth rate and number of competitors have a positive effect on A_i. GNP per capita, state control of the economy, and number of previous countries that already adopted do not have any effect on either A_i or B_i.

Table 2.1 Cont'd

Kumar, Ganesh, and Echambadi (1998)	14 European countries	VCRs, microwave ovens, cellular phones, home computers, and CD players	From product introduction year for each product to 1990	Replication study of Gatignon, Eliashberg, and Robertson (1989), Takada and Jain (1991), and Helsen, Jedidi, and DeSarbo (1993)	Same methodologies as in the original studies	Although the relative influences of country-specific and time lag variables differ across product categories, different products, on the average, have similar diffusion parameters. Generally supported the results of the original studies.
Ganesh, Kumar, and Subramaniam (1997)	11 (for cellular phones) to 16 (for all others) European countries	Cellular phones, microwave ovens, home computers, VCRs	From product introduction year for each product to 1990	Geographical proximity, cultural similarity, economic similarity, time lag, type of innovation, existence of technical standard	Nonlinear least squares for the basic Bass (1969) model, simultaneous generalized least squares for the learning effect equations	Cross-cultural learning effect is a function of cultural similarity, economic similarity, time lag, type of innovation, and existence of technical standard, but not geographical proximity.
Putsis, Balasubramanian, Kaplan, and Sen (1997)	10 European countries	CD players, home computers, microwave ovens, VCRs	Late 1970s-Early 1990s	TV ownership, and GNP per capita	Simultaneous estimation of the equation representing the system across countries	TV ownership, and GNP per capita have a positive effect on the speed of diffusion.

Table 2.1 Cont'd.

Helsen, Jedidi, and DeSarbo (1993)	12 European countries and U.S.	Color TVs, CD players, VCRs	From the year of product introduction to	Mobility, health, trade, lifestyle, cosmopolitanism	Latent class structure methodology	Wealth and health status have positive effects on the

Table 2.1 Cont'd.

Helsen, Jedidi, and DeSarbo (1993)	12 European countries and U.S.	Color TVs, CD players, VCRs	From the year of product introduction to 1990	Mobility, health, trade, lifestyle, cosmopolitanism	Latent class structure methodology	Wealth and health status have positive effects on the coefficients of innovation and imitation. Macro level country segmentation and diffusion based segmentation are not in agreement.
Takada and Jain (1991)	4 countries in the Pacific Rim (U.S., Japan, South Korea, Taiwan)	Air conditioners, B&W TVs, calculators, radios, electric refrigerators, electric washing machines, passenger cars, vacuum cleaners	Various time periods for each product in each country Ex: 1921-1954 for refrigerators in U.S.; 1975-1986 for calculators in Taiwan	Social system homogeneity	Nonlinear least squares for the diffusion equation Simple regression for the time effect	Homogeneity of the social system has a positive effect on coefficient of imitation. Countries that adopt later have faster diffusion rates.
Gatignon, Eliashberg, and Robertson (1989)	14 countries in Europe	Color TVs, car radios, deep freezers, dishwashers, lawnmowers, pocket calculators	1965-1980	Cosmopolitanism, mobility, women in the labor force	Generalized least square	Cosmopolitanism has a positive effect on the coefficient of innovation. The effects of mobility and the women in the labor force depend on product context.

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CHAPTER 3

METHODOLOGY

The early models of diffusion of new products such as the Bass model (1969) have the major limitation that they do not explicitly incorporate variables that managers and policy makers use for decision/policy making. Therefore, these models are not useful for strategic planning with respect to, for example, pricing and advertising policies or entry decisions of the firms. The importance of the role of decision variables or covariates in understanding the dynamics of the diffusion process has been emphasized by various researchers (e.g., Mahajan and Muller 1979, Kalish and Sen 1986, Mahajan and Wind 1986, Mahajan, Muller, and Bass 1990). In fact, the earliest study to modify the Bass model to include covariates was by Robinson and Lakhani (1975). Their study was followed by others that propose numerous modifications and extensions of the Bass model to examine the effects of covariates on the diffusion process of new products. Some of these studies incorporated the effect of price (e.g., Bass 1980, Kalish 1985, Kamakura and Balasubramanian 1988, Jain and Rao 1990, Horsky 1990) into the Bass model while others examined the impact of advertising (e.g., Horsky and Simon 1983, Simon an Sebastian 1987). Few other studies (e.g., Bass, Krishnan, and Jain 1994, Bass, Jain, and Krishnan 2000) included both price and advertising effects on the diffusion of new products. Marketing mix variables are not the only covariates researchers included in the diffusion models. For example, Dekimpe, Parker, and Sarvary (1998) include demographic factors such as annual average population growth rate and number of major population centers, economic factors such as GNP per capita and crude death rate, and socia

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social system factors such as number of ethnic groups in a country in their model for investigating the diffusion of cellular phones in 184 countries. Similarly, Talukdar, Sudhir, and Ainslie (2002) include factors such as purchasing power parity adjusted per capita income, Gini index, urbanization, international trade volume, illiteracy rate, number of ethnicities in their Hierarchical Bayesian analysis of diffusion of six consumer durable products for 31 countries.

For the purposes of this dissertation, these studies are interesting from a methodological point of view. The manner in which covariates are incorporated in the Bass model is our main concern. Hence, the remaining of the discussion will include an overview of the Bass model, and examples of its modifications where covariates are introduced to the model. Then the model to be used in the dissertation will be described along with the AKF(C-D) estimation methodology, and the data characteristics.

Before getting into the details of the methodological issues, however, it is necessary to lay out the desirable properties of a diffusion model with covariates. This will enable better evaluation of the usefulness of the diffusion model developed in this dissertation. The guidelines regarding the desirable properties of diffusion models with covariates are mainly based on the prescriptions by Bass, Krishnan, and Jain (1994) and Bass, Jain and Krishnan (2000):

- It is desirable for the diffusion models with covariates to describe the empirical diffusion process. Since Bass model is an empirical generalization that describes the diffusion of new products, diffusion models with covariates should reduce to or be approximately equivalent to the Bass model curve. Empirical generalization can be described as "a pattern or regularity that repeats over different circumstances and that can be described simply by mathematical, graphic, or symbolic methods" (Bass 1995, p. G7). The diffusion patterns for new products usually take the form of an S-shaped curve. The central proposition of the Bass model describes this phenomenon as the conditional probability that an adoption will be made at time t given that an adoption has not yet been made is a linear function of the number of previous adopters. It is appropriate to call the Bass model an empirical generalization because although the indicated diffusion pattern does not always prevail, it usually does.

- The behavioral rationale of the Bass model suggests that the timing of adoption of those who have not yet adopted at any time t is influenced by the number of previous adopters due to learning or imitation. This implies that the greater the number of adopters today the greater will be the influence on the remaining potential adopters to adopt at each future time period. In the context of diffusion models with covariates, this "carry-through" property means that any change in the covariate variables will affect the diffusion of the new product not only today but also in all future time periods.
- Diffusion models with covariates should be capable of empirical estimation, and yield plausible parameter estimates. Such empirical support will enhance the credibility of the model, particularly when the number of data sets for which empirical estimates of parameters is large.

- Goodness of fit alone is not an adequate criterion for evaluating the validity of the diffusion models with covariates.
- When a diffusion model has a closed-form solution, this makes it easier to understand and interpret the relationships among the variables and the time pattern of adoption. Hence, it is desirable, though not always sufficient for validity, that the diffusion models with covariates have closed-form solutions.
- Diffusion models with covariates should be constructed in such a way that the managers/policy makers can interpret the parameters of the model either by intuition or with reference to comparison to other products.
- Diffusion models with covariates should also be implementable for new products without data.

The Overview of the Bass Model

The framework originally proposed by Bass (1969) constitutes a single-equation model of first purchase with parameters that remain constant over time. It postulates the likelihood that an individual would adopt a new product at time *t*, given that he/she has not yet adopted. The model can be stated as follows:

$$s(t) = \frac{dx(t)}{dt} = \left[p + \left\{q\frac{x(t)}{m}\right\}\right][m - x(t)] = pm + [(q-p)x(t)] - \left[\left(\frac{q}{m}\right)x(t)^2\right] \qquad (3.1)$$

where $s(t)$ is the sales rate at time t, $x(t)$ is the cumulative number of adopters at time t (with $x(0) = 0$), and m is the maximum number of potential adopters. The parameter p is the coefficient of innovation or the coefficient of external influence. It reflects the tendency to adopt at time 0. Note that $s(0) = pm$. The parameter q is the coefficient of imitation or th

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imitation or the coefficient of internal influence. It reflects word-of–mouth communication.

Defining $f(t)$ as the density function describing the time of adoption for a population, and $F(t)$ as the cumulative density, the hazard function describing the probability of adoption at time t is given by:

$$\frac{f(t)}{1-F(t)} = p + qF(t) \tag{3.2}$$

Assuming $F(0) = 0$,

$$F(t) = \left[\frac{1-e^{-(p+q)t}}{1+\frac{q}{p}e^{-(p+q)t}} \right] \tag{3.3}$$

Assuming that each adopter only buys one unit, the sales rate, $s(t) = mf(t)$, where $f(t)$ is given by:

$$f(t) = \left[\frac{\frac{(p+q)^2}{p}e^{-(p+q)t}}{\left(1+\frac{q}{p}e^{-(p+q)t}\right)^2} \right] \tag{3.4}$$

The point of inflection in $F(t)$ occurs at time t^*, which corresponds to the maximum penetration rate.

$$F(t^*) = \frac{1}{2} - \frac{p}{2q} \tag{3.5}$$

$$t^* = -\left[\frac{1}{(p+q)}\right]\ln\left(\frac{p}{q}\right) \tag{3.6}$$

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Models with Marketing Mix Variables

In the next two sections an overview of the modifications to the original Bass (1969) model will be given. We will start with examples of models that include marketing mix variables as covariates. Then we will give examples of studies where macro level covariates are included in the Bass model. For our purposes, these models are interesting in terms of the manner in which the covariates are incorporated in the model.

Models with Price Alone

Robinson and Lakhani (1975) and Others

Robinson and Lakhani (1975) were the first to introduce decision variables into the diffusion models. The model they used to examine the profit differences due to optimal pricing sequence over the planning horizon versus a myopically optimal pricing policy (i.e., marginal revenue equals marginal cost in each period) is:

$$S(t) = (m - Y)(p + qY)e^{-k\,\mathrm{Pr}(t)} \tag{3.8}$$

where Y is the cumulative sales, $Pr(t)$ is price at time t, and k is a price coefficient.

The main problem with the Robertson-Lakhani model is that it is not viable for empirical estimation unless k is near 0 or price is constant (then it reduces to the Bass model). Other models similar to the Robertson-Lakhani model are used in Horsky and Simon (1983) and Dockner ar

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and Dockner and Jorgenson (1988). Estimation with these models is generally problematic as well (Bass, Jain, and Krishnan 2000).

Bass (1980)

The Bass (1980) model starts with a constant elasticity demand function:

$$Q(t) = f(t)c[\Pr(t)]^{\eta} \tag{3.9}$$

where $Q(t)$ is the quantity demanded at time t, $\Pr(t)$ is the price of product at time t, $f(t)$ is the Bass model specification given in Equation 3.2, c is the cost function, and η is the price elasticity parameter. Under the assumptions firms are choosing prices to maximize profits myopically, and marginal costs follow the experience curve with λ as the learning rate parameter the closed form solution for demand at time t is:

$$Q(t) = \left[\frac{m}{(1-\lambda\eta)}\right] f(t)F(t)^{\lambda\eta/(1-\lambda\eta)} \tag{3.10}$$

This equation is capable of empirical estimation of p, q, m, and η once λ is estimated from the historic relationship of price and experience curve, and then substituted in the equation. Although closed form solution and capability of empirical estimation are desirable properties, the above equation does not reduce to the Bass (1969) model when prices are changing. It also lacks the carry-through property; it is a current-effects model. Hence its managerial usefulness and implementation are limited.

Kalish (1985)

In Kalish (1985) study the main argument is that it is the information about the new product, not the new product per se, that diffuses in the social system through advertising and

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and word-of-mouth. Hence the model is built to capture how the new product is perceived in the market with respect to the uncertainty surrounding its performance, its utility to the potential adopter, and its price. The two simultaneous differential equations (one for the awareness process, the other for the adoption process) representing the model are:

$$\begin{aligned} \frac{dI}{dt} &= [1-I]\left[f(A(t)) + bI + b'\left(\frac{Y(t)}{m}\right)\right] \\ \frac{dY}{dt} &= \left[g\left(\frac{\Pr(t)}{u(Y(t)/m)}\right)I - Y(t)\right]k \end{aligned} \tag{3.11}$$

where $Y(t)$ is the cumulative sales up to time t, $\Pr(t)$ is the price at time t, $A(t)$ is the advertising at time t, I is the information or awareness level, m is the initial market potential, g, f, and u are function operators, and b, b', and k are parameters.

Assuming I to be 1, g has an exponential and u has a quadratic specification at the empirical stage, the model reduces to the following empirically testifiable form where advertising is no longer included:

$$S(t) = \left[m \exp\left\{-\frac{\beta \Pr(t)(1+\gamma a)}{\gamma a + (Y(t)/m)^2}\right\} - Y(t)\right]k \tag{3.12}$$

where β and γ are new parameters.

This model has the desirable carry-through property since price is included in the model in such a way that an impact on sales at time t created by a price change at time t is carried to the future periods through the diffusion effect. However, this model has no solution expressed as a function of time, price and advertising alone (a closed form lin

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solution), and contains constructs difficult to measure in a real market, which in turn limits its managerial usefulness.

Kamakura and Balasubramanian (1988)

The main purpose of the Kamakura and Balasubramanian (1988) model was to use an extended data set that goes well beyond the usually used a few years of data in a modified Bass model to test the impact of price on diffusion speed or market potential. The model where the price effect is incorporated explicitly is:

$$S(t) = [p + qY(t)]\Pr(t)^{\beta_1}\left[\theta M(t)\Pr(t)^{\beta_2} - Y(t)\right] \quad (3.13)$$

where β_1 represents the impact of price on the adoption speed, β_2 represents the impact of price on the market potential, $M(t)$ is the number of households with electricity at time t, and θ is the ultimate penetration level.

Kamakura and Balasubramanian (1988) estimated this model using a discrete time formulation while the diffusion equation is a continuous one. This may have introduced a time-interval bias in the parameter estimates (Schmittlein and Mahajan 1982). Although this model has the carry-through property, it does not reduce to the Bass model unless price is constant, and it does not have a closed form solution.

Jain and Rao (1990)

Jain and Rao (1990) used the continuous time formulation of the Bass (1969) model (to overcome the methodological shortcomings of the Kamakura and Balasubramanian (1988) model, and proposed two model specifications that include price:

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$$S(t) = \left(m\,\Pr(t)^{-\eta} - Y(t-1) \right) \frac{F(t) - F(t-1)}{1 - F(t-1)}$$
$$S(t) = \left(m - Y(t-1) \right) \Pr(t)^{-\eta} \frac{F(t) - F(t-1)}{1 - F(t-1)} \tag{3.14}$$

where $F(.)$ is the Bass (1969) model given by Equation 3.3. In the first model, price affects the market potential whereas in the second model it affects the remaining sales potential. The estimation results yielded that the second model is better in terms of fit.

It should be noted that price is modeled to affect the sales function (Equation 3.3) rather than the basic diffusion process (Equation 3.1). This sales function was derived independently by solving the differential Equation 3.1. Also, the Jain and Rao (1990) model does not have the carry-through property, and has a closed form solution for part of the model that does not include the price variable.

Horsky (1990)

The model Horsky (1990) built is based on an economic principle that a new product is adopted because it maximizes the net utility for the household. The consumer evaluates the benefits of the new product (time saving, and utility enhancement) using reservation price (the maximum price a consumer is willing to pay given the benefits of the new product), his wage rate, and the price of the new product. The final form of the diffusion model Horsky (1990) used is:

$$S(t) = \left[\frac{\theta M(t)}{1 + \exp\left\{ - \dfrac{K + w(t) - k\Pr(t)}{\delta(t)} \right\}} - Y(t) \right] [p + qY(t)] \tag{3.15}$$

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where $w(t)$ is the average wage rate of the population, $Pr(t)$ is the average market price of the product, δ represents the dispersion of both of these distributions, K and k are the time-saving and utility enhancing attributes of the new product, respectively, $Y(t)$ is the cumulative sales up to time t, $M(t)$ is the total number of households in the U.S. population, θ is the fraction who are potential buyers, and p and q are the diffusion parameters. Note that both the wage distribution across the population and the price distribution change over time. The first part of the model is the income-price-market saturation component, and the second part is the diffusion process.

The Horsky (1990) model has the desirable carry-through property. It does not have a closed form solution though. Further, the empirical results of the study are open to criticism that Horsky (1990) used data sets with long time intervals introducing bias to the parameter estimates due to replacement purchases. Although it was assumed that 70 percent of the demand in later years was replacement purchases, there is no empirical support for this assumption on which empirical results heavily depend. Still, it should be noted that Horsky (1990) attempts to explain why rather than when individuals buy a new product, an approach that should be commanded.

Models with Advertising Alone

Horsky and Simon (1983)

The underlying proposition of the Horsky and Simon (1983) model is that advertising affects the innovative characteristics of the adoption population. Their model is:

$$S(t) = \left[\alpha + \beta \ln A(t) + qY(t-1)\right]\left[m - Y(t-1)\right] \qquad (3.16)$$

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where $A(t)$ is the advertising at time t, and β is the effectiveness of advertising.

The empirical estimation of the model (using data for telephone banking in five cities) provided good fit and significant estimates for advertising effectiveness.

Simon and Sebastian (1987)

The argument of the Simon and Sebastian (1987) study is that advertising could affect either innovation or imitation component of the diffusion process. Hence, they empirically test the following two models using telephone adoption data in Germany.

$$\begin{aligned} S(t) &= [p + pf(A(t)) + qY(t-1)][m - Y(t-1)] \\ S(t) &= [p + \{q + qf(A(t))\}Y(t-1)][m - Y(t-1)] \end{aligned} \tag{3.17}$$

where $A(t)$ is the advertising in time t. The function f had one of the three alternative forms: $\ln(A(t))$, $\sum_{\tau=0}^{t} \ln(A(t))$, or $\ln(WA(t))$ where $WA(t)$ is the weighted average of the advertising from time 0 to time t. The empirical estimation of the (six) models yielded the conclusion that advertising affects the imitation component of the diffusion process.

Given that both of the two studies that incorporated advertising in the diffusion model used data for only one product and OLS as the estimation procedure, their empirical results need to be accepted with caution. Also notice that, although both Horsky and Simon (1983) and Simon and Sebastian (1987) models possess the carry-through property, neither have a closed form solution.

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Models with Price and Advertising

Generalized Bass Model (Bass, Krishnan, and Jain 1994)

Bass, Krishnan, and Jain (1994) have proposed a generalized form of the Bass model that incorporates the effects of marketing mix variables on the likelihood of adoption of the new product. They added a multiplicative factor $Z(t)$ to the original Bass (1969) model:

$$s(t) = \frac{dx(t)}{dt} = \left[p + \left\{q\frac{x(t)}{m}\right\}\right][m - x(t)]Z(t) \tag{3.18}$$

where

$$Z(t) = 1 + \alpha\left[\frac{P'(t)}{P(t)}\right] + \beta\left[\frac{A'(t)}{A(t)}\right] \tag{3.19}$$

$P(t)$ and $A(t)$ are the price and advertising at time t. $P'(t)$ and $A'(t)$ are the rate of change in price and advertising respectively at time t.

The generalized Bass model is solvable to yield sales as an explicit function of time, price, and advertising in the following form:

$$S(t) = m\frac{(p+q)^2}{p}\left(1 + \beta_1\frac{\Pr'(t)}{\Pr(t)} + \beta_2\frac{A'(t)}{A(t)}\right)\frac{e^{-(p+q)(t+\beta_1\ln(\Pr)+\beta_2\ln(A)}}{\left[1+\frac{q}{p}e^{-(p+q)(t+\beta_1\ln(\Pr)+\beta_2\ln(A)}\right]^2} \tag{3.20}$$

The generalized Bass model has all of the desirable properties described at the beginning of this chapter. It reduces to the Bass model when prices and other decision variables are changing by a constant percentage; it has a closed form solution; and it has the carry-through property. The model is managerially useful and implementable as well. The generalized Bass model has strong theoretical and empirical support. It provides an explanation of the existence of the empirical generalization of the Bass diffusion curve, which is almost always observed in diffusion phenomena. One practical concern, however, arises because the covariates in the generalized Bass model act through percentage changes in the variables rather than the levels of the variables. This problem can partially be handled by an assumption that the initial price acts as a reference point, and subsequent changes in price may be used to convert to price levels (Krishnan, Bass, Jain 1999).

Proportional Hazard Models (Bass, Jain and Krishnan 2000)

Bass, Jain and Krishnan (2000) present a proportional-hazard model of diffusion using the proportional-hazard framework introduced by Cox (1972). Although these models have the limitation of being current-effects models, they are worth comparing with the generalized Bass model, particularly because both changes and levels of the covariates can be used in these diffusion models.

The hazard function is given by $\lambda(t, Z)$ where t, time to adoption, is a random variable with the distribution function F and the density function f. $\lambda(t, Z)$ represents the instantaneous probability of adoption at time t given that the individual did not adopt before time t. Hence, it can be expressed as:

$$\lambda(t,Z) = \frac{f(t,Z)}{[1-F(t,Z)]} \tag{3.21}$$

Integrating Equation (3.21) and using $F(t,Z) = 0$ as the initial condition, the distribution function showing the one-to-one correspondence between the distribution function and the hazard function of the random variable Z is:

$$F(t,Z) = 1 - \exp\left[-\int_0^t \lambda(u,Z)du\right] \quad (3.22)$$

Following Cox (1972), the conditional hazard rate $\lambda(t, Z)$ can be expressed as

$\lambda(t,Z) = \lambda_0(t)\theta\{Z(t)\}$.

Using the specification of the Bass (1969) model (Equation 3.2) as the base-line hazard function (λ_0), and modeling function of the marketing mix variables, $\theta\{Z(t)\}$, that act multiplicatively on the baseline hazard rate as an exponential function (i.e., $\exp\{Z(t)\beta\}$ where β is the set of unknown coefficients associated with the marketing mix variables), the hazard function and the distribution function can be expressed as:

$$\lambda(t,Z) = \frac{p+q}{\left[1 + \frac{q}{p}\exp((p+q)t)\right]}\exp\{Z(t)\} \quad (3.23)$$

$$F(t,Z) = 1 - \exp\left[-\int_0^t \left\{\frac{p+q}{1 + \frac{q}{p}\exp((p+q)u}\right\}\exp\{Z(u)\beta\}du\right] \quad (3.24)$$

Equation 3.24 takes the following form after using the properties of definite integrals and evaluating it:

$$F(t,Z) = 1 - \exp\left[\Sigma_{\tau=1}^{t}\left\{\exp\{Z(\tau)\beta\}\log\left\{\frac{\frac{q}{p} + \exp((p+q)\tau)}{\frac{q}{p} + \exp((p+q)(\tau-1)}\right\}\right\}\right] \quad (3.25)$$

Equation 3.25 represents the distribution function of adoption time T in the presence of marketing mix variables.

Since, in practice, the number of individuals who have adopted the product in each time period rather than the individual adoption times are known, Bass, Jain and Krishnan (2000) worked on the discrete proportional-hazard model for grouped data (Kalbfleisch and Prentice 1980) in order to estimate the diffusion parameters.

$$\frac{F(t_i,Z)-F(t_{i=1},Z)}{1-F(t_{i-1},Z)}=1-\left[\exp\left[-\exp\{Z(t_i)\beta\}\log\left\{\frac{\frac{q}{p}+\exp((p+q)t_i)}{\frac{q}{p}+\exp((p+q)(t_{i-1})}\right\}\right]\right]$$

$$=1-\left[\exp\left[-(p+q)(t_i-t_{i-1})\left\{\frac{1+\frac{q}{p}+\exp(-(p+q)t_{i-1})}{1+\frac{q}{p}+\exp((p+q)(t_i)}\right\}\right]\right]^{\exp\{Z(t_i)\beta\}} \tag{3.26}$$

The time at which sales rate reaches its peak for Equation (3.26) is:

$$t^* = \frac{1}{p+q}\ln\left(\frac{q}{p}\right) \tag{3.27}$$

which is identical to the time peak expression for the original Bass (1969) model.

The sales process that Bass, Jain and Krishnan (2000) derived using Equation (3.26) can be expressed as:

$$S(t_i)=\lfloor m-X(t_{i-1})\rfloor J(t_{i-1},t_i)+u(t_i) \tag{3.28}$$

$$\text{where } J(t_{i-1},t_i)=1-\left[\exp\left[-(p+q)\left\{\frac{1+\frac{q}{p}\exp(-(p+q)t_{i-1})}{1+\frac{q}{p}+\exp((p+q)(t_i)}\right\}\right]\right]^{\exp\{Z(t_i)\beta\}} \tag{3.29}$$

assuming intervals (t_{i-1},t_i) to be equally spaced and of unit length.

Bass, Jain and Krishnan (2000) compared the empirical results of the generalized Bass model, and two proportional-hazard models (one using levels of the covariates, and one using percentage changes in the covariates). For the proportional-hazard model with levels (PHM-L), the model estimates of *p*, *q*, and *m* as well as of the price and advertising coefficients turned out to be very different from the estimates for the generalized Bass model (GBM) and the proportional-hazard model with percentage changes (PHM-D). PHM-L produced higher R^2s and generally higher t-ratios than both GBM and PHM-D, most probably due to the form of the input variables (level versus percentage change). One-step ahead forecast performance of the PHM-L model was superior compared to the other two models as well.

Models with Macro Variables as Covariates

The examples we have chosen for this section are two of the most recent multinational studies with the rationale that these have built on the previous ones, particularly with respect to methodological issues.

Dekimpe, Parker, and Sarvary (1998)

Dekimpe, Parker, and Sarvary (1998) proposed a three-stage estimation process that they suggested is temporally consistent with the evolutionary nature of the diffusion process. For a given country *i*, they defined the following adoption function over time:

$$s_{i,t} = \left[\left(\frac{s_i(1)}{C_i SZ_i}\right) + \left(\frac{B_i x_i(t-1)}{C_i SZ_i}\right)\right]\left[C_i SZ_i - x_i(t-1)\right] \qquad (3.30)$$

where $s_{i,t}$ is sales in country i over the t^{th} time interval, and $x_i(t-1)$ is cumulative sales (adoptions) through the end of period t-1. The term $s_i(1)$ represents the penetration level at the end of the first period, SZ_i denotes the social system size (population), and C_i $(0 \le C_i \le 1)$ captures the long-run adoption ceiling. $A_{i1} = \left(\frac{s_i(1)}{C_i SZ_i} \right)$ represents the intercept of the penetration curve, which is specified as endogenous to the social system. The parameter B_i is defined as the growth-rate parameter that captures the growth that occurs between the intercept and the adoption ceiling. Country-specific covariates are incorporated using logistic transformations $A_{it} = \left[1 + e^{-d_1 X_i} \right]^{-1}$ and $B_i = \left[1 + e^{-d_2 X_i} \right]^{-1}$ where X_i denotes a country-specific set of covariates.

The first stage of the three-stage estimation procedure Dekimpe, Parker, and Sarvary (1998) used consists of external estimation of the social system sizes and long-run adoption ceilings across countries. These are specified as exogenous. In the second stage, the intercepts for each country, which are exogenous to the next stage, are calculated. In the third stage, internal estimation of each country's growth parameters specified as endogenous to the social system is undertaken using data pooled across countries. The estimation procedure requires sample matching, which entails matching countries based on external criteria. Dekimpe, Parker, and Sarvary (1998) suggested that four components of the diffusion process (the social system size, the adoption ceiling, the time intercept origin, and the growth rate) require matching. Once the countries are matched according to these criteria, the diffusion process based on similar sets of countries can be understood better. Since the diffusion process is temporally sequential in nature (for example, social infrastructure is established before the product launch), the matched samples can be used to estimate diffusion parameters sequentially, rather than simultaneously.

The advantages of the staged estimation procedure include sufficient flexibility to explain cross-country variation using either endogenous or exogenous covariates as well as provision of a reasonable basis for testing hypotheses when only the earliest adoption figures are available. This procedure also allows for estimation when products are launched at different times across countries. However, there are also limitations. For example, estimated parameters for the intercept, the long-run adoption ceiling, and the social system size for each country are fixed in the third stage while the ceiling and the population size may change over time. Sequential rather than simultaneous estimation may make parameter estimates inconsistent (Anderson 1970). Accordingly, the estimation procedure employed needs to consider that diffusion of the product may be related across countries after launch in a simultaneous manner (see e.g., Putsis et al.1997).

Talukdar, Sudhir, and Ainslie (2002)

The base model of the Talukdar, Sudhir, and Ainslie (2002) study is the discrete time version of the Bass (1969) diffusion model. They modify this base model by introducing an autocorrelated error term in a multiplicative fashion.

$$S_{pr,c}(t) - S_{pr,c}(t-1) = \alpha_{pr,c}(F_{pr,c}(t) - F_{pr,c}(t-1))e^{\varepsilon_{pr,c}(t)} \qquad (3.31)$$

where $S_{pr,c}(t)$ is the per capita cumulative sales of product *pr* in country *c* at time *t*, $F_{pr,c}(t)$ is the cumulative density function for the diffusion process for a particular product-country pair at time *t*, $\alpha_{pr,c}$ is the market penetration potential for the product, and $\varepsilon_{pr,c}(t)$ is the autocorrelated error term.

Note that:

$$F_{pr,c}(t) = \left[\frac{1 - \exp(-(p_{pr,c} + q_{pr,c})t)}{1 + \frac{q_{pr,c}}{p_{pr,c}} \exp(-(p_{pr,c} + q_{pr,c})t)} \right] \qquad (3.32)$$

and

$$m_{pr,c} = \alpha_{pr,c} N_c(t) \qquad (3.33)$$

where $m_{pr,c}$ is the total market potential in a country, and $N_c(t)$ is the population of the country *c* at time *t*.

Talukdar, Sudhir, and Ainslie (2002) estimate the diffusion model parameters (*p*, *q*, and *α*) by nonlinear least squares approach proposed by Srinivasan and Mason (1986). Then, they model they model the heterogeneity structure of the (transformed) parameters by separating each parameter into a component that is common across all countries for a particular product, a component that is common across all products for a particular country, and a component that is unique the particular product-country combination as represented in Equation (3.34). Specifically,

$\alpha_{pr,c} = \exp(\alpha^*_{pr,c})$, $p_{pr,c} = \exp(p^*_{pr,c})$, and $q_{pr,c} = \exp(q^*_{pr,c})$

$$\begin{bmatrix} \alpha^*_{pr,c} \\ p^*_{pr,c} \\ q^*_{pr,c} \end{bmatrix} = \begin{bmatrix} \alpha^*_{pr} + \alpha^*_{c} \\ p^*_{pr} + p^*_{c} \\ q^*_{pr} + q^*_{c} \end{bmatrix} + \begin{bmatrix} v_{\alpha,pr,c} \\ v_{p,pr,c} \\ v_{q,pr,c} \end{bmatrix} \qquad (3.34)$$

Further, each component of the diffusion parameters is modeled in the following manner. Note that country specific covariates are modeled as time-invariant in Equation (3.36), and Equation (3.37) does not contain any hierarchical regressors (it is a random effects model).

$$\begin{bmatrix} v_{\alpha,pr,c} \\ v_{p,pr,c} \\ v_{q,pr,c} \end{bmatrix} = \begin{bmatrix} X'_{\alpha,pr,c}\beta_{\alpha,pr,c} \\ X'_{p,pr,c}\beta_{p,pr,c} \\ X'_{q,pr,c}\beta_{q,pr,c} \end{bmatrix} + \begin{bmatrix} \pi_{\alpha,pr,c} \\ \pi_{p,pr,c} \\ \pi_{q,pr,c} \end{bmatrix}, \quad \begin{bmatrix} \pi_{\alpha,pr,c} \\ \pi_{p,pr,c} \\ \pi_{q,pr,c} \end{bmatrix} \sim MVN(0,?) \qquad (3.35)$$

$$\begin{bmatrix} \alpha^*_{c} \\ p^*_{c} \\ q^*_{c} \end{bmatrix} = \begin{bmatrix} X'_{\alpha,c}\beta_{\alpha,c} \\ X'_{p,c}\beta_{p,c} \\ X'_{q,c}\beta_{q,c} \end{bmatrix} + \begin{bmatrix} \pi_{\alpha,c} \\ \pi_{p,c} \\ \pi_{q,c} \end{bmatrix}, \quad \begin{bmatrix} \pi_{\alpha,c} \\ \pi_{p,c} \\ \pi_{q,c} \end{bmatrix} \sim MVN(0,?_{c}) \qquad (3.36)$$

$$\begin{bmatrix} \alpha^*_{pr} \\ p^*_{pr} \\ q^*_{pr} \end{bmatrix} = \begin{bmatrix} \pi_{\alpha,pr} \\ \pi_{p,pr} \\ \pi_{q,pr} \end{bmatrix}, \quad \begin{bmatrix} \pi_{\alpha,pr} \\ \pi_{p,pr} \\ \pi_{q,pr} \end{bmatrix} \sim MVN(0,?_{pr}) \qquad (3.37)$$

Talukdar, Sudhir, and Ainslie (2002) estimated the above equations using the Hierarchical Bayesian estimation methodology. Note that more details about the covariates and related results are given in Chapter 2. For the purposes of this chapter, we will present results that are directly related to the methodological aspect of the study. Talukdar, Sudhir, and Ainslie (2002) found that modeling the correlations between α, p, and q using the multivariate error structure as shown in Equations (3.35), (3.36), and (3.37) improved the efficiency of the estimates because many of these correlations were high. In general, the error terms of p and q were negatively correlated, while the error terms of p and α are negatively correlated, and the error terms of q and α are positively correlated. Talukdar, Sudhir, and Ainslie (2002) also found that modeling serial correlation for product errors improved the efficiency of the estimates as well. With respect to the variance decomposition of heterogeneity, most of the variance for α^*, was captured by country effects while for p^*, and q^*, it was the product effects that accounted for the majority of the variance in them.

The methodological review of the diffusion studies with particular emphasis on the model specifications reveals that the covariates are incorporated in the models in one of two ways. They are either entered in the model as a multiplicative component (just like, for example, in the case of the Generalized Bass Model) or the covariates are allowed to impact specific diffusion parameters (just like in, for example, Dekimpe, Parker, Sarvay 1998). In this dissertation we will prefer to use a specification similar to the one on the Generalized Bass Model with the rationale that the validity of this model is well established in the literature, and that it has the desirable properties mentioned in Bass, Krishnan, and Jain (1994) and Bass, Jain and Krishnan (2000). These are listed in the beginning of the chapter.

In the next section, we will present the details of our model. However, first we will present more information on the Augmented Kalman Filter with Continuous State and Discrete Observations methodology since certain advantages of this estimation procedure provide the flexibility to specify our model the way we do.

Methodology and Model

What is a Kalman Filter?

Theoretically, the Kalman Filter is an estimator for what is called the linear-quadratic problem, which is the problem of estimating the instantaneous state of a linear dynamic system perturbed by white noise (by using measurements linearly related to the state but corrupted by white noise. The resulting estimator is statistically optimal with respect to any quadratic function of estimation error. Practically, Kalman filter is a mathematical tool for inferring the nature of a dynamic system from indirect and noisy measurements. It is also used for predicting the likely future courses of dynamic systems that may or may not be controlled.

The Kalman filter is a complete statistical characterization of an estimation problem. In fact, it is more than an estimator because it propagates the entire probability distribution of the variables it is tasked to estimate. This yields a complete characterization of the current state of knowledge of the dynamic system, including the influence of all past measurements.

A "filter" is a physical device for removing unwanted fractions of mixtures. Prior to 1930s the term was applied to analog circuits that filter electronic signals. This concept was extended in the 1930s and 1940s to the separation of signals from noise. Kalmogorov and Wiener used the statistical characterization of the probability distributions of signals and noise in forming an optimal estimate of the signal, given the sum of the signal and the noise. With Kalman filtering (1960), the term gained a meaning beyond the idea of separation of the components of a mixture. It has also come to include the solution of an inversion problem where the measurable variables are represented as functions of the variables of principle interest. The Kalman filter inverts this functional relationship and estimates the independent variables as inverted functions of the dependent (measurable) variables. These variables of interest are also allowed to be dynamic.

For the purposes of this dissertation, we are specifically interested in two extensions of the Kalman filter methodology: Extended Kalman Filter (see Lewis (1986) for details) and Augmented Kalman Filter (see Stengel (1986) for details). Although the Kalman filter was originally derived for a linear problem, it can be applied to nonlinear problems successfully. In that case, it is called an extended Kalman filter. The idea behind such applications is to use partial derivatives as approximations of nonlinear relations. McGee and Schmidt (1985) introduced the idea of evaluating these partial derivatives at the estimated value of the state variables. The state estimators of the Extended Kalman Filter are formulated under the assumption that dynamic system parameters and input or measurement error statistics are known. However, there is usually some degree of uncertainty regarding the system coefficients and covariates. Simultaneously estimating the uncertain parameters and statistics, and using this additional information to adapt the model coefficients to the measurements can improve state estimators. Augmented Kalman Filter enables such adaptive estimation of the model parameters through the estimation of the augmented state vector. The augmented state vector consists of the original state vector of the state-space model and the vector of model parameters to be estimated.

In the marketing literature, Xie et al. (1997) combined the Extended Kalman Filter and Augmented Kalman Filter methods to form the Augmented Kalman Filter with Continuous State and Discrete Observations (AKF (C-D)) in order to examine the diffusion of innovations. As noted earlier, AKF (C-D) is the methodology to be used in this dissertation as well.

Before presenting the details of the AKF (C-D), the standard Kalman Filter and the advantages of using AKF (C-D) compared to the standard Kalman Filter within the context of diffusion of innovations will be described.

Standard Kalman Filter vs. Augmented Kalman Filter with Continuous State and Discrete Observations

The basic form of Kalman filter consists of two sets of equations. System (transition) equations describe the evolution of the state variable y_k. Measurement equations describe how the observations are related to the state of the system. Together, the set of system and measurement equations represents a state space model.

System equations are:

$$y_{k+1} = f_k\left[y_k, \beta, u_k, t_k\right] + G_k w_k \qquad y_0 \sim \left(\bar{y}_0, P_0\right), w_k \sim (0, Q) \tag{3.38}$$

Measurement equations are:

$$z_k = H_k y_k + v_k \qquad v_k \sim (0, R) \tag{3.39}$$

where y_k is the state vector, z_k is the observation vector. w_k and v_k are stationary white noise processes uncorrelated with y_k and with each other. f_k is a vector function of state (y_k), parameter vector (β), control vector u_k and time t_k., G_k and H_k are known matrices, and Q and R are covariance matrices of the process and measurement noises, respectively.

The AKF (C-D) has certain advantages compared to the standard Kalman filter with respect to the application to diffusion of innovations. In a standard Kalman filter, both the system and the measurement equations are either discrete or continuous. AKF (C-D), on the other hand, is able to handle a hybrid structure where the system equation is continuous and the measurement equation is discrete, which is the appropriate framework for estimating a continuous diffusion equation without introducing time interval bias due to discretization. Second, the standard Kalman filter treats the parameter vector as given, but in the estimation of diffusion models, the parameters (p, q, and m in the Bass model) are often unknown. AKF (C-D) is capable of overcoming this situation due to the adaptive nature of the estimation process. Further, the standard Kalman filter can only be applied to situations where the differential equation has an analytical solution whereas AKF (C-D) does not have such a requirement in order to yield plausible estimates.

The formulation of the AKF(C-D) model is as follows:

$$\begin{aligned} \frac{dx(t)}{d(t)} &= f_x[x(t), \phi(t), \beta, t] + w_x \\ \frac{d\beta}{dt} &= f_\beta[\beta, x(t), t] + w_\beta \\ z_k &= x_k + v_k \end{aligned} \tag{3.38}$$

where $x(t)$ is the cumulative number of adopters, $\phi(t)$ is a vector of covariates (for example, marketing mix variables, or globalization drivers), β is the unknown parameter vector, w_x and w_β are the process noise, x_k and z_k are the true and observed cumulative number of adopters at time t_k, and v_k is the observation noise. It is assumed that $x(0) \sim (x_0, \sigma_{x0})$ and $\beta(0) \sim (\beta_0, P_{\beta 0})$, $\{w_x, w_\beta\}$ and $\{v_k\}$ are white noises. $\{w_x, w_\beta\} \sim (0, Q)$ and $\{v_k\} \sim (0, r)$, and $\{w_x, w_\beta\}$ and $\{v_k\}$ are not correlated to one another. The process noise, w_x, includes model specification errors (due to omitted variables and/or misspecification), and sampling errors which can occur when using the model to describe the diffusion process of a sampled group instead of the entire population. The measurement error, v_k, includes random errors in the data collection.

Without loss of generality, an augmented state vector ($y(t)$) that consists of the original state vector ($x(t)$) and the unknown parameter vector (β) can be formed. Then the original state space model can be rewritten as:

$$\frac{dy(t)}{dt} = f_y\big(y(t), \phi(t), t\big) + w_y \qquad f_y = (f_x, f_\beta)^{\mathsf{T}}$$

$$z_k = x_k + v_k \tag{3.39}$$

The AKF(C-D) algorithm is essentially a Bayesian updating procedure. Using prior experience and knowledge, one gives the initial estimates for the unknown parameters. AKF(C-D) updates the parameter estimates of the diffusion model as new data become available. It estimates parameters and updates the state variables through a time updating process and a measurement updating process.

The model that will be used in the dissertation will be an extension of the Bass model where augmented state vector (y) includes the cumulative adoption rate (x), the coefficient of innovation (p), the coefficient of imitation (q), and the number of potential adopters (m), and the vector of covariates (ϕ) includes the globalization drivers (FDI inflows, trade volume, and GDP).

Some of the other major advantages of AKF (C-D) methodology are general applicability, capability of estimating time varying parameters, and capability of incorporating observation noise into the estimation process. AKF (C-D) can be applied to estimate all differential diffusion models in the marketing literature including the extensions of the Bass (1969) model where covariates are incorporated to the model, and models with parameters changing over time. Since one of the purposes of this dissertation is to examine how diffusion parameters change over time due to the impact of certain globalization drivers, AKF (C-D) presents itself as a very useful tool. It essentially is a Bayesian updating process that starts with prior estimates of the parameters and updates them as data accumulates. Thus, it is capable of capturing the dynamic nature of the diffusion parameters, namely coefficient of external influence, coefficient of internal influence, and market potential. These parameters can change over time due to a variety of factors such as changing characteristics of the potential adopter population, technological changes, product modifications, pricing changes, general economic conditions etc. (Bretschneider and Mahajan 1980).

Time-varying characteristics of the diffusion parameter can be captured by the AKF (C-D) methodology in one of two ways. First, if how parameters change over time is known, the parameters can be updated using the time-updating process of the AKF (C-D) methodology. This is because the diffusion parameters are modeled as state variables in the augmented state vector y. It is possible to handle both deterministic and random changes in the parameters over time. If the changes in parameters over time are modeled in a deterministic manner (which suggests there is knowledge regarding both the system and the specification of the model), the value of the parameters can be updated by integrating $\frac{d\beta}{dt} = f_{\beta}\left[\beta, x(t), t\right]$ in the time-updating process. If the changes in parameters over time are modeled in a random manner (which suggests there is some knowledge of the system but not the specification of the model), the variance of the fluctuation in the noise matrix, Q, can be incorporated and used to update the variance of the parameters.

Second, if both there is little knowledge of the system and the specification of how the diffusion parameters change over time is not known, AKF (C-D) is still useful in capturing these changes by adjusting to prediction error. Since the number of adopters in each period is a function of the diffusion parameters, changes in the parameters will be reflected in the prediction error. Once a new observation is incorporated, information about parameter changes, through prediction error, will be used to generate new parameter estimates. Thus, AKF (C-D) yields self-adaptive diffusion parameters that automatically adjust to changing diffusion data patterns (Xie et al. 1997). Using such an adaptive approach is particularly useful when the causes of the diffusion parameters are not known.

In this dissertation, this second approach will be used. This will enable to observe how diffusion parameters change over time due to certain globalization drivers without imposing any particular specifications as to the nature of the parameter changes. Yet, due to the Bayesian updating capability of the AKF (C-D) methodology, good quality estimates of the diffusion parameters will be obtained. Given that the diffusion parameters can change over time due to many reasons such as the changing characteristics of the potential adopter population, technological changes, pricing changes, general economic conditions as well as other endogenous and exogenous factors (Bretschneider and Mahajan 1980), and there are forty-three different countries in the sample (for some of which there is no prior knowledge of the diffusion phenomenon), it is necessary to take advantage of the flexible approach the methodology can provide.

Model

Once again, the general form of an augmented state space model is:

$$\frac{dy(t)}{dt} = f_y(y(t), \phi(t), t) + w_y \qquad f_y = (f_x, f_\beta)^T$$

$$z_k = x_k + v_k$$

In our model:

$$f_x = s(t) = \left[p(t) + \left\{ q(t)\frac{x(t)}{m} \right\} \right] [m(t) - x(t)] g(t)$$

$$g(t) = 1 + a\frac{T'(t)}{T(t)} + b\frac{D'(t)}{D(t)} + c\frac{I'(t)}{I(t)}$$

where $T(t)$ is trade volume at time t, $T'(t)$ is the rate of change in trade volume at time t, $D(t)$ is foreign direct investment inflows at time t, $D'(t)$ is the rate of change in foreign direct investment inflows at time t, $I(t)$ is GDP at time t, $I'(t)$ is the rate of change in GDP at time t. The ratios of growth rate to level for the covariates create indexes that allow comparability across countries. The specification of our model is inspired by the Generalized Bass Model as mentioned earlier. z_k is observed sales.

Algorithm

The formulation of the AKF (C-D) procedure is:

$$\frac{dx(t)}{d(t)} = f_x[x(t), \phi(t), \beta, t] + w_x$$

$$\frac{d\beta}{dt} = f_\beta[\beta, x(t), t] + w_\beta \qquad (3.38)$$

$$z_k = x_k + v_k$$

where $x(t)$ is the cumulative number of adopters, $\phi(t)$ is a vector of covariates (for example, marketing mix variables, or globalization drivers), β is the unknown parameter vector, w_x and w_β are the process noise, x_k and z_k are the true and observed cumulative number of adopters at time t_k, and v_k is the observation noise. It is assumed that $x(0) \sim (x_0, \sigma_{x0})$ and $\beta(0) \sim (\beta_0, P_{\beta 0})$, $\{w_x, w_\beta\}$ and $\{v_k\}$ are white noises. $\{w_x, w_\beta\} \sim (0, Q)$ and $\{v_k\} \sim (0, r)$, and $\{w_x, w_\beta\}$ and $\{v_k\}$ are not correlated to one another. Note also that the augmented version is:

$$\frac{dy(t)}{dt} = f_y(y(t), \phi(t), t) + w_y \qquad f_y = (f_x, f_\beta)^{\mathrm{T}}$$

$$z_k = x_k + v_k$$

AKF (C-D) algorithm is essentially a Bayesian updating procedure, which takes the following steps:

1. At $t = t_0$ $(k = 0)$, based on prior information, the best prior estimate of the parameter distributions ($\hat{y}_0$ and $\hat{P}_0$) and the noise statistics (r and Q) are developed to initialize the filter.

2. Time update: At a given time t_k, the diffusion model predicts sales and parameter values for the next time period t_{k+1} through the time updating process, which generates an a priori estimate of the state defined by $\hat{y}_{k+1}^-$

$$\hat{y}_{k+1}^- = E(\hat{y}_{k+1} | z_k) \qquad (3.\mathrm{A}1)$$

where $z_k = \{z_1, z_2, ..., z_k\}$ includes all variable observations at t_k. The corresponding error covariance matrix of the a priori estimate is given by

$$\hat{P}_{k+1}^{-} = Cov\left(\hat{y}_{k+1}^{-}{}^{T}\ \hat{y}_{k+1}^{-} | z_k\right) \quad (3.A2)$$

Time updating is accomplished by integrating Equations (3.A3) and (3.A4) over time interval (t_k, t_{k+1}):

$$\frac{dy}{dt} = f_y(y, \phi, t) \quad (3.A3)$$

$$\frac{dP}{dt} = F(y,t)P^T + PF^T(y,t) + Q \quad (3.A4)$$

where $F(y,t) = \frac{\partial f_y(y(t), \phi(t), t)}{\partial y} | y(t) = y$ and Equation 3.A3 is the augmented system equation without process noise.

3. Measurement update: When a new observation z_{k+1} becomes available, the estimate is modified using the forecasting error. Forecasting error is the difference between the observed sales, z_{k+1}, and the predicted sales $\hat{x}_{k+1}$. The measurement updating process generates a posterior estimate defined by $\hat{y}_{k+1}$:

$$\hat{y}_{k+1} = E\left(y_{k+1} | z_{k+1}\right) \quad (3.A5)$$

The corresponding error covariance matrix is given by:

$$\hat{P}_{k+1} = Cov\left(\hat{y}_{k+1}{}^{T}\ \hat{y}_{k+1} | z_{k+1}\right)$$

The measurement updating process is accomplished by Equations (3.A6) and (3.A7):

$$\hat{y}_{k+1} = \hat{y}_{k+1}^{-} + \psi_{k+1}(z_{k+1} - \hat{x}_{k+1}^{-}) \quad (3.A6)$$

$$\hat{P}_{k+1} = \left[I - \psi_{k+1}h\right]\hat{P}_{k+1}^{-} \quad (3.A7)$$

where I is an identity matrix, h = [1, 0, 0,….], and

$$\psi_{k+1} = \hat{P}_{k+1}^{-}h^{T}\left[h\hat{P}_{k+1}^{-}h^{T} + R\right]^{-1}$$

4. Go back to step 2 and iterate.

Data and Data Sources

As stated in Chapter 1 as well, the main data sources are the Global Market Information Database, European Marketing Data and Statistics, and International Marketing Data and Statistics by Euromonitor. Data for forty-three countries on annual sales or possession of four consumer durable goods (video camera, compact disc (CD) player, home computer, cellular phone), exports, imports, foreign direct investment inflows, GDP and population are collected. The list of countries is as follows: *Argentina*, Australia, Austria, Belgium, *Brazil*, Canada, *Chile*, *China*, Denmark, *Egypt*, Finland, France, Germany, Greece, *Hong Kong (China)*, *Hungary*, *India*, *Indonesia*, Ireland, Israel, Italy, Japan, *Malaysia*, *Mexico*, the Netherlands, New Zealand, Norway, *Pakistan*, Portugal, *Poland*, *Russia*, *Singapore*, *South Africa*, *South Korea*, Spain, Sweden, Switzerland, *Taiwan*, *Thailand*, *Tunisia*, *Turkey*, the United Kingdom, the United States of America (the countries written in *italic* are the developing countries).

CHAPTER 4

DATA AND ANALYSIS

In this chapter, first, data will be described. Second, the model and the algorithm will be explained. Then the analyses performed will be described.

Data

Data for forty-three countries on annual sales or possession of four consumer durable goods (compact disc (CD) player, home computer, mobile phone and video camera), exports, imports, foreign direct investment inflows, gross domestic product (GDP), and population are collected from the Global Market Information Database, European Marketing Data and Statistics, and International Marketing Data and Statistics by Euromonitor. The list of countries is as follows: *Argentina*, Australia, Austria, Belgium, *Brazil*, Canada, *Chile*, *China*, Denmark, *Egypt*, Finland, France, Germany, Greece, *Hong Kong (China)*, *Hungary*, *India*, *Indonesia*, Ireland, Israel, Italy, Japan, *Malaysia*, *Mexico*, the Netherlands, New Zealand, Norway, *Pakistan*, Portugal, *Poland*, *Russia*, *Singapore*, *South Africa*, *South Korea*, Spain, Sweden, Switzerland, *Taiwan*, *Thailand*, *Tunisia*, *Turkey*, the United Kingdom, the United States of America (the twenty-one countries written in *italic* are the developing countries). In order to ensure comparability of model parameters across countries all data for sales/possession, trade volume (exports plus imports), foreign direct investment inflows and GDP are calculated on per capita basis, urban population is used as a percentage of total population.

Model

As stated in the previous chapters, general form of an augmented state space model is:

$$\frac{dy(t)}{dt} = f_y(y(t),\phi(t),t) + w_y \qquad f_y = (f_x, f_\beta)^T$$

$$z_k = x_k + v_k$$

In our diffusion model:

$$f_x = s(t) = \left[p(t) + \left\{q(t)\frac{x(t)}{m}\right\}\right][m(t) - x(t)]g(t)$$

$$g(t) = 1 + a\frac{T'(t)}{T(t)} + b\frac{D'(t)}{D(t)} + c\frac{I'(t)}{I(t)}$$

where *T*(*t*) is trade volume at time *t*, *T* '(*t*) is the rate of change in trade volume at time *t*, *D*(*t*) is foreign direct investment inflows at time *t*, *D* '(*t*) is the rate of change in foreign direct investment inflows at time *t*, *I*(*t*) is GDP at time *t*, *I* '(*t*) is the rate of change in GDP at time *t*. The ratios of growth rate to level for the covariates create indexes that allow comparability across countries.

Algorithm

The formulation of the AKF (C-D) procedure is:

$$\frac{dx(t)}{d(t)} = f_x[x(t),\phi(t),\beta,t] + w_x$$

$$\frac{d\beta}{dt} = f_\beta[\beta,x(t),t] + w_\beta$$

$$z_k = x_k + v_k$$

where *x*(*t*) is the cumulative number of adopters, $\phi(t)$ is a vector of covariates (in our case globalization drivers), β is the unknown parameter vector, w_x and w_β are the process noise, x_k and z_k are the true and observed cumulative number of adopters at time t_k, and v_k is the observation noise. It is assumed that $x(0) \sim (x_0, \sigma_{x_0})$ and $\beta(0) \sim (\beta_0, P_{\beta_0})$, $\{w_x, w_\beta\}$ and $\{v_k\}$ are white noises. $\{w_x, w_\beta\} \sim (0,Q)$ and $\{v_k\} \sim (0, r)$, and $\{w_x, w_\beta\}$ and $\{v_k\}$ are not correlated to one another. Note also that the augmented version is:

$$\frac{dy(t)}{dt} = f_y(y(t), \phi(t), t) + w_y \qquad f_y = (f_x, f_\beta)^T$$

$$z_k = x_k + v_k$$

AKF (C-D) algorithm is essentially a Bayesian updating procedure, which takes the following steps:

5. At $t = t_0$ ($k = 0$), based on prior information, the best prior estimate of the parameter distributions ($\hat{y}_0$ and $\hat{P}_0$) and the noise statistics (r and Q) are developed to initialize the filter.

6. Time update: At a given time t_k, the diffusion model predicts sales and parameter values for the next time period t_{k+1} through the time updating process, which generates an a priori estimate of the state defined by $\hat{y}_{k+1}^-$

$$\hat{y}_{k+1}^- = E(\hat{y}_{k+1} | z_k) \tag{4.1}$$

where $z_k = \{z_1, z_2, ..., z_k\}$ includes all variable observations at t_k. The corresponding error covariance matrix of the a priori estimate is given by

$$\hat{P}_{k+1}^{-} = Cov\left(\hat{y}_{k+1}^{-} \;\; \hat{y}_{k+1}^{-T} | z_k\right) \qquad (4.2)$$

Time updating is accomplished by integrating Equations (4.3) and (4.4) over time interval (t_k, t_{k+1}):

$$\frac{dy}{dt} = f_y(y, \phi, t) \qquad (4.3)$$

$$\frac{dP}{dt} = F(y,t)P^T + PF^T(y,t) + Q \qquad (4.4)$$

where $F(y,t) = \frac{\partial f_y(y(t), \phi(t), t)}{\partial y} | y(t) = y$ and Equation 4.3 is the augmented system equation without process noise.

7. Measurement update: When a new observation z_{k+1} becomes available, the estimate is modified using the forecasting error. Forecasting error is the difference between the observed sales, z_{k+1}, and the predicted sales $\hat{x}_{k+1}$. The measurement updating process generates a posterior estimate defined by $\hat{y}_{k+1}$:

$$\hat{y}_{k+1} = E(y_{k+1} | z_{k+1}) \qquad (4.5)$$

The corresponding error covariance matrix is given by:

$$\hat{P}_{k+1} = Cov\left(\hat{y}_{k+1} \;\; \hat{y}_{k+1}^{T} | z_{k+1}\right) \qquad (4.6)$$

The measurement updating process is accomplished by Equations (4.7) and (4.8):

$$\hat{y}_{k+1} = \hat{y}_{k+1}^{-} + \psi_{k+1}(z_{k+1} - \hat{x}_{k+1}^{-}) \qquad (4.7)$$

$$\hat{P}_{k+1} = \left[I - \psi_{k+1}h\right]\hat{P}_{k+1}^{-} \tag{4.8}$$

where I is an identity matrix, h is the measurement matrix [1 0 0 0 0 0]'

and the Kalman gain is

$$\psi_{k+1} = \hat{P}_{k+1}^{-}h^{T}\left[h\hat{P}_{k+1}^{-}h^{T} + r\right]^{-1} \tag{4.9}$$

8. Go back to step 2 and iterate.

The specifics of the application of this algorithm to the model in this dissertation are described below. First, it is necessary to realize that we have only one differential equation explaining the diffusion process. Due to lack of prior information, particularly for developing countries, no differential equations that explain the behaviors of p, q, a, b and c over time are specified. Kalman filtering update is performed for only the per capita sales over time. Then p, q, a, b and c are estimated using nonlinear data fitting such that the sum of squared errors among the observed and estimated per capita sales are minimized. Due to concerns regarding degrees of freedom, only p and q are estimated in a time-varying manner for each of the ten time periods Kalman updating is performed; a, b, and c are assumed to be constant over time.

The initial values for starting the Kalman filtering are as follows:

Xie et al. (1997) is followed in setting the priors (both the means and the variances) for the coefficient of external influence (p) in the order of 10^{-2} and for the coefficient of internal influence (q) in the order of 10^{-1}. The priors for the coefficients of trade volume (a), foreign direct investment inflow (b) and income (c) are set in the order of 10^{-1} (For some developing countries, the orders of these priors are 10^{-3}, 10^{-2}, 10^{-2}, 10^{-2}, and 10^{-2} for p, q, a, b and c, respectively.). P_0 is the variance-covariance matrix for the augmented state vector y (y = $[x\ p\ q\ a\ b\ c]'$; note that m is not included because it is entered as the percentage of urban population in each country). The diagonal elements (variances) are set as described above; variance of per capita sales is set in the order of 10^{-2} as well. The covariances are set as 10^{-5}. Q_0 is the variance-covariance matrix of the error terms for the differential equations. Since we have only one (the diffusion equation), it is necessary to specify only the variance of the error term for that equation. It is set as 10^{-5} since the order of per capita data is comparable, particularly for the early years. The rest of the elements are zeros. r_0 is the variance of the error term for per capita sales and is set in the order of 10^{-5} as well.

It is important to notice the treatment of m (the market potential) in the application of the algorithm in this dissertation. It is not estimated like the other parameters (p, q, a, b and c) of the model; urban population of each country is used as the market potential for each time period. This approach follows, for example, Van den Bulte and Lilien (1997) and Lilien, Rangaswamy and Van den Bulte (2000) where exogenous information on m is used rather than having it be a part of the estimation procedure. Given the nature of the products used for analysis (technological, possibly high-priced, at least when first introduced), urban population is the choice for this exogenous information. In the data there are a few cases where the cumulative sales of the product exceeded the market potential. In such cases, the estimation procedure is applied for eight or nine time periods instead of ten time periods in order to obtain stable parameter estimates for the model.

Given the priors as described above, the first time updating step of the Kalman filter is accomplished by integrating the following equations over one time period:

$$\frac{dx(t)}{dt} = \left[p(t) + \left\{ q(t)\frac{x(t)}{m} \right\} \right] [m(t) - x(t)] \left[1 + a\frac{T'(t)}{T(t)} + b\frac{D'(t)}{D(t)} + c\frac{I'(t)}{I(t)} \right]$$

$$\frac{dP}{dt} = F(y,t)P^T + PF^T(y,t) + Q$$

where $F(y,t) = \frac{\partial f_y(y(t),\phi(t),t)}{\partial y} | y(t) = y$

F(y,t) is the 6x6 Jacobian matrix of the augmented state equations. The first row (six elements) of it is the partial derivative of $\frac{dx(t)}{dt}$ with respect to x, p, q, a, b and c, respectively. The rest of the matrix consists of zeros since we have only one differential equation describing the diffusion process.

The measurement update in the first time period uses the time updated per capita cumulative sales (x) and the time updated variance-covariance matrix of the augmented state variables (P). First the Kalman gain is calculated.

$$\psi_{k+1} = \hat{P}_{k+1}^{-} \mathrm{h}^{\mathrm{T}} \left[\mathrm{h}\hat{P}_{k+1}^{-} \mathrm{h}^{\mathrm{T}} + r \right]^{-1}$$

h is the measurement matrix [1 0 0 0 0 0]'

Then the measurement update is completed in the following manner:

$$\hat{x}_{k+1}^{+} = \hat{x}_{k+1}^{-} + \psi_{k+1}(z_{k+1} - \hat{x}_{k+1}^{-})$$

$$\hat{P}_{k+1} = [\mathrm{I} - \psi_{k+1}\mathrm{h}]\hat{P}_{k+1}^{-}$$

where I is an identity matrix.

The time and measurement updated results of the first time period are the initial values for the second time period. The process continues in the same manner for ten time periods. The Kalman filtering process is continued for ten time periods only in order to minimize the effect of replacement sales. This is consistent with other studies in the literature (for example, Talukdar, Sudhir and Ainslie 2000)

Analyses

The superior performance of the AKF(C-D) methodology in one-step ahead forecasting of the diffusion patterns of durable goods is already shown in the literature. Xie et al. (1997) evaluated four other commonly used time invariant estimation methods and one time varying method in comparison to AKF (C-D). The time-invariant methods are Ordinary Least Squares (OLS) (Bass 1969), Maximum Likelihood Estimation (MLE) (Schmittlein and Mahajan 1982), Nonlinear Least Squares (NLS) (Srinivasan and Mason 1986) and Algebraic Estimation (AE) (Mahajan and Sharma 1986). In evaluating the one-step ahead forecast performance of these time-invariant methods, Mahajan, Mason and Srinivasan (1986) concluded the NLS produces the best results. Xie at al (1997) included Adaptive Filter (AF) (Bretschneider and Mahajan 1980), a time-varying method, as well as AKF (C-D) in addition to these four methods in their analysis of comparative one-step ahead forecast performances. Using mean squared error, mean absolute deviation, and mean absolute percentage deviation as criteria, Xie et al (1997) concluded that AKF (C-D) provides better one-step ahead forecasting than other five methods in case of consumer durable goods. This superior performance is attributed to the following characteristics of the AKF (C-D) methodology. First, AKF (C-D) is applied directly to the Bass model and hence avoids time interval bias. Second, the diffusion parameters in the Bass model can vary over time (Bretschneider and Mahajan 1980) and AKF (C-D) is an adaptive filter capable of adjusting automatically to changing diffusion parameters even without a priori knowledge of how the parameters change over time. Third, AKF (C-D) explicitly models observation errors as a measurement noise (v_k) and the error variance (r) is used as input to the measurement updating process.

In this dissertation, the superior performance of the AKF (C-D) methodology over other methodologies is assumed from the beginning. However, for the sake of a complete argument two cases are compared; one with Kalman filtering, the other without Kalman filtering for one developed country (USA) and one developing country (Turkey) for all four consumer durable products (CD player, home computer, mobile phone and video camera). First, the per capita cumulative sales is estimated using Kalman filtering and then p, q, a, b and c are estimated using nonlinear regression such that sum of squared errors (SSE) are minimized. Second, the per capita cumulative sales are estimated simply by solving the diffusion equation and then the nonlinear regression to estimate p, q, a, b, and c is performed. Then the SSEs for these two methods are compared. The results suggest that when Kalman filtering is applied, the accuracy of the results (measured by SSE) is improved. Please see Table 4.1 at the end of the chapter.

The next step in the analysis was to apply the AKF (C-D) methodology to the data for each of the forty-three countries and four products in order to obtain the model parameters. The results are given in Appendix A. The graphical representations of the

results for p and q over ten time periods for each of the country-product combination are given in Appendix B; Appendix C shows the diffusion patterns of each product in each country.

The results regarding the parameters of our diffusion model were further analyzed using five two-way ANOVAs where each of p, q, a, b, c is the dependent variable and the country type (developed country (DC) and less developed country (LDC); notice the term "less developed" instead of "developing" is used for labeling purposes) and product type (CD player, home computer, mobile phone, video camera) are the independent variables. Then a MANOVA analysis, where all of the parameters are the dependent variables simultaneously, is performed to make sure the results are consistent with those of the individual ANOVA analyses. The post hoc test used is Tukey's Studentized Range (HSD) test in both cases. The results are given in Chapter 5.

Another way the results are presented for examination is through graphs. Appendix D contains graphs for developed countries and less developed countries for p and q for each of the four products. This allows a visual evaluation of the differences between developed countries and developing countries with respect to the coefficient of external influence (p) and the coefficient of internal influence (q). In fact, in order for a more clear presentation of these differences a second set of graphs are created (see Appendix E) where the averages of p and q across developed countries and developing countries for each of the ten time periods are plotted for each of the four products. The trends in p and q are seen quite clearly in order to evaluate the differences across country types. The same information is presented in a third way through graphs of p and q for all four products shown for each country type (see Appendix F). This allows comparison of the patterns for all products across developed countries and developing countries. Finally, in Appendix G, the graphical representation of the interaction effects of country type and product type on the five model parameters (p, q, a, b, c) are shown.

Table 4.1			
Turkey			
CD Player		**Home Computer**	
No Kalman	**Kalman**	**No Kalman**	**Kalman**
p = 0.0035	p = 0.0076*	p = 0.0008	p = 0.0016*
q = 0.1839	q = 0.1865*	q = 0.3120	q = 0.3361*
a = 1.2492	*a* = 0.3888	*a* = 0.0000	*a* = 0.1209
b = 0.5874	b = 0.3056	b = 0.0000	b = 0.9923
c = 0.0000	c = 0.2693	c = 0.0000	c = 0.0553
SSE=0.000330725	SSE=0.000000004	SSE=0.0000181904	SSE=0.0000000004
Mobile Phone		**Video Camera**	
No Kalman	**Kalman**	**No Kalman**	**Kalman**
p = 0.0000	p = 0.0067*	p = 0.0013	p = 0.0018*
q = 0.4559	q = 0.5050*	q = 0.1867	q = 0.2556*
a = 0.0000	*a* = 0.1006	*a* = 0.0420	*a* = 0.0282
b = 0.2033	b = 0.0035	b = 0.3665	b = 0.0734
c = 0.0000	c = 0.0402	c = 0.5124	c = 0.0242
SSE=0.000098363	SSE=0.000000086	SSE=0.0000135986	SSE=0.000000009
USA			
CD Player		**Home Computer**	
No Kalman	**Kalman**	**No Kalman**	**Kalman**
p = 0.0058	p = 0.2087*	p = 0.0056	p = 0.0340*
q = 0.7855	q = 0.3881*	q = 0.3415	q = 0.2011*
a = 0.0000	*a* = 1.2219	*a* = 0.0000	*a* = 0.8053
b = 0.0000	b = 0.3377	b = 0.0260	b = 0.8024
c = 0.0000	c = 3.0300	c = 1.5326	c = 0.3337
SSE=0.00007285880	SSE=0.000000042	SSE=0.0000541532	SSE=0.000000036
Mobile Phone		**Video Camera**	
No Kalman	**Kalman**	**No Kalman**	**Kalman**
p = 0.0022	p = 0.0382*	p = 0.0081	p = 0.0462*
q = 0.5650	q = 0.2816*	q = 0.4387	q = 0.2526*
a = 0.0000	*a* = 0.1545	*a* = 0.0000	*a* = 0.7040
b = 0.0000	b = 0.2769	b = 0.0000	b = 0.1588
c = 0.0000	c = 0.1424	c = 0.0000	c = 0.3490
SSE=0.00002272151	SSE=0.000000157	SSE=0.00001574728	SSE=0.000002342

*Average value over ten time periods

CHAPTER 5

RESULTS AND DISCUSSION

The purpose of this dissertation was to examine the impact of macro level globalization drivers (trade volume, foreign direct investment inflows and gross domestic product) on the diffusion of innovations in developed and developing countries. It was expected that the diffusion process has become more similar and faster due to the globalization phenomenon reflected through these globalization drivers. To evaluate these hypotheses, data for twenty-two developed and twenty-one developing countries for four consumer durable products (CD player, home computer, mobile phone and video camera) were processed using the Generalized Bass Model and the Augmented Kalman Filter for Continuous State and Discrete Measurements (AKF (C-D)) methodology. The model parameters that are obtained are p (coefficient of external influence), q (coefficient of internal influence), a (coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita trade volume), b (coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita FDI inflows) and c (coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita GDP).

Further analysis of the model parameters using five two-way ANOVAs where each of p, q, a, b and c were the dependent variables and the country type (developed or developing) and the product type (CD player, home computer, mobile phone and video camera) were the independent variables yielded the following results.

Table 5.1 ANOVA Results for *p*

Cell Means for *p*	CD Player	H. Computer	M. Phone	Video Cam
Developed Countries	0.0824	0.0421	0.0311	0.0167
Less Developed Co.	0.0133	0.0139	0.0158	0.0046

ANOVA					
Dependent Variable: *p*					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Model	7	0.09569633	0.01367090	15.30	< 0.0001
Error	164	0.14655195	0.00089361		
Total	171	0.24224828			
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Country type	1	0.04163342	0.04163342	46.59	***< 0.0001***
Product	3	0.03070763	0.01023588	11.45	***< 0.0001***
Country x Product	3	0.02217083	0.00739028	8.27	***< 0.0001***

Tukey's Studentized Range (HSD) Test for *p*				
Alpha				0.05
Error Degrees of Freedom				164
Error Mean Square				0.000894
Critical Value of Studentized Range				3.67070
Minimum Significant Difference				0.0167
Means with the same letter are not significantly different.				
Tukey Grouping		**Mean**	**N**	**Product**
	A	0.048650	43	CD Player
	B	0.028355	43	Home Computer
C	B	0.023623	43	Mobile Phone
C		0.010793	43	Video Camera

Table 5.2 ANOVA Results for *q*

Cell Means for *q*	CD Player	H. Computer	M. Phone	Video Cam
Developed Countries	0.2821	0.2385	0.2425	0.1973
Less Developed Co.	0.1979	0.2002	0.2401	0.1790

ANOVA					
Dependent Variable: *q*					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr>F**
Model	7	0.17589373	0.02512768	9.96	< 0.0001
Error	164	0.41378102	0.00252306		
Total	171	0.58967475			
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Country type	1	0.05504926	0.05504926	21.82	***< 0.0001***
Product	3	0.07947266	0.02649089	10.50	***< 0.0001***
Country x Product	3	0.04049389	0.01349796	5.35	***0.0015***

Tukey's Studentized Range (HSD) Test for *q*			
Alpha			0.05
Error Degrees of Freedom			164
Error Mean Square			0.002523
Critical Value of Studentized Range			3.67070
Minimum Significant Difference			0.0281
Means with the same letter are not significantly different.			
Tukey Grouping	**Mean**	**N**	**Product**
A	0.24129	43	Mobile Phone
A	0.24095	43	CD Player
A	0.21980	43	Home Computer
B	0.18833	43	Video Camera

Table 5.3 ANOVA Results for *a*

Cell Means for *a*	CD Player	H. Computer	M. Phone	Video Cam
Developed Countries	0.2985	0.3044	0.2249	0.2943
Less Developed Co.	0.2816	0.7801	0.33157	0.3031

ANOVA					
Dependent Variable: *a*					
Source	DF	Sum of Squares	Mean Square	F-value	Pr>F
Model	7	4.57054236	0.65293462	1.26	0.2740
Error	164	85.07702515	0.51876235		
Total	171	89.64756751			
Source	DF	Sum of Squares	Mean Square	F-value	Pr > F
Country type	1	0.83786927	0.83786927	1.62	0.2056
Product	3	2.12861139	0.70953713	1.37	0.2545
Country x Product	3	1.68659298	0.56219766	1.08	0.3576

Tukey's Studentized Range (HSD) Test for *a*			
Alpha	0.05		
Error Degrees of Freedom	164		
Error Mean Square	0.518762		
Critical Value of Studentized Range	3.67070		
Minimum Significant Difference	0.4032		
Means with the same letter are not significantly different.			
Tukey Grouping	Mean	N	Product
A	0.5367	43	Home Computer
A	0.2986	43	Video Camera
A	0.2902	43	CD Player
A	0.2692	43	Mobile Phone

Table 5.4 ANOVA Results for *b*

Cell Means for b	CD Player	H. Computer	M. Phone	Video Cam
Developed Countries	0.1617	0.1742	0.1658	0.1296
Less Developed Co.	0.1219	0.5512	0.1668	0.1400

ANOVA RESULTS					
Dependent Variable: *b*					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr>F**
Model	7	2.99897480	0.42842497	2.77	0.0095
Error	164	25.35825131	0.15462348		
Total	171	28.35722612			
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Country type	1	0.32635737	0.32635737	2.11	0.1482
Product	3	1.51439940	0.50479980	3.26	***0.0229***
Country x Product	3	1.21920468	0.40640156	2.63	*0.0521*

Tukey's Studentized Range (HSD) Test for *b*	
Alpha	0.05
Error Degrees of Freedom	164
Error Mean Square	0.154623
Critical Value of Studentized Range	3.67070
Minimum Significant Difference	0.2201
Means with the same letter are not significantly different.	

Tukey Grouping		Mean	N	Product
	A	0.35832	43	Home Computer
B	A	0.16630	43	Mobile Phone
B	A	0.14223	43	CD Player
B		0.13470	43	Video Camera

Table 5.5 ANOVA Results for *c*

Cell Means for c	CD Player	H. Computer	M. Phone	Video Cam
Developed Countries	0.3545	0.2299	0.2247	0.2008
Less Developed Co.	0.2972	0.6488	0.2624	0.3105

ANOVA RESULTS					
Dependent Variable: *c*					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr>F**
Model	7	3.06473834	0.43781976	1.49	0.1746
Error	164	48.23314227	0.29410453		
Total	171	51.29788061			
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Country type	1	0.69625159	0.69625159	2.37	0.1258
Product	3	1.03990055	0.34663352	1.18	0.3196
Country x Product	3	1.36898336	0.45632779	1.55	0.2032

Tukey's Studentized Range (HSD) Test for *c*			
Alpha			0.05
Error Degrees of Freedom			164
Error Mean Square			0.294105
Critical Value of Studentized Range			3.67070
Minimum Significant Difference			0.3036
Means with the same letter are not significantly different.			
Tukey Grouping	**Mean**	**N**	**Product**
A	0.4345	43	Home Computer
A	0.3265	43	CD player
A	0.2544	43	Video Camera
A	0.2431	43	Mobile Phone

Following the individual ANOVA analyses, a MANOVA analysis is run as well in order to ensure there are no differences in the results when the model parameters (p, q, a, b and c) are used as dependent variables simultaneously. The MANOVA analysis allows assessing the effect of country type (developed and developing), product type (CD player, home computer, mobile phone and video camera) and the interaction of country type and product type on all of the model parameters (p, q, a, b and c) as a set of dependent variables. The results are given in the following tables.

Table 5.6 MANOVA Results

For *p*					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Model	7	0.09569633	0.01367090	15.30	< 0.0001
Error	164	0.14655195	0.00089361		
Total	171	0.24224828			
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Country type	1	0.04163342	0.04163342	46.59	***< 0.0001***
Product	3	0.03070763	0.01023588	11.45	***< 0.0001***
Country x Product	3	0.02217083	0.00739028	8.27	***< 0.0001***

For *q*					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr>F**
Model	7	0.17589373	0.02512768	9.96	< 0.0001
Error	164	0.41378102	0.00252306		
Total	171	0.58967475			
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Country type	1	0.05504926	0.05504926	21.82	***< 0.0001***
Product	3	0.07947266	0.02649089	10.50	***< 0.0001***
Country x Product	3	0.04049389	0.01349796	5.35	***0.0015***

Table 5.6 Cont'd.					
For *a*					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr>F**
Model	7	4.57054236	0.65293462	1.26	0.2740
Error	164	85.07702515	0.51876235		
Total	171	89.64756751			
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Country type	1	0.83786927	0.83786927	1.62	0.2056
Product	3	2.12861139	0.70953713	1.37	0.2545
Country x Product	3	1.68659298	0.56219766	1.08	0.3576

For *b*					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr>F**
Model	7	2.99897480	0.42842497	2.77	0.0095
Error	164	25.35825131	0.15462348		
Total	171	28.35722612			
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Country type	1	0.32635737	0.32635737	2.11	0.1482
Product	3	1.51439940	0.50479980	3.26	***0.0229***
Country x Product	3	1.21920468	0.40640156	2.63	*0.0521*

For *c*					
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr>F**
Model	7	3.06473834	0.43781976	1.49	0.1746
Error	164	48.23314227	0.29410453		
Total	171	51.29788061			
Source	**DF**	**Sum of Squares**	**Mean Square**	**F-value**	**Pr > F**
Country type	1	0.69625159	0.69625159	2.37	0.1258
Product	3	1.03990055	0.34663352	1.18	0.3196
Country x Product	3	1.36898336	0.45632779	1.55	0.2032

Table 5.7 MANOVA Hypotheses and Results

H_0: No overall effect of country type			
Wilks' Lambda	**F-value**	**Degrees of Freedom**	**Pr >F**
0.73298807	11.66	5	**< 0.0001**
H_0: No overall effect of product type			
Wilks' Lambda	**F-value**	**Degrees of Freedom**	**Pr >F**
0.68959859	4.25	15	**< 0.0001**
H_0: No overall interaction effect of country type and product type			
Wilks' Lambda	**F-value**	**Degrees of Freedom**	**Pr >F**
0.78908264	2.64	15	**0.0008**

All three hypotheses are rejected. Significant overall effects of country type, product type and interaction of country type and product type are found.

Table 5.7 Tukey's Studentized Range (HSD) Test (for effect of country type)

Means with the same letter are not significantly different.										
Country type	**Mean for *p***		**Mean for *q***		**Mean for *a***		**Mean for *b***		**Mean for *c***	
Developed	0.043	**A**	0.240	**A**	0.281	**A**	0.158	**A**	0.253	**A**
Developing	0.012	**B**	0.204	**B**	0.420	**A**	0.245	**A**	0.380	**A**

Table 5.8 Tukey's Studentized Range (HSD) Test (for effect of product type)

Means with the same letter are not significantly different.			
For *p*			
Tukey Grouping		**Mean**	**Product**
	A	0.048650	CD Player
	B	0.028355	Home Computer
C	B	0.023623	Mobile Phone
C		0.010793	Video Camera
For *q*			
Tukey Grouping		**Mean**	**Product**
A		0.24129	Mobile Phone
A		0.24095	CD Player
A		0.21980	Home Computer
B		0.18833	Video Camera

Table 5.8 Cont'd.			
For *a*			
Tukey Grouping		**Mean**	**Product**
A		0.5367	Home Computer
A		0.2986	Video Camera
A		0.2902	CD Player
A		0.2692	Mobile Phone
For *b*			
Tukey Grouping		**Mean**	**Product**
	A	0.35832	Home Computer
B	A	0.16630	Mobile Phone
B	A	0.14223	CD Player
B		0.13470	Video Camera
For *c*			
Tukey Grouping		**Mean**	**Product**
A		0.4345	Home Computer
A		0.3265	CD player
A		0.2544	Video Camera
A		0.2431	Mobile Phone

Table 5.9 Marginal Cell Means (for interaction effect of country and product type)

		p	*q*	*a*	*b*	*c*
Developed Countries	**CD Player**	0.082369	0.282063	0.298467	0.161685	0.354450
	Home Comp.	0.042124	0.238490	0.304352	0.174184	0.229882
	Mobile Phone	0.031052	0.242469	0.224870	0.165816	0.224653
	Video Camera	0.016679	0.197259	0.294337	0.129641	0.200835
Developing Countries	**CD Player**	0.013325	0.197878	0.281579	0.121859	0.297204
	Home Comp.	0.013930	0.200213	0.780106	0.551221	0.648788
	Mobile Phone	0.015841	0.240061	0.315738	0.166816	0.262429
	Video Camera	0.004628	0.178970	0.303113	0.140001	0.310526

The graphical representations of the interaction effects for *p*, *q*, *a*, *b*, *c* are given in Appendix G.

These results indicate that:

- There is a significant main effect of country type for the coefficient of external influence (p).
- There is a significant main effect of product type for the coefficient of external influence (p).
- For coefficient of external influence (p): CD player is significantly different than home computer, mobile phone and video camera; video camera is significantly different than CD player and home computer; mobile phone and video camera are not significantly different from each other.
- There is a significant interaction effect of country type and product type for the coefficient of external influence (p).
- There is a significant main effect of country type for the coefficient of internal influence (q).
- There is a significant main effect of product type for the coefficient of internal influence (q).
- For coefficient of internal influence (q): Video camera is significantly different than CD player, home computer and mobile phone; CD player, home computer and mobile phone are not significantly different from each other.
- There is a significant interaction effect of country type and product type for the coefficient of internal influence (q).
- There is not a significant main effect of country type for the coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita trade volume (a).

- There is not a significant main effect of product type for the coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita trade volume (a).
- There is not a significant interaction effect of country type and product type for the coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita trade volume (a).
- There is not a significant main effect of country type for the coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita FDI inflows (b).
- There is a significant main effect of product type for the coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita FDI inflows (b).
- For the coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita FDI inflows (b): Video camera is significantly different than CD player, home computer and mobile phone; home computer is significantly different than CD player, mobile phone and video camera; CD player and mobile phone are not significantly different from each other.
- There is not a significant interaction effect of country type and product type for coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita FDI inflows (b).
- There is not a significant main effect of country type for the coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita GDP (c).

- There is not a significant main effect of product type for the coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita GDP (*c*).
- There is not a significant interaction effect of country type and product type for the coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita GDP (*c*).

Based on these, we can conclude that:

- The coefficients of external influence (*p*) for the developed countries and the developing countries have not converged and are still different from each other.
- The coefficients of internal influence (*q*) for the developed countries and the developing countries have not converged and are still different from each other.
- Globalization drivers (per capita trade volume, per capita FDI inflows and per capita GDP) impact the diffusion process in a similar way for the developed countries and the developing countries. One might find this result surprising, particularly with respect to the impact of per capita GDP. It should be noted that all of the products used in the data analysis were technological products and we used the percentage of urban population as the market potential. Urban population in both developed countries and developing countries are probably more technologically savvy and less price sensitive with respect to the purchase of products such as CD player, home computer, mobile phone and video camera compared to the general population. Hence, no difference regarding the impact of

per capita income on the diffusion process in the developed and the developing countries are detected.

The values of the model parameters p, q, a, b and c for each of the forty-three countries and each of the four products are given in Appendix A. Appendix B contains the graphical representation of the coefficient of external influence (p) and coefficient of internal influence (q) over time for each country-product combination. Appendix C contains the graphical presentation of the diffusion patterns of each product in each country. In order to facilitate the visual examination of the results, same information is presented in different forms. In Appendix D, the graphs show the coefficients of external influence (p) and coefficients of internal influence (q) of each developed country and each developing country over time plotted as a group for each of the four products. Appendix E contains the graphs where the averages of p and q across developed countries and developing countries for each of the ten time periods are plotted for each of the four products. Appendix F presents the same information in a third way through graphs of the averages of p and q across developed countries and developing countries for all four products shown for each country type. Finally, Appendix G contains the graphical representations of interaction effects for p, q, a, b and c.

Based on the examination of the graphs given in the Appendices, one can conclude that:

- The coefficient of external influence (p) increases over time for both developed and developing countries contributing to faster diffusion of innovations.

- The coefficient of internal influence (q) tends to slightly decrease over time for both developed and developing countries. Hence, it does not contribute to faster diffusion of innovations.

In summary:

Hypothesis 1: The diffusion rates for the developed and the developing countries have converged and became similar. *Not supported.*

Hypothesis 2a: The coefficient of external influence (p) for the developed and the developing countries have increased over time contributing to faster diffusion rates. *Supported.*

Hypothesis 2b: The coefficient of internal influence (q) for the developed and the developing countries have increased over time contributing to faster diffusion rates. *Not supported.*

Contributions

The contributions of this dissertation from academic and managerial perspectives are discussed below. The approach in this dissertation allowed quantifying the impact of macro level globalization drivers on the diffusion of innovations process in forty-three developed and developing countries. The model parameters a, b and c reflect the effectiveness of per capita trade volume, per capita FDI inflows and per capita income over the simple time-based diffusion. It was expected that, once the impact of the globalization phenomenon was accounted for by the globalization drivers in the model, we would find convergence of the coefficient of external influence and coefficient of internal influence for developed and developing countries. This would have significant managerial implications as well. Convergence in the diffusion rates of new products due to the impact of globalization drivers would not only mean the possibility of using a standardized global approach through global brands and marketing strategies but also have implications for the timing and order of entry in the global markets. Similarities in diffusion rates of new products among different countries could suggest that firms adopt a sprinkler approach (Kalish, Mahajan, and Muller 1995) instead of a more prudent waterfall strategy, which in turn could translate into first-mover advantages such as consumer loyalty and high market share. Although the hypothesis of convergence of the diffusion rates for developed and developing countries was not supported, the results still have significance in terms of increasing the knowledge base regarding the values of diffusion parameters in a wide range of countries for moderately to highly technological consumer durable products. This knowledge not only provides more informed priors regarding diffusion parameters for researchers but also can be used in forecasting and strategy making by the managers and by the policy makers alike. It is also important to note that globalization impacts the developed and developing countries in a similar manner since no statistically significant differences regarding the coefficients of the globalization drivers between developed and developing countries were found.

The methodology used in this dissertation, Augmented Kalman Filter with Continuous State and Discrete Observations (AKF (C-D)) was introduced in the literature by Xie et al. (1997). The advantages of the AKF (C-D) methodology include not only its superior predictive performance compared to other procedures such as Ordinary Least Squares

(OLS) (Bass 1969), Maximum Likelihood Estimation (MLE) (Schmittlein and Mahajan 1982), Nonlinear Least Squares (NLS) (Srinivasan and Mason 1986), Algebraic Estimation (AE) (Mahajan and Sharma 1986) and Adaptive Filter (AF) (Bretschneider and Mahajan 1980) but also other desirable characteristics. First, it is a general estimation approach that is not restricted by the model structure or by the nature of the unknown parameters. It can be applied directly to a differential diffusion model without requiring the diffusion model to be replaced by a discrete analog or requiring that the diffusion model have an analytical solution. It can be used to estimate parameters changing over time (both deterministic and stochastic changes). Also, AKF (C-D) is a Bayesian estimation procedure. It can provide better forecasts from the early stages of the diffusion process by incorporating any information on the prior distributions of the parameters in the estimation process and updating the estimates adaptively. Third, AKF (C-D) is capable of estimating time-varying parameters with or without a prior knowledge of how the parameters change over time. Further, uncertainty about parameter estimates can be built into the estimation. Hence, the model is useful in situations where strong parameters on the parameter estimates are present as well as in situations where little information is known about the parameter estimates. We have taken advantage of all of these characteristics of the AKF (C-D) methodology and applied it for the first time in the literature to a Generalized Bass Model that incorporates the impact of three macro level globalization drivers using data for a wide range of developed and developing countries for four moderately to highly technological consumer durable products. As a result, we obtained five model parameter estimates (p, q, a, b, c) in a highly accurate manner where two of them, the coefficient of external influence (p) and the coefficient of internal influence

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influence (q), were estimated over time. This enabled evaluation of the second hypothesis of the dissertation, which suggested faster diffusion rates (reflected in increasing p and q over time) due to globalization. Evidence for increasing p over time for all products in both developed and developing countries were found. The coefficient of internal influence, on the other hand, shows a slight decline trend over time for all products in both developed and developing countries. One important implication of estimating p and q in a time-varying manner is that now we have a better idea of how these parameters change over time. This will enable us to model the behavior of these parameters and incorporate in the model and the analysis explicitly in future research.

Limitations and Future Research

Limitations of the research in this dissertation provide the opportunity for future research endeavors related to the multinational diffusion of innovations. These are:

- Although this dissertation addresses an important gap in the multinational diffusion of innovations research by including a wide range of countries (both developed and developing countries that have economic significance in their respective regions and the world), only four products were included in the analyses. There is a definite need to expand the scope of products in the future research of multinational diffusion of innovations.
- Similarly, there is need to expand the scope of the covariates included in the model. In this dissertation only three macro level globalization drivers, which are also the major indicators of a country's economic health, were included. In future research, other covariates such as social and cultural factors as well as factors

reflecting the level of development of the country (technological infrastructure, education infrastructure, etc.) should be included in the model.

- In this dissertation, only two of the five model parameters are estimated in a time-varying manner. Another possible improvement via future research would be estimation of all model parameters over time. This would allow better understanding of the dynamics of the diffusion process in different countries. It would also provide the knowledge base to explicitly model the over time behavior of model parameters, which can easily be incorporated to the AKF (C-D) algorithm in the subsequent research projects.

APPENDIX A

x: Estimated per capita sales

z: Observed per capita sales

p: Coefficient of external influence

q: Coefficient of internal influence

a: Coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita trade volume

b: Coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita FDI inflows

c: Coefficient that shows the increase in diffusion speed resulting from a one percent increase in per capita GDP

SSE: Sum of squared errors

ARGENTINA

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.001048	0.001048	0.0011267	0.22527
2	0.003691	0.003691	0.0016794	0.5371
3	0.007993	0.007993	0.0030941	0.13496
4	0.017132	0.017132	0.0082497	0.1834
5	0.031429	0.031429	0.011039	0.2182
6	0.050309	0.050309	0.012587	0.21841
7	0.074835	0.074835	0.018758	0.14852
8	0.10343	0.10343	0.019004	0.16574
9	0.13832	0.13832	0.028184	0.12525
10	0.17935	0.17935	0.028734	0.15197
a = 0.033103	b = 0.0069365	c = 0.162		
SSE = 0.000000060227				

Home Computer (Introduction year: 1987)

t	x	z	p	q
1	0.00021707	0.000217	0.00025985	0.13044
2	0.0015492	0.001549	0.0010551	0.17098
3	0.003919	0.003919	0.0017026	0.21449
4	0.0071961	0.007196	0.0014348	0.18621
5	0.01363	0.01363	0.003414	0.36766
6	0.026937	0.026937	0.0094675	0.15159
7	0.047122	0.047122	0.012235	0.17028
8	0.074318	0.074318	0.018603	0.16763
9	0.10769	0.10769	0.012505	0.22259
10	0.14964	0.14964	0.031999	0.16645
a = 0.33644	b = 0.34562	c = 0.63364		
SSE = 0.00000049762				

Mobile Phone (Introduction year: 1989)

t	x	z	p	q
1	0.000062538	0.0000628	0.000048201	0.17055
2	0.00043452	0.000434	0.00018866	0.16103
3	0.0011984	0.001198	0.0011217	0.088313
4	0.0026128	0.002613	0.00059943	0.292
5	0.0059422	0.005942	0.0012319	0.27511
6	0.013011	0.013011	0.0044791	0.2001
7	0.022875	0.022875	0.0036391	0.24391
8	0.039106	0.039106	0.01379	0.25108
9	0.083907	0.083907	0.011346	0.10139
10	0.15438	0.15438	0.14003	0.27278
a = 0.2944	b = 0.8842	c = 0.33135		
SSE = 0.00000088967				

Video Camera (Introduction year: 1977)

t	x	z	p	q
1	0.0017862	0.001786	0.0012933	0.30211
2	0.0038705	0.00387	0.00091493	0.27912
3	0.0067034	0.006703	0.0020848	0.20985
4	0.010394	0.010394	0.0033501	0.40114
5	0.014898	0.014897	0.003622	0.1731
6	0.020301	0.020301	0.0028128	0.16794
7	0.026426	0.026426	0.0049902	0.096249
8	0.033545	0.033545	0.0063845	0.10909
9	0.041202	0.041202	0.0050637	0.082723
10	0.049501	0.049501	0.0043309	0.042248
a = 1.0524	b = 0.0099771	c = 0.8647		
SSE = 0.0000011484				

AUSTRALIA

Compact Disc Player (Introduction year: 1982)

t	x	z	p	q
1	0.0009115	0.000912	0.00089989	0.40478
2	0.0026906	0.002689	0.0013652	0.44141
3	0.0068102	0.00681	0.0017527	0.21885
4	0.01381	0.01381	0.0055417	0.10226
5	0.026794	0.026794	0.012105	0.12434
6	0.055088	0.055088	0.018329	0.2737
7	0.098916	0.098915	0.023015	0.35307
8	0.16038	0.16038	0.063568	0.13483
9	0.24368	0.24368	0.094162	0.18328
10	0.34421	0.34421	0.098076	0.21289

a = 0.24291 | b = 0.1445 | c = 0.05528

SSE = 0.000002422

Home Computer (Introduction year: 1984)

t	x	z	p	q
1	0.001416	0.001416	0.00097843	0.22004
2	0.0083514	0.008352	0.0045572	0.46968
3	0.020919	0.020919	0.0057411	0.5316
4	0.038787	0.038787	0.0095537	0.30311
5	0.062459	0.06246	0.016289	0.20986
6	0.092575	0.092576	0.016075	0.24813
7	0.13127	0.13127	0.033725	0.16051
8	0.1756	0.17561	0.041683	0.1084
9	0.22776	0.22776	0.059357	0.096492
10	0.28616	0.28616	0.059639	0.11521

a = 0.18166 | b = 0.096932 | c = 0.080752

SSE = 0.000001959

Mobile Phone (Introduction year: 1987)

t	x	z	p	q
1	0.00024546	0.000245	0.00021336	0.031618
2	0.0021786	0.002179	0.0018103	0.24222
3	0.0078218	0.007823	0.0037855	0.43866
4	0.018696	0.018696	0.014176	0.17896
5	0.035621	0.035621	0.010306	0.2177
6	0.064205	0.064206	0.017477	0.38674
7	0.10347	0.10347	0.023056	0.21523
8	0.17221	0.17221	0.042388	0.081794
9	0.29708	0.29708	0.1446	0.39211
10	0.51642	0.51642	0.27298	0.36068

a = 0.31889 | b = 0.49804 | c = 0.6173

SSE = 0.0000020833

Video Camera (Introduction year: 1981)

t	x	z	p	q
1	0.0030339	0.003033	0.0029391	0.37797
2	0.0094189	0.00942	0.005444	0.41629
3	0.019068	0.019067	0.0053013	0.36654
4	0.032201	0.0322	0.0073637	0.087171
5	0.048544	0.048545	0.012465	0.088767
6	0.068246	0.068246	0.010437	0.17541
7	0.091021	0.091022	0.012582	0.12438
8	0.11716	0.11716	0.017097	0.11635
9	0.14777	0.14777	0.028306	0.089759
10	0.18408	0.18408	0.03338	0.1166

a = 0.7053 | b = 0.13189 | c = 0.1303

SSE = 0.0000027341

AUSTRIA

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.0019977	0.0019975	0.0023212	0.2822
2	0.0091084	0.0091082	0.0081265	0.28476
3	0.019601	0.019601	0.0083234	0.21008
4	0.036858	0.036858	0.018831	0.18939
5	0.060803	0.060803	0.024385	0.16789
6	0.09715	0.09715	0.041968	0.15601
7	0.14381	0.14381	0.066475	0.17172
8	0.21672	0.21672	0.071419	0.082657
9	0.3152	0.3152	0.14214	0.3281
10	0.43872	0.43872	0.32232	0.22587
a = 0.10695	b = 0.21978	c = 0.067637		
SSE = 0.0000007335				

Home Computer (Introduction year: 1989)

t	x	z	p	q
1	0.0049238	0.0049239	0.0050423	0.37136
2	0.017404	0.017404	0.015265	0.31537
3	0.035132	0.035132	0.010407	0.19539
4	0.061435	0.061435	0.027777	0.28864
5	0.10092	0.10092	0.033764	0.23259
6	0.15376	0.15376	0.037159	0.25463
7	0.22035	0.22035	0.07397	0.15065
8	0.2942	0.2942	0.11714	0.22596
9	0.37853	0.37853	0.10846	0.24253
10	0.47374	0.47374	0.21828	0.34417
a = 0.65771	b = 0.17084	c = 0.56935		
SSE = 0.00000025354				

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	0.0025144	0.002515	0.0025785	0.41995
2	0.0059506	0.00595	0.0025282	0.38886
3	0.010834	0.010834	0.0042335	0.24161
4	0.017543	0.017543	0.003356	0.28192
5	0.027166	0.027166	0.011455	0.12427
6	0.041969	0.041969	0.0081299	0.22609
7	0.06383	0.06383	0.024681	0.17965
8	0.091587	0.091587	0.025851	0.16906
9	0.12629	0.12629	0.02352	0.20982
10	0.17406	0.17406	0.056938	0.13985
a = 0.4475	b = 0.058472	c = 0.077964		
SSE = 0.0000011542				

Video Camera (Introduction year: 1986)

t	x	z	p	q
1	0.0046918	0.004692	0.0049339	0.18924
2	0.01443	0.01443	0.011766	0.19418
3	0.029075	0.029076	0.015148	0.19302
4	0.048546	0.048546	0.020414	0.15648
5	0.073089	0.073089	0.023979	0.23746
6	0.10311	0.10311	0.017523	0.11091
7	0.138	0.138	0.023396	0.25783
8	0.17783	0.17783	0.03246	0.18738
9	0.22291	0.22291	0.04752	0.16415
10	0.27338	0.27338	0.058097	0.10761
a = 0.20899	b = 0.21396	c = 0.0905		
SSE = 0.0000010348				

BELGIUM

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.0061622	0.006162	0.0049797	0.33711
2	0.018257	0.018256	0.0081686	0.30843
3	0.046963	0.046964	0.014925	0.36061
4	0.091044	0.091044	0.023811	0.29663
5	0.15219	0.15219	0.041739	0.22759
6	0.22819	0.22819	0.050367	0.21756
7	0.32537	0.32537	0.081322	0.20272
8	0.44863	0.44863	0.084807	0.30369
9	0.59417	0.59417	0.17818	0.29452
10	0.76882	0.76882	0.31201	0.4195
a = 0.20852	**b** = 0.033991	**c** = 0.25426		
SSE = 0.0000016634				

Home Computer (Introduction year: 1989)

t	x	z	p	q
1	0.015687	0.015687	0.012508	0.37164
2	0.049752	0.049752	0.022051	0.41168
3	0.099142	0.099143	0.041417	0.14656
4	0.16828	0.16828	0.046726	0.28252
5	0.25053	0.25053	0.070426	0.16934
6	0.35597	0.35597	0.063464	0.26328
7	0.46987	0.46987	0.072735	0.29168
8	0.61465	0.61465	0.17895	0.30629
9	0.75733	0.75733	0.2153	0.34152
10	0.92018	0.92018	0.46231	0.5365
a = 0.21909	**b** = 0.11995	**c** = 0.24569		
SSE = 0.0000016413				

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	0.00040739	0.000406	0.00033005	0.24821
2	0.0011171	0.001117	0.00053375	0.19799
3	0.0030603	0.00306	0.0013359	0.30115
4	0.0061662	0.006167	0.0021845	0.19779
5	0.010478	0.010477	0.0019272	0.29732
6	0.015585	0.015584	0.0043779	0.063425
7	0.021669	0.021671	0.0044056	0.11026
8	0.028423	0.028424	0.0034013	0.14035
9	0.041098	0.041097	0.0044956	0.23811
10	0.064293	0.064294	0.016506	0.15695
a = 0.13882	**b** = 0.028375	**c** = 0.17447		
SSE = 0.0000028118				

Video Camera (Introduction year: 1986)

t	x	z	p	q
1	0.0052419	0.005241	0.0040409	0.21514
2	0.016618	0.016617	0.007318	0.30823
3	0.034066	0.034066	0.0083321	0.36898
4	0.057713	0.057712	0.014232	0.20759
5	0.088593	0.088594	0.015807	0.2451
6	0.12597	0.12597	0.024844	0.15451
7	0.16985	0.16985	0.032917	0.14696
8	0.22035	0.22035	0.040753	0.11224
9	0.27726	0.27726	0.047206	0.10168
10	0.33979	0.33979	0.046436	0.14651
a = 0.29422	**b** = 0.050129	**c** = 0.097609		
SSE = 0.0000023341				

BRAZIL

Compact Disc Player (Introduction year: 1986)

t	x	z	p	q
1	0.00027362	0.000274	0.00030621	0.1995
2	0.0021814	0.002181	0.0022168	0.1395
3	0.0053779	0.005378	0.0028374	0.30304
4	0.010292	0.010292	0.0046416	0.239
5	0.018331	0.018331	0.005966	0.26991
6	0.029139	0.02914	0.0072796	0.22856
7	0.043122	0.043122	0.01148	0.14842
8	0.057817	0.057817	0.0084879	0.14647
9	0.076861	0.076861	0.010378	0.15593
10	0.10207	0.10207	0.019505	0.12992

a = 0.23392 | b = 0.043106 | c = 0.92632

SSE = 0.0000008324

Home Computer (Introduction year: 1988)

t	x	z	p	q
1	0.0015599	0.00156	0.0020899	0.14104
2	0.0069122	0.006912	0.0055601	0.38834
3	0.013524	0.013524	0.0053555	0.28324
4	0.025219	0.025219	0.0096403	0.18549
5	0.040669	0.040668	0.010192	0.24716
6	0.061932	0.061932	0.011349	0.1831
7	0.089952	0.089952	0.0083887	0.24221
8	0.12392	0.12392	0.017583	0.19167
9	0.16561	0.16561	0.027974	0.16183
10	0.21258	0.21258	0.040805	0.14401

a = 0.37208 | b = 0.14154 | c = 0.7854

SSE = 0.00000097094

Mobile Phone (Introduction year: 1990)

t	x	z	p	q
1	6.6377e-006	7e-006	8.2362e-006	0.18198
2	5.5442e-005	5.52e-005	5.0302e-005	0.21533
3	0.000272	0.000272	0.00023629	0.11746
4	0.0014869	0.001487	0.00086474	0.35681
5	0.0052618	0.005262	0.0028717	0.21264
6	0.0136	0.0136	0.0084341	0.11385
7	0.029572	0.029572	0.0086148	0.40706
8	0.058268	0.058268	0.019995	0.3557
9	0.10411	0.10411	0.046364	0.24264
10	0.19642	0.19642	0.070526	0.29525

a = 0.83613 | b = 0.072192 | c = 0.67834

SSE = 0.00000057403

Video Camera (Introduction year: 1978)

t	x	z	p	q
1	0.00023799	0.000238	0.00021933	0.47167
2	0.000979	0.000979	0.00053807	0.43055
3	0.002064	0.002064	0.0010973	0.2407
4	0.003505	0.003505	0.0018056	0.16687
5	0.005256	0.005256	0.0019029	0.16527
6	0.007448	0.007448	0.00077244	0.24207
7	0.00997	0.00997	0.0019747	0.15017
8	0.012786	0.012786	0.0022302	0.13195
9	0.016053	0.016053	0.0020845	0.087688
10	0.019714	0.019714	0.0014345	0.11722

a = 0.91921 | b = 0.055204 | c = 0.42182

SSE = 0.00000080472

CANADA	
Compact Disc Player (Introduction ... 1983)	*Home Computer (Introduction ... 1983)*

CANADA

Compact Disc Player (Introduction year: 1982)

t	x	z	p	q
1	0.00035749	0.000358	0.00025054	0.17274
2	0.00071781	0.000717	0.00030244	0.18623
3	0.0017053	0.001705	0.0009696	0.211
4	0.0035366	0.003536	0.0012303	0.31091
5	0.015203	0.015203	0.010417	0.30829
6	0.034165	0.034165	0.017433	0.22105
7	0.06464	0.06464	0.028437	0.21746
8	0.10654	0.10654	0.045617	0.13713
9	0.16058	0.16058	0.043065	0.25473
10	0.23506	0.23506	0.091544	0.13727

a = 0.16523 | **b** = 0.032665 | **c** = 0.20354

SSE = 0.0000012921

Home Computer (Introduction year: 1982)

t	x	z	p	q
1	0.0032528	0.003252	0.0020152	0.21966
2	0.012899	0.012899	0.0076338	0.39595
3	0.028992	0.028992	0.0078952	0.5209
4	0.051768	0.051769	0.015019	0.2774
5	0.081238	0.081238	0.019039	0.219
6	0.11774	0.11774	0.028696	0.18529
7	0.1609	0.1609	0.044192	0.13513
8	0.21163	0.21163	0.031792	0.22554
9	0.26885	0.26885	0.045346	0.21151
10	0.33514	0.33514	0.04763	0.22909

a = 0.11721 | **b** = 0.039278 | **c** = 0.24773

SSE = 0.0000015292

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	0.002277	0.002277	0.0017454	0.26623
2	0.006791	0.006791	0.0036214	0.42579
3	0.014083	0.014083	0.0066937	0.22135
4	0.026766	0.026766	0.0051942	0.4203
5	0.047978	0.047977	0.024837	0.17883
6	0.075826	0.075826	0.025673	0.11268
7	0.11224	0.11224	0.014345	0.32324
8	0.15894	0.15894	0.029578	0.19209
9	0.22358	0.22358	0.038528	0.2789
10	0.31229	0.31229	0.079271	0.27776

a = 0.089238 | b = 0.20976 | c = 0.15193

SSE = 0.0000012196

Video Camera (Introduction year: 1984)

t	x	z	p	q
1	0.0011526	0.001152	0.0014441	0.15307
2	0.0068129	0.006813	0.0054212	0.28982
3	0.017063	0.017063	0.0073601	0.29812
4	0.032016	0.032016	0.011073	0.26929
5	0.051692	0.051692	0.013246	0.25516
6	0.076075	0.076075	0.016783	0.20865
7	0.10554	0.10554	0.019947	0.21586
8	0.1403	0.1403	0.027014	0.15307
9	0.18005	0.18005	0.035463	0.14011
10	0.22422	0.22422	0.033029	0.15227

a = 0.15642 | b = 0.062228 | c = 0.14432

SSE = 0.00000078032

CHILE

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	0.00029002	0.00029	0.00037497	0.094077
2	0.0010148	0.001015	0.00061394	0.15865
3	0.0024601	0.00246	0.00089339	0.20263
4	0.005193	0.005193	0.0010102	0.25737
5	0.011352	0.011353	0.0043905	0.2796
6	0.024965	0.024965	0.0056696	0.41977
7	0.039899	0.039899	0.010723	0.26818
8	0.0579	0.0579	0.0091805	0.20809
9	0.076622	0.076622	0.0058295	0.21097
10	0.09619	0.09619	0.014875	0.097325
a = 0.15783	**b** = 0.27986		**c** = 0.1694	
SSE = 0.00000061234				

Home Computer (Introduction year: 1990)

t	x	z	p	q
1	0.00271	0.002711	0.002858	0.099591
2	0.0076175	0.007617	0.0027381	0.41973
3	0.017671	0.017671	0.0080356	0.22093
4	0.033612	0.033613	0.0097713	0.17338
5	0.054401	0.054401	0.014638	0.14123
6	0.079362	0.079362	0.01074	0.19366
7	0.10901	0.10901	0.015365	0.19903
8	0.14242	0.14242	0.03361	0.089534
9	0.18012	0.18012	0.019291	0.16087
10	0.22165	0.22165	0.035794	0.14195
a = 0.54152	**b** = 0.20177		**c** = 0.2715	
SSE = 0.000001681				

Mobile Phone (Introduction year: 1989)

t	x	z	p	q
1	0.00038255	0.000383	0.00038944	0.3243
2	0.0014539	0.001454	0.00091458	0.28219
3	0.0041897	0.00419	0.0013623	0.50307
4	0.0089864	0.008987	0.0026356	0.36734
5	0.015224	0.015224	0.0036194	0.19909
6	0.023558	0.023558	0.0036924	0.22933
7	0.037549	0.037549	0.010036	0.13644
8	0.059867	0.059867	0.015348	0.20129
9	0.088084	0.088085	0.02388	0.14518
10	0.15358	0.15358	0.048353	0.27412
a = 0.35801	b = 0.1045		c = 0.35818	
SSE = 0.0000012317				

Video Camera (Introduction year: 1977)

t	x	z	p	q
1	0.00054409	0.000544	0.00044696	0.1438
2	0.0015911	0.001592	0.00054711	0.30195
3	0.0031553	0.003155	0.00073847	0.19399
4	0.0053172	0.005318	0.00076527	0.26182
5	0.0080464	0.008046	0.0026519	0.41089
6	0.011242	0.011241	0.002556	0.22545
7	0.014931	0.014932	0.0027187	0.087891
8	0.019025	0.019026	0.0033215	0.094256
9	0.023541	0.023542	0.0032503	0.075049
10	0.028573	0.028572	0.002963	0.066439
a = 1.081	b = 0.021514		c = 0.86857	
SSE = 0.0000022759				

CHINA

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	0.00005912	0.00005888	0.00022041	0.34718
2	0.00029865	0.0002985	0.00051369	0.64548
3	0.00083661	0.0008367	0.0014398	0.28055
4	0.0017043	0.0017044	0.00096596	0.50558
5	0.0028433	0.0028432	0.0031238	0.13914
6	0.0041925	0.0041926	0.0028888	0.17662
7	0.0057063	0.0057063	0.0036875	0.11279
8	0.0075827	0.0075827	0.004208	0.1055
9	0.0098223	0.0098224	0.0031227	0.14164
10	0.012224	0.012224	0.0038589	0.10936
a = 0.10392	b = 0.047573	c = 0.056649		
SSE = 0.00000040723				

Home Computer (Introduction year: 1991)

t	x	z	p	q
1	0.00005054	0.00004977	0.00016985	0.06255
2	0.00020148	0.00020146	0.00045087	0.15942
3	0.00043348	0.00043311	0.00060072	0.18331
4	0.00095441	0.00095398	0.0012847	0.21091
5	0.01424	0.014239	0.043376	0.093803
6	0.030774	0.030774	0.056479	0.033757
7	0.05156	0.05156	0.044362	0.25424
8	0.078772	0.078772	0.063096	0.22796
9	0.11353	0.11353	0.12198	0.11693
10	0.15284	0.15284	0.16687	0.10255
a = 0.010467	b = 0.020176	c = 0.010441		
SSE = 0.0000011877				

Mobile Phone (Introduction year: 1987)

t	x	z	p	q
1	8.848e-007	9.14e-007	3.3165e-006	0.11837
2	3.2409e-006	3.61e-006	5.8123e-006	0.41757
3	1.2318e-005	1.25e-005	2.7107e-005	0.1931
4	2.9009e-005	2.82e-005	5.3917e-005	0.077606
5	6.9314e-005	6.97e-005	0.00012978	0.077602
6	0.00022183	0.000221	0.00047786	0.093365
7	0.00075996	0.000759	0.0016537	0.12086
8	0.0020666	0.002067	0.0035601	0.18921
9	0.0050638	0.005064	0.0073363	0.24015
10	0.010663	0.010663	0.018304	0.0252
a = 0.019567	b = 0.012799	c = 0.019959		
SSE = 0.0000016696				

Video Camera (Introduction year: 1983)

t	x	z	p	q
1	3.9136e-005	3.93e-005	0.00014911	0.20571
2	0.00010497	0.000105	2.4779e-005	0.81037
3	0.00017211	0.000172	0.00021364	0.098693
4	0.00023994	0.00024	2.4214e-005	0.28118
5	0.00033297	0.000333	0.00015485	0.16533
6	0.00047303	0.000473	0.00028943	0.1622
7	0.00061312	0.000613	0.00038151	0.06709
8	0.00078284	0.000783	0.00033486	0.099576
9	0.00095697	0.000957	0.00019458	0.12255
10	0.00116	0.00116	0.00025414	0.10901
a = 0.13006	b = 0.0048132	c = 0.34404		
SSE = 0.00000029002				

DENMARK

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.0028636	0.002864	0.001459	0.29345
2	0.0075395	0.00754	0.0033646	0.2609
3	0.017214	0.017214	0.0048985	0.45495
4	0.035605	0.035605	0.0098448	0.18302
5	0.072612	0.072613	0.030066	0.19249
6	0.14698	0.14698	0.05235	0.31133
7	0.25797	0.25797	0.10961	0.23169
8	0.40653	0.40653	0.15783	0.33099
9	0.59268	0.59268	0.26151	0.4491
10	0.8163	0.8163	0.91795	0.87011
a = 0.25118	b = 0.08826		c = 0.26391	
SSE = 0.0000015312				

Home Computer (Introduction year: 1983)

t	x	z	p	q
1	0.0027037	0.002704	0.0026841	0.51292
2	0.011032	0.011032	0.0050084	0.13573
3	0.025729	0.025728	0.0099874	0.27918
4	0.045516	0.045517	0.013346	0.25125
5	0.072537	0.072536	0.014171	0.15754
6	0.10445	0.10445	0.015848	0.22061
7	0.14483	0.14483	0.026291	0.17233
8	0.2097	0.2097	0.031388	0.29702
9	0.28418	0.28418	0.030963	0.31616
10	0.39122	0.39121	0.14472	0.15199
a = 0.23376	b = 0.071498		c = 0.25473	
SSE = 0.0000016376				

Mobile Phone (Introduction year: 1985)

t	x	z	p	q
1	0.0087986	0.008799	0.0083122	0.21145
2	0.020075	0.020075	0.0084453	0.30367
3	0.0352	0.0352	0.0054949	0.21069
4	0.05506	0.055059	0.01309	0.17028
5	0.079229	0.079229	0.0095271	0.23968
6	0.10809	0.10809	0.018717	0.16203
7	0.14229	0.14229	0.017948	0.20079
8	0.18316	0.18316	0.033503	0.12304
9	0.25226	0.25226	0.049389	0.15375
10	0.34925	0.34925	0.089886	0.23357
a = 0.22148	b = 0.10124		c = 0.17637	
SSE = 0.0000014403				

Video Camera (Introduction year: 1985)

t	x	z	p	q
1	0.0054789	0.005478	0.0050329	0.18967
2	0.017845	0.017846	0.0096951	0.32357
3	0.038099	0.038099	0.0091012	0.25845
4	0.06543	0.06543	0.019685	0.19599
5	0.10127	0.10127	0.015988	0.27473
6	0.14315	0.14315	0.028102	0.18614
7	0.19457	0.19457	0.043472	0.15378
8	0.25052	0.25052	0.049305	0.14452
9	0.31132	0.31132	0.023755	0.19389
10	0.37676	0.37676	0.05756	0.15811
a = 0.25899	b = 0.076625		c = 0.57771	
SSE = 0.0000019323				

EGYPT

Compact Disc Player (Introduction year: 1987)

t	x	z	p	q
1	0.000103	0.000103	0.00012675	0.065106
2	0.000663	0.000663	0.0014896	0.27044
3	0.001575	0.001575	0.0024464	0.28047
4	0.002862	0.002862	0.054633	0.36276
5	0.004886	0.004886	0.0034009	0.14149
6	0.007076	0.007076	0.0043777	0.13245
7	0.009561	0.009561	0.0021964	0.06384
8	0.012592	0.012592	0.0051097	0.045691
9	0.016135	0.016135	0.0059769	0.042313
10	0.019925	0.019925	0.0051221	0.079654
a = 1.902	b = 0.08925		c = 0.16118	
SSE = 0.000000022957				

Home Computer (Introduction year: 1985)

t	x	z	p	q
1	0.00029408	0.000294	0.00052962	0.37901
2	0.001127	0.001127	0.0017267	0.14117
3	0.0023212	0.002321	0.0012922	0.17824
4	0.0039809	0.003981	0.0029447	0.13805
5	0.006011	0.006011	0.0038661	0.26766
6	0.008419	0.008419	0.0065076	0.6219
7	0.011307	0.011307	0.0014442	0.12118
8	0.014602	0.014602	0.0041794	0.12935
9	0.018116	0.018116	0.0022835	0.041049
10	0.022007	0.022007	0.0046591	0.17058
a = 0.52516	b = 0.61887		c = 0.53527	
SSE = 0.00000028369				

Mobile Phone (Introduction year: 1987)

t	x	z	p	q
1	5.4693e-005	5.47e-005	9.1967e-005	0.023479
2	0.000116	0.000116	6.5556e-005	0.38534
3	0.000188	0.000188	0.00029298	0.065133
4	0.000265	0.000265	0.00089543	0.227
5	0.00035198	0.000352	4.282e-005	0.081031
6	0.00044399	0.000444	0.00012144	0.1034
7	0.00057	0.00057	6.0114e-005	0.039456
8	0.00070298	0.000703	0.00031801	0.19677
9	0.000832	0.000832	0.00013531	0.087183
10	0.000958	0.000958	0.00010947	0.045906
a = 0.28777	b = 1.0011		c = 0.012657	
SSE = 0.000000027464				

Video Camera (Introduction year: 1985)

t	x	z	p	q
1	0.00081796	0.000818	0.0015525	0.26598
2	0.0016349	0.001635	0.0013476	0.314
3	0.0039071	0.003907	0.0026149	0.26291
4	0.0071589	0.007159	0.0036903	0.29586
5	0.011233	0.011233	0.0052274	0.36837
6	0.015563	0.015563	0.015744	0.13395
7	0.020295	0.020295	0.0021729	0.11619
8	0.025271	0.025271	0.0087329	0.061096
9	0.030714	0.030714	0.0028841	0.05564
10	0.036455	0.036455	0.012535	0.094738
a = 0.15183	b = 0.6127		c = 0.44077	
SSE = 0.00000027613				

FINLAND

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.00034466	0.000345	0.00048287	0.35243
2	0.007281	0.007281	0.0068572	0.28643
3	0.019741	0.019741	0.016174	0.1799
4	0.039257	0.039257	0.011612	0.35524
5	0.063757	0.063757	0.022991	0.24072
6	0.096437	0.096437	0.028633	0.20645
7	0.14172	0.14172	0.053594	0.33365
8	0.19992	0.19992	0.032429	0.22375
9	0.28345	0.28345	0.10465	0.2214
10	0.39277	0.39277	0.17021	0.28042
a = 0.16415	b = 0.1427		c = 0.30551	
SSE = 0.00000088117				

Home Computer (Introduction year: 1985)

t	x	z	p	q
1	0.0042855	0.004286	0.0053796	0.1262
2	0.013352	0.013352	0.0087434	0.40713
3	0.028718	0.028717	0.010504	0.38446
4	0.048202	0.048203	0.02109	0.19695
5	0.07543	0.07543	0.030823	0.15007
6	0.10851	0.10851	0.043208	0.2127
7	0.15113	0.15113	0.039769	0.14787
8	0.20339	0.20339	0.075875	0.11392
9	0.26562	0.26562	0.053897	0.22728
10	0.33784	0.33784	0.073762	0.28183
a = 0.22067	b = 0.086414		c = 0.13952	
SSE = 0.0000014542				

Mobile Phone (Introduction year: 1980)

t	x	z	p	q
1	0.0049212	0.004921	0.0062778	0.34448
2	0.010835	0.010835	0.0072286	0.25894
3	0.017891	0.017891	0.0034042	0.1583
4	0.026637	0.026637	0.0072481	0.20092
5	0.037345	0.037345	0.0131	0.10745
6	0.051195	0.051196	0.010858	0.15206
7	0.061393	0.061393	0.009755	0.083858
8	0.076029	0.076029	0.01456	0.097632
9	0.097313	0.097313	0.015468	0.1708
10	0.12925	0.12925	0.028679	0.17441
a = 0.25138	b = 0.038792		c = 0.069293	
SSE = 0.00000081488				

Video Camera (Introduction year: 1982)

t	x	z	p	q
1	0.00034386	0.000344	0.00037501	0.29058
2	0.0036449	0.003645	0.0048866	0.15199
3	0.009748	0.009748	0.0070794	0.27869
4	0.018866	0.018866	0.006201	0.34282
5	0.031127	0.031127	0.012721	0.16549
6	0.046371	0.046372	0.013805	0.18344
7	0.064848	0.064848	0.018414	0.1524
8	0.086177	0.086177	0.02215	0.13054
9	0.11103	0.11103	0.036746	0.094456
10	0.13914	0.13914	0.033171	0.10558
a = 0.26663	b = 0.015527		c = 0.18469	
SSE = 0.00000082541				

FRANCE									
Compact Disc Player (Introduction year: 1984)					**Home Computer (Introduction year: 1984)**				
t	**x**	**z**	**p**	**q**	**t**	**x**	**z**	**p**	**q**
1	0.0019199	0.00192	0.0021179	0.27364	1	0.0077527	0.007753	0.0078128	0.50351
2	0.0132	0.0132	0.0099649	0.30522	2	0.023509	0.023509	0.012661	0.32459
3	0.033542	0.033543	0.0068252	0.49353	3	0.04731	0.04731	0.020892	0.17342
4	0.064018	0.064018	0.025985	0.11992	4	0.079506	0.079505	0.028333	0.15984
5	0.10347	0.10347	0.036144	0.16206	5	0.1199	0.1199	0.030571	0.21793
6	0.15389	0.15389	0.042491	0.21667	6	0.16912	0.16912	0.026558	0.25907
7	0.21169	0.21169	0.034011	0.24977	7	0.22562	0.22562	0.056965	0.16787
8	0.27742	0.27742	0.028194	0.25506	8	0.29262	0.29262	0.052561	0.22059
9	0.35046	0.35046	0.13382	0.14295	9	0.37475	0.37475	0.10359	0.25585
10	0.43291	0.43291	0.13629	0.12789	10	0.46719	0.46719	0.073365	0.33712
a = 0.31674	b = 0.33119		c = 0.50145		a = 0.41341	b = 0.098059		c = 0.21663	
SSE = 0.0000010699					SSE = 0.0000015425				
Mobile Phone (Introduction year: 1985)					**Video Camera (Introduction year: 1982)**				
t	**x**	**z**	**p**	**q**	**t**	**x**	**z**	**p**	**q**
1	7.2709e-005	7.27e-005	7.8738e-005	0.25451	1	0.00025078	0.000251	0.00030212	0.24454
2	0.00023521	0.000235	0.00015344	0.20086	2	0.0025611	0.002561	0.0027964	0.14456
3	0.00093803	0.000938	0.00047467	0.49242	3	0.007028	0.007028	0.0045214	0.23591
4	0.0026881	0.002688	0.0018174	0.18872	4	0.013649	0.013649	0.00566	0.21904
5	0.0058609	0.005861	0.0018404	0.42416	5	0.022388	0.022388	0.0059212	0.22587
6	0.010863	0.010863	0.0033702	0.29026	6	0.033195	0.033195	0.0071883	0.19139
7	0.017454	0.017454	0.0053865	0.16125	7	0.046218	0.046218	0.0097533	0.15781
8	0.025092	0.025092	0.0047346	0.22463	8	0.061521	0.061521	0.0098599	0.16547
9	0.035035	0.035035	0.0052776	0.19409	9	0.078921	0.078921	0.017839	0.0822
10	0.050317	0.050317	0.011723	0.13902	10	0.09879	0.09879	0.010969	0.15444
a = 0.14888	b = 0.1219		c = 0.29897		a = 0.12955	b = 0.056183		c = 0.076423	
SSE = 0.00000037499					SSE = 0.00000063884				

GERMANY

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.00095095	0.000951	0.00089665	0.38359
2	0.025612	0.025612	0.020091	0.23862
3	0.073634	0.073634	0.016589	0.60985
4	0.14631	0.14631	0.057873	0.30149
5	0.24193	0.24193	0.041916	0.19107
6	0.36575	0.36575	0.1667	0.15142
7	0.51024	0.51024	0.19319	0.22126
8	0.68057	0.68057	0.36105	0.60254
a = 0.33811	b = 0.11493	c = 0.35698		
SSE = 0.00000033789				

Home Computer (Introduction year: 1981)

t	x	z	p	q
1	0.00023931	0.000239	0.0002679	0.03521
2	0.0098564	0.009857	0.0095256	0.27652
3	0.028926	0.028926	0.013196	0.46861
4	0.057411	0.05741	0.0206	0.28605
5	0.097381	0.097381	0.031785	0.16311
6	0.14725	0.14725	0.02904	0.23769
7	0.2116	0.2116	0.060166	0.16281
8	0.29059	0.29059	0.041228	0.2157
9	0.38595	0.38595	0.082097	0.24726
10	0.49521	0.49521	0.16523	0.16528
a = 0.21566	b = 0.041237	c = 0.1669		
SSE = 0.0000017875				

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	0.00039335	0.000393	0.00039935	0.1072
2	0.0011927	0.001193	0.00071382	0.21843
3	0.002808	0.002808	0.0011715	0.19187
4	0.0054652	0.005465	0.00091696	0.42588
5	0.0098211	0.009821	0.0023974	0.28354
6	0.016491	0.016491	0.004723	0.22018
7	0.0286	0.0286	0.0085629	0.27271
8	0.050508	0.050508	0.01206	0.12981
9	0.081133	0.081133	0.014815	0.26848
10	0.12682	0.12682	0.022991	0.31745
a = 0.33673	b = 0.026532	c = 0.12537		
SSE = 0.00000071211				

Video Camera (Introduction year: 1989)

t	x	z	p	q
1	0.0015788	0.001579	0.0016364	0.20324
2	0.0044621	0.004462	0.0020422	0.31563
3	0.012773	0.012773	0.0069803	0.39188
4	0.020732	0.020733	0.0071237	0.18933
5	0.038899	0.038899	0.005012	0.13057
6	0.067772	0.067772	0.011453	0.33818
7	0.096674	0.096674	0.022401	0.16736
8	0.12602	0.12602	0.020524	0.12562
9	0.16347	0.16347	0.028158	0.11567
10	0.19906	0.19906	0.026723	0.095844
a = 0.25408	b = 0.076671	c = 0.16109		
SSE = 0.0000010116				

GREECE

Compact Disc Player (Introduction year: 1985)

t	x	z	p	q
1	0.00073302	0.000733	0.0010727	0.21205
2	0.0025081	0.002508	0.0017187	0.37674
3	0.0060816	0.006082	0.0035245	0.2817
4	0.014796	0.014796	0.010589	0.27984
5	0.028219	0.028219	0.011459	0.29108
6	0.047096	0.047096	0.015066	0.28142
7	0.077249	0.077249	0.025067	0.29871
8	0.11524	0.11524	0.027872	0.32394
9	0.15472	0.15472	0.049468	0.15932
10	0.19959	0.19959	6.2961e-006	0.028348
a = 0.15536	b = 0.17703	c = 0.19763		
SSE = 0.00000050909				

Home Computer (Introduction year: 1986)

t	x	z	p	q
1	0.00096138	0.000963	0.0014473	0.1375
2	0.0032519	0.003253	0.0029124	0.248
3	0.0062834	0.006281	0.0030072	0.25482
4	0.011026	0.011025	0.0044442	0.2349
5	0.019685	0.019685	0.0080557	0.26131
6	0.031307	0.031307	0.0090711	0.26446
7	0.047542	0.047542	0.012978	0.25939
8	0.066483	0.066484	0.014126	0.22038
9	0.0894	0.089401	3.3284e-006	0.029994
10	0.11533	0.11533	0.033486	0.10779
a = 0.12754	b = 0.068102	c = 0.081065		
SSE = 0.0000036533				

Mobile Phone (Introduction year: 1989)

t	x	z	p	q
1	0.0007966	0.000797	0.00097686	0.45818
2	0.0019846	0.001983	0.00062693	0.57792
3	0.00365	0.00365	0.0014198	0.2896
4	0.0060791	0.006078	0.0028633	0.17937
5	0.010716	0.010716	0.0052352	0.18578
6	0.025412	0.025414	1.994e-006	0.10491
7	0.051556	0.051556	0.034385	0.17713
8	0.10239	0.10239	0.067039	0.25478
9	0.19184	0.19184	0.088281	0.57329
10	0.38659	0.38659	0.28175	0.14582
a = 0.1898	b = 0.14889	c = 0.29394		
SSE = 0.0000027964				

Video Camera (Introduction year: 1984)

t	x	z	p	q
1	0.00053393	0.000534	0.00083646	0.29041
2	0.0029098	0.00291	0.0031355	0.20688
3	0.007242	0.007242	0.0025543	0.31021
4	0.013626	0.013626	0.0043696	0.22427
5	0.022187	0.022187	0.011078	0.21417
6	0.032114	0.032114	0.0031849	0.22285
7	0.043546	0.043546	0.013911	0.067997
8	0.05523	0.05523	0.012685	0.099778
9	0.067216	0.067216	0.013382	0.13088
10	0.08399	0.08399	0.020523	0.090844
a = 0.25074	b = 0.8754	c = 0.23159		
SSE = 0.00000053591				

HONG KONG

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	0.000741	0.000741	0.0007052	0.11347
2	0.0087876	0.008787	0.0082795	0.20336
3	0.024564	0.024564	0.008481	0.14424
4	0.048324	0.048324	0.012919	0.21247
5	0.080243	0.080243	0.01754	0.24202
6	0.12028	0.12028	0.013579	0.32428
7	0.16853	0.16853	0.035924	0.1235
8	0.22523	0.22523	0.028595	0.2136
9	0.29078	0.29078	0.043956	0.10938
10	0.36565	0.36565	0.07129	0.098827

a = 0.14967 | b = 0.063176 | c = 0.21904

SSE = 0.0000013313

Home Computer (Introduction year: 1985)

t	x	z	p	q
1	0.0045636	0.004563	0.0021149	0.34605
2	0.013736	0.013736	0.0056223	0.2274
3	0.027821	0.027821	0.0060385	0.40031
4	0.046665	0.046665	0.015112	0.15512
5	0.070423	0.070423	0.011106	0.22012
6	0.099019	0.099019	0.02709	0.059853
7	0.13294	0.13294	0.016924	0.11685
8	0.17198	0.17198	0.019883	0.14949
9	0.216	0.216	0.015394	0.19456
10	0.2631	0.2631	0.030151	0.13281

a = 0.059943 | b = 0.082147 | c = 0.24116

SSE = 0.0000010926

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	0.0018309	0.00183	0.0011673	0.16568
2	0.0065372	0.006537	0.0028349	0.47097
3	0.015677	0.015678	0.0076403	0.24622
4	0.031475	0.031476	0.0078144	0.29237
5	0.055065	0.055065	0.01894	0.18213
6	0.088233	0.088234	0.013471	0.14531
7	0.12857	0.12857	0.024244	0.14014
8	0.17831	0.17831	0.023122	0.2172
9	0.25957	0.25957	0.055061	0.23103
10	0.39048	0.39048	0.089738	0.25758

a = 0.095755 | b = 0.16674 | c = 0.24889

SSE = 0.0000020418

Video Camera (Introduction year: 1981)

t	x	z	p	q
1	0.0038352	0.003835	0.0039103	0.40563
2	0.012278	0.012278	0.0069786	0.27659
3	0.025497	0.025497	0.0073958	0.28898
4	0.04363	0.04363	0.019474	0.25092
5	0.067064	0.067064	0.0037031	0.08125
6	0.095871	0.095871	0.0096929	0.1137
7	0.13017	0.13017	0.01322	0.22095
8	0.16975	0.16975	0.026075	0.19116
9	0.21479	0.21479	0.025702	0.11465
10	0.26537	0.26537	0.037979	0.15925

a = 0.16169 | b = 0.25927 | c = 0.30313

SSE = 0.0000019666

HUNGARY

Compact Disc Player (Introduction year: 1985)

t	x	z	p	q
1	0.00042847	0.000428	0.00047047	0.58209
2	0.00183	0.00183	0.0016524	0.28279
3	0.0043336	0.004334	0.002895	0.20369
4	0.0087577	0.008758	0.0036523	0.22913
5	0.017844	0.017844	0.0092612	0.28139
6	0.033178	0.033178	0.012441	0.30452
7	0.052059	0.052059	0.018629	0.20365
8	0.078422	0.078422	0.01522	0.30335
9	0.1122	0.1122	0.039505	0.13222
10	0.15713	0.15713	0.052738	0.13695
a = 0.27517	b = 0.012647		c = 0.58668	
SSE = 0.0000011143				

Home Computer (Introduction year: 1987)

t	x	z	p	q
1	0.0010893	0.001089	0.0014476	0.24752
2	0.0042959	0.004296	0.0021249	0.42412
3	0.010167	0.010167	0.0060065	0.32553
4	0.017814	0.017814	0.0054848	0.27614
5	0.033032	0.033032	0.014712	0.26459
6	0.055703	0.055703	0.027981	0.14853
7	0.08199	0.08199	0.014471	0.26195
8	0.10459	0.10459	0.024317	0.080142
9	0.12723	0.12723	0.028285	0.066507
10	0.14977	0.14977	0.013663	0.12407
a = 0.41891	b = 0.021778		c = 0.75336	
SSE = 0.00000071812				

Mobile Phone (Introduction year: 1989)

t	x	z	p	q
1	0.00011784	0.000118	0.00017369	0.023187
2	0.00037256	0.000373	0.00012423	0.36966
3	0.0011455	0.001146	0.0010988	0.11579
4	0.003371	0.003371	0.0016905	0.45605
5	0.0078323	0.007832	0.0048581	0.28918
6	0.021747	0.021747	0.0084671	0.29635
7	0.047612	0.047612	0.032314	0.23008
8	0.093928	0.093928	0.033165	0.41266
9	0.16332	0.16332	0.082679	0.2301
10	0.26889	0.26889	0.12434	0.33628
a = 0.18156	b = 0.15274		c = 0.39084	
SSE = 0.00000076588				

Video Camera (Introduction year: 1987)

t	x	z	p	q
1	0.0011249	0.001125	0.0017006	0.092967
2	0.0031515	0.003153	0.001834	0.28621
3	0.0064428	0.006443	0.0034896	0.25035
4	0.010491	0.010492	0.0026583	0.27952
5	0.01453	0.01453	0.0043739	0.11178
6	0.018557	0.018557	0.0040065	0.09685
7	0.022583	0.022584	0.0042072	0.067463
8	0.026686	0.026686	0.0039951	0.059676
9	0.030636	0.030633	0.0032745	0.068512
10	0.034657	0.034656	0.0037344	0.05191
a = 0.13271	b = 0.011137		c = 0.37708	
SSE = 0.0000038381				

INDIA

Compact Disc Player (Introduction year: 1985)

t	x	z	p	q
1	5.5599e-005	5.5617e-005	0.00021007	0.15283
2	0.00023831	0.00023842	0.00063973	0.14315
3	0.00072803	0.00072809	0.0014708	0.22157
4	0.001381	0.0013811	0.0013479	0.29656
5	0.0022519	0.0022518	0.0010774	0.32851
6	0.00339	0.0033899	0.0018279	0.25128
7	0.0046173	0.0046173	0.002661	0.13365
8	0.0060788	0.0060787	0.0026721	0.13106
9	0.0075695	0.0075696	0.0034778	0.084319
10	0.0090165	0.0090165	0.0026839	0.07717
a = 0.12727	b = 0.063623	c = 0.1216		
SSE = 0.00000024451				

Home Computer (Introduction year: 1993)

t	x	z	p	q
1	0.00017334	0.00017335	0.0005556	0.29669
2	0.00048342	0.00048341	0.00034588	0.13193
3	0.0010492	0.0010492	0.00047456	0.28982
4	0.0016305	0.0016305	0.0009448	0.11311
5	0.0023467	0.0023467	0.0017039	0.30111
6	0.0032119	0.0032119	0.0027839	0.2643
7	0.0042739	0.0042739	0.0023332	0.10889
8	0.0054199	0.0054199	0.0015538	0.1489
a = 0.077774	b = 1.2898	c = 0.076501		
SSE = 0.000000020403				

Mobile Phone (Introduction year: 1989)

t	x	z	p	q
1	5.1072e-006	5.31e-006	1.8817e-005	0.057506
2	1.2264e-005	1.18e-005	1.8822e-005	0.28724
3	2.4083e-005	2.42e-005	4.2936e-005	0.038738
4	4.1043e-005	4.15e-005	5.285e-005	0.031787
5	6.7857e-005	6.79e-005	7.012e-005	0.12043
6	0.00010713	0.000107	6.6223e-005	0.16544
7	0.00018881	0.000189	0.00020817	0.12844
8	0.00053483	0.000535	0.0010987	0.073462
9	0.0014494	0.001449	0.0033795	0.028139
10	0.0026663	0.002666	0.0041862	0.042382
a = 0.38056	b = 0.13547	c = 0.032714		
SSE = 0.00000087433				

Video Camera (Introduction year: 1991)

t	x	z	p	q
1	1.7481e-005	1.75e-005	6.4257e-005	0.081687
2	6.9749e-005	6.97e-005	0.00017619	0.09166
3	0.00013893	0.000139	0.00020696	0.1332
4	0.00017396	0.000174	6.7992e-005	0.094186
5	0.00020802	0.000208	9.3758e-005	0.041196
6	0.00024201	0.000242	8.46e-005	0.046335
7	0.00029297	0.000293	8.7099e-005	0.10342
8	0.00034399	0.000344	0.00010072	0.073361
9	0.00039497	0.000395	0.00010552	0.056288
10	0.00047898	0.000479	0.00020726	0.056989
a = 0.066107	b = 0.045057	c = 0.078494		
SSE = 0.00000010949				

INDONESIA

Compact Disc Player (Introduction year: 1986)

t	x	z	p	q
1	0.00013195	0.00013207	0.00044542	0.16951
2	0.00060809	0.00060822	0.0015666	0.09603
3	0.0012613	0.0012612	0.0014849	0.23878
4	0.0020939	0.002093	0.002496	0.049658
5	0.0031749	0.0031746	0.0020455	0.17333
6	0.0045117	0.0045114	0.0021678	0.17263
7	0.0059957	0.0059958	0.0032483	0.084692
8	0.0076066	0.0076068	0.0025394	0.11522
9	0.0094403	0.0094405	0.0039163	0.057417
10	0.011335	0.011334	0.0028384	0.089245
a = 0.047104	b = 0.010844	c = 0.0034921		
SSE = 0.0000011002				

Home Computer (Introduction year: 1992)

t	x	z	p	q
1	0.00017597	0.000196	0.00015323	0.35793
2	0.0007252	0.000699	2.7036e-005	0.47896
3	0.0012737	0.001273	1e-006	0.080493
4	0.0021765	0.002164	1e-006	0.14592
5	0.0033948	0.003042	0.019366	1e-006
6	0.0031601	0.003972	1e-006	1e-006
7	0.0038081	0.005072	1e-006	1e-006
8	0.0061733	0.006171	0.00075499	1e-006
9	0.0073408	0.007337	0.022845	1e-006
a = 8.9686	b = 4.2499	c = 5.8893		
SSE = 0.0015435				

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	2.7309e-005	2.73e-005	8.6987e-005	0.27152
2	6.4578e-005	6.46e-005	6.4908e-005	0.41462
3	0.00011704	0.000117	8.1947e-005	0.31413
4	0.00019	0.00019	0.0001477	0.18136
5	0.00029001	0.00029	0.00017606	0.18612
6	0.00042398	0.000424	0.00016441	0.22669
7	0.00061503	0.000615	0.00036926	0.13353
8	0.000898	0.000898	0.00063421	0.08972
9	0.001304	0.001304	0.00060541	0.16865
10	0.002383	0.002383	0.0018754	0.21915
a = 0.015164	b = 0.019651	c = 0.1057		
SSE = 0.000000071752				

Video Camera (Introduction year: 1983)

t	x	z	p	q
1	2.0995e-005	2.0983e-005	0.00018043	0.27675
2	6.3299e-005	6.3289e-005	6.2585e-005	0.11674
3	0.00012729	0.00012731	0.00010462	0.4074
4	0.00017131	0.00017133	6.7965e-005	0.16073
5	0.00023624	0.00023626	7.4897e-005	0.1003
6	0.00030157	0.00030155	9.132e-005	0.074369
7	0.00038909	0.00038911	6.711e-005	0.10009
8	0.00049949	0.00049948	0.00010429	0.10486
9	0.0005886	0.0005886	0.0001577	0.048596
10	0.00072355	0.00072355	0.00021942	0.071822
a = 0.26358	b = 1.0963	c = 0.093049		
SSE = 0.00000004511				

IRELAND

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	8.552e-005	8.5013e-005	0.00014644	0.090795
2	0.00017038	0.00017003	0.00010046	0.21307
3	0.0023467	0.0023468	0.0035799	0.20798
4	0.0059021	0.0059018	0.0034815	0.26002
5	0.011591	0.011591	0.0055778	0.28982
6	0.022581	0.022581	0.012561	0.24296
7	0.037394	0.037394	0.010101	0.19857
8	0.058409	0.058409	0.019451	0.22264
9	0.088509	0.088509	0.029458	0.23449
10	0.1306	0.1306	0.051973	0.20968

$a = 0.095152$ | $b = 0.049415$ | $c = 0.042782$

SSE = 0.00000078467

Home Computer (Introduction year: 1984)

t	x	z	p	q
1	0.0037596	0.0037598	0.0057705	0.24454
2	0.014227	0.014227	0.014161	0.28526
3	0.0307	0.030701	0.017118	0.2456
4	0.054469	0.054469	0.017102	0.35636
5	0.083838	0.083838	0.031635	0.21313
6	0.1216	0.1216	0.018721	0.27091
7	0.16337	0.16337	0.020558	0.29781
8	0.20687	0.20687	0.046569	0.19384
9	0.2534	0.2534	0.077504	0.14773
10	0.3021	0.3021	0.096774	0.12675

$a = 0.2051$ | $b = 0.024809$ | $c = 0.075952$

SSE = 0.00000079137

Mobile Phone (Introduction year: 1985)

t	x	z	p	q
1	2.8654e-005	2.86e-005	4.7468e-005	0.13729
2	0.0043215	0.004322	0.0061091	0.23432
3	0.0053155	0.005315	0.0008604	0.10208
4	0.0071169	0.007117	0.0024148	0.069026
5	0.011012	0.011012	0.0038517	0.13817
6	0.01814	0.01814	0.008206	0.16988
7	0.027229	0.027229	0.0087024	0.19207
8	0.039632	0.039632	0.0086683	0.2485
9	0.05675	0.05675	0.01062	0.25572
10	0.081309	0.081309	0.023733	0.18711

$a = 0.092883$ | $b = 0.019783$ | $c = 0.072444$

SSE = 0.00000078096

Video Camera (Introduction year: 1984)

t	x	z	p	q
1	0.0014979	0.001498	0.0024714	0.10605
2	0.0044888	0.004489	0.0037871	0.31447
3	0.0090736	0.009074	0.0043015	0.24046
4	0.015265	0.015265	0.0055075	0.25176
5	0.02303	0.02303	0.0090366	0.14653
6	0.03254	0.03254	0.010059	0.080794
7	0.043501	0.043501	0.011636	0.1221
8	0.056224	0.056224	0.011511	0.14221
9	0.07048	0.07048	0.012416	0.14299
10	0.086461	0.086461	0.011156	0.15001

$a = 0.11876$ | $b = 0.035141$ | $c = 0.069442$

SSE = 0.00000062625

ISRAEL

Compact Disc Player (Introduction year: 1985)

t	x	z	p	q
1	0.0014581	0.001458	0.001204	0.37251
2	0.0082162	0.008216	0.0039235	0.48838
3	0.020451	0.020451	0.0075169	0.39301
4	0.038018	0.038018	0.0093977	0.3511
5	0.061058	0.061058	0.010537	0.29031
6	0.088441	0.088441	0.011524	0.21365
7	0.12096	0.12097	0.018482	0.18977
8	0.15824	0.15824	0.017703	0.161
9	0.19707	0.19707	0.030891	0.10991
10	0.23807	0.23807	0.031282	0.066865
a = 0.33137	b = 0.098539	c = 0.25089		
SSE = 0.00000074176				

Home Computer (Introduction year: 1981)

t	x	z	p	q
1	0.004457	0.004458	0.0042968	0.42894
2	0.017115	0.017116	0.0095539	0.31121
3	0.037525	0.037526	0.013843	0.35086
4	0.066847	0.066847	0.020972	0.19045
5	0.10404	0.10404	0.01936	0.25049
6	0.14858	0.14858	0.02902	0.16025
7	0.19991	0.19991	0.03154	0.20017
8	0.26127	0.26127	0.057758	0.14359
9	0.3273	0.3273	0.039834	0.20731
10	0.40333	0.40333	0.098622	0.066947
a = 0.14914	b = 0.09596	c = 0.13226		
SSE = 0.0000019793				

Mobile Phone (Introduction year: 1989)

t	x	z	p	q
1	0.0019866	0.001987	0.0017399	0.39734
2	0.0053096	0.005309	0.0025079	0.17971
3	0.010098	0.010098	0.0016926	0.43808
4	0.017248	0.017248	0.0043105	0.17682
5	0.029574	0.029574	0.00428	0.37815
6	0.054526	0.054526	0.013561	0.20051
7	0.13585	0.13585	0.065192	0.32108
8	0.3225	0.32249	0.19413	0.30999
9	0.61305	0.61305	0.53681	0.29088
a = 0.36339	b = 0.11176	c = 0.051402		
SSE = 0.0000012781				

Video Camera (Introduction year: 1981)

t	x	z	p	q
1	0.00059276	0.000593	0.00070911	0.16407
2	0.0026412	0.002641	0.0013573	0.31904
3	0.0062889	0.006289	0.0033178	0.23203
4	0.01146	0.01146	0.0026754	0.22115
5	0.01834	0.01834	0.0042898	0.1522
6	0.0265	0.0265	0.0025593	0.1924
7	0.036198	0.036198	0.0061192	0.14014
8	0.047449	0.047449	0.0091255	0.109
9	0.060193	0.060193	0.010008	0.077828
10	0.074034	0.074034	0.0030142	0.13086
a = 0.31498	b = 0.23113	c = 0.27147		
SSE = 0.00000042773				

ITALY

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.0027987	0.002799	0.003381	0.4238
2	0.013421	0.013421	0.012817	0.32285
3	0.031382	0.031382	0.0045893	0.11284
4	0.057454	0.057454	0.023189	0.22675
5	0.090561	0.090562	0.044774	0.1138
6	0.12895	0.12895	0.019281	0.2206
7	0.17156	0.17156	0.065869	0.094733
8	0.21569	0.2157	0.038132	0.17719
9	0.26059	0.26059	0.059974	0.1333
10	0.30659	0.30659	0.066611	0.12377
a = 0.33208	b = 0.089813		c = 0.066818	
SSE = 0.0000011008				

Home Computer (Introduction year: 1983)

t	x	z	p	q
1	0.0029197	0.00292	0.0033452	0.43913
2	0.013844	0.013844	0.01205	0.35219
3	0.032184	0.032184	0.020878	0.22777
4	0.058835	0.058835	0.0080191	0.11653
5	0.092728	0.092728	0.025462	0.23991
6	0.13548	0.13548	0.041734	0.21762
7	0.18456	0.18456	0.058414	0.10021
8	0.24161	0.24161	0.081217	0.15149
9	0.29947	0.29947	0.039897	0.24839
10	0.35972	0.35973	0.087522	0.19005
a = 0.20584	b = 0.063937		c = 0.27662	
SSE = 0.0000016882				

Mobile Phone (Introduction year: 1985)

t	x	z	p	q
1	3.3736e-005	3.38e-005	4.2369e-005	0.25849
2	0.0001936	0.000194	0.00011594	0.2568
3	0.00048688	0.000487	0.00028203	0.27266
4	0.0010814	0.001081	0.00072765	0.13127
5	0.002246	0.002246	0.00037112	0.51509
6	0.0069369	0.006937	0.0050288	0.31173
7	0.016947	0.016947	0.0074066	0.43476
8	0.030743	0.030743	0.014083	0.2247
9	0.051932	0.051933	0.018956	0.22783
10	0.091136	0.091136	0.01746	0.41271
a = 0.22574	b = 0.017712		c = 0.1511	
SSE = 0.0000011237				

Video Camera (Introduction year: 1985)

t	x	z	p	q
1	0.0032796	0.003279	0.0043363	0.17094
2	0.010292	0.010292	0.0035059	0.24362
3	0.021098	0.021098	0.01086	0.2016
4	0.035096	0.035096	0.012251	0.22683
5	0.051881	0.051881	0.011508	0.19617
6	0.070359	0.070359	0.020817	0.10885
7	0.090323	0.090323	0.012518	0.17116
8	0.11061	0.11061	0.018506	0.12151
9	0.13183	0.13183	0.011849	0.14309
10	0.15518	0.15518	0.018898	0.10079
a = 0.24305	b = 0.028358		c = 0.22766	
SSE = 0.0000010373				

JAPAN

Compact Disc Player (Introduction year: 1982)

t	x	z	p	q
1	0.0033491	0.003349	0.0037491	0.32115
2	0.016263	0.016263	0.013488	0.29443
3	0.050877	0.050877	0.012876	0.19124
4	0.10348	0.10348	0.024255	0.52592
5	0.1795	0.1795	0.041457	0.36261
6	0.26958	0.26959	0.07663	0.3061
7	0.37698	0.37699	0.13246	0.26605
8	0.49996	0.49996	0.16681	0.30913
9	0.63663	0.63663	0.38058	0.41458

a = 0.15341 | b = 0.025443 | c = 0.056219

SSE = 0.0000012723

Home Computer (Introduction year: 1981)

t	x	z	p	q
1	0.0016057	0.001606	0.001747	0.31429
2	0.0054211	0.005421	0.0032045	0.41648
3	0.01298	0.01298	0.007523	0.20116
4	0.022157	0.022157	0.0015719	0.12934
5	0.036041	0.036042	0.013568	0.12948
6	0.05444	0.05444	0.008643	0.21595
7	0.07762	0.07762	0.013167	0.22444
8	0.10578	0.10578	0.022171	0.16724
9	0.13932	0.13932	0.023599	0.14068
10	0.17783	0.17783	0.031439	0.14871

a = 0.22737 | b = 0.03489 | c = 0.21116

SSE = 0.0000014343

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	0.0007848	0.000785	0.0004743	0.30794
2	0.0020269	0.002027	0.0015924	0.19489
3	0.0040155	0.004015	0.0023928	0.15762
4	0.0080092	0.008009	0.0017751	0.24082
5	0.015049	0.015049	0.0038127	0.38965
6	0.026158	0.026158	0.0072323	0.19288
7	0.039923	0.039923	0.012997	0.19905
8	0.057003	0.057003	0.0076466	0.07105
9	0.091642	0.091642	0.029307	0.28088
10	0.18501	0.18501	0.012132	0.14385

a = 0.14981 | b = 0.15345 | c = 0.14915

SSE = 0.00000085771

Video Camera (Introduction year: 1979)

t	x	z	p	q
1	0.00021092	0.000211	0.00022381	0.14652
2	0.0070719	0.007072	0.0071735	0.32559
3	0.020632	0.020632	0.013053	0.27142
4	0.040946	0.040946	0.015974	0.30014
5	0.06838	0.06838	0.023854	0.19629
6	0.1029	0.1029	0.012716	0.037555
7	0.14494	0.14494	0.047974	0.095729
8	0.19357	0.19357	0.031752	0.15371
9	0.24918	0.24918	0.049752	0.16622
10	0.31231	0.31231	0.066192	0.17502

a = 0.39919 | b = 0.040495 | c = 0.20066

SSE = 0.00000083423

MALAYSIA

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.0012324	0.001232	0.0024817	0.24554
2	0.0054336	0.005434	0.0084777	0.15835
3	0.013091	0.013091	0.010619	0.29731
4	0.02351	0.02351	0.012628	0.21365
5	0.037786	0.037786	0.019586	0.11986
6	0.054323	0.054323	0.009815	0.26454
7	0.075526	0.075526	0.029741	0.11906
8	0.097964	0.097964	0.028778	0.13062
9	0.1215	0.1215	0.020023	0.17148
10	0.14623	0.14623	0.04545	0.069821

a = 0.081643 | b = 0.10702 | c = 0.12075

SSE = 0.00000072261

Home Computer (Introduction year: 1984)

t	x	z	p	q
1	0.00090493	0.000905	0.0019153	0.18869
2	0.0046171	0.004617	0.0075396	0.20874
3	0.010953	0.010953	0.0085331	0.30411
4	0.02047	0.02047	0.016461	0.047831
5	0.032399	0.032399	0.0090437	0.21453
6	0.047798	0.047798	0.019005	0.13944
7	0.065045	0.065045	0.022064	0.11157
8	0.086781	0.086781	0.01476	0.21801
9	0.11239	0.11239	0.016081	0.22384
10	0.14151	0.14151	0.018997	0.22386

a = 0.14845 | b = 0.17446 | c = 0.094546

SSE = 0.00000051515

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	0.00068204	0.000682	0.0013217	0.19608
2	0.001707	0.001707	0.0012536	0.32602
3	0.003296	0.003296	0.0023819	0.1208
4	0.005537	0.005537	0.0031844	0.13671
5	0.010412	0.010412	0.0073393	0.13677
6	0.017517	0.017517	0.011096	0.10997
7	0.028236	0.028236	0.011962	0.21729
8	0.045937	0.045937	0.025299	0.16136
9	0.07503	0.07503	0.039948	0.17923
10	0.12501	0.12501	0.081572	0.1659

a = 0.039645 | b = 0.071644 | c = 0.015655

SSE = 0.000000086482

Video Camera (Introduction year: 1983)

t	x	z	p	q
1	0.0020673	0.002067	0.0046363	0.12113
2	0.0070719	0.007072	0.0095248	0.23444
3	0.014911	0.014911	0.0082139	0.47044
4	0.025688	0.025688	0.014807	0.19569
5	0.039388	0.039388	0.010454	0.22712
6	0.056108	0.056108	0.017617	0.11355
7	0.07579	0.07579	0.021088	0.14007
8	0.098382	0.098382	0.03369	0.077169
9	0.12406	0.12406	0.029317	0.13797
10	0.15321	0.15321	0.019214	0.20124

a = 0.19634 | b = 0.21737 | c = 0.17577

SSE = 0.00000081792

MEXICO

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	0.00010618	0.000106	0.0001436	0.16468
2	0.00069613	0.000696	0.00069689	0.25008
3	0.002625	0.002625	0.0023013	0.22086
4	0.005905	0.005905	0.002667	0.34321
5	0.010541	0.010541	0.0020912	0.35675
6	0.016668	0.016668	0.003925	0.23553
7	0.024117	0.024117	0.0063346	0.1398
8	0.033267	0.033267	0.0063291	0.15296
9	0.043818	0.043818	0.0057864	0.16647
10	0.055864	0.055864	0.0070771	0.15461

a = 0.11371 | b = 0.07321 | c = 0.11753

SSE = 0.00000030791

Home Computer (Introduction year: 1987)

t	x	z	p	q
1	7.468e-005	7.45e-005	9.1407e-005	0.15339
2	0.00054692	0.000547	0.00055367	0.19405
3	0.0016611	0.001661	0.0011416	0.21691
4	0.0038801	0.00388	0.0019408	0.25524
5	0.007411	0.007411	0.0024443	0.28072
6	0.012237	0.012237	0.0031633	0.23637
7	0.018629	0.018629	0.005169	0.13863
8	0.026095	0.026095	0.0074338	0.10958
9	0.035394	0.035394	0.0042775	0.19805
10	0.045438	0.045438	0.0063669	0.13176

a = 0.16134 | b = 0.044882 | c = 0.53291

SSE = 0.00000047418

Mobile Phone (Introduction year: 1988)

t	x	z	p	q
1	2.4554e-005	2.49e-005	2.8202e-005	0.21772
2	0.00013512	0.000135	0.00012699	0.16396
3	0.0009037	0.000904	0.00074017	0.2899
4	0.0028029	0.002803	0.0017835	0.24658
5	0.0064261	0.006426	0.0028458	0.35538
6	0.010805	0.010805	0.0029444	0.16883
7	0.017161	0.017161	0.005065	0.22996
8	0.02472	0.02472	0.005985	0.14996
9	0.035743	0.035743	0.0077646	0.15983
10	0.054211	0.054211	0.01501	0.19861

a = 0.12627 | b = 0.17088 | c = 0.13688

SSE = 0.00000056389

Video Camera (Introduction year: 1986)

t	x	z	p	q
1	0.00045836	0.000458	0.00056986	0.25635
2	0.0012764	0.001277	0.00099211	0.1083
3	0.0025059	0.002506	0.000629	0.4118
4	0.0042153	0.004215	0.0021011	0.051456
5	0.0063766	0.006376	0.0011627	0.24096
6	0.0087232	0.008723	0.0013264	0.17874
7	0.011239	0.011239	0.0019646	0.10843
8	0.013843	0.013843	0.002333	0.063685
9	0.01662	0.016621	0.0012513	0.12971
10	0.019561	0.019561	0.0017833	0.092

a = 0.031113 | b = 0.037779 | c = 0.18355

SSE = 0.0000012626

THE NETHERLANDS

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.013179	0.013179	0.013863	0.18456
2	0.050345	0.050345	0.018966	0.37675
3	0.11007	0.11007	0.04801	0.29494
4	0.19755	0.19755	0.067102	0.14061
5	0.30502	0.30502	0.090351	0.17335
6	0.4453	0.4453	0.10542	0.29783
7	0.60028	0.60028	0.3334	0.2776
8	0.79768	0.79768	0.80286	0.38599

a = 0.2441 | b = 0.31658 | c = 0.2427

SSE = 0.00000019712

Home Computer (Introduction year: 1981)

t	x	z	p	q
1	0.0030764	0.003076	0.0030737	0.41971
2	0.014427	0.014427	0.0089971	0.44218
3	0.034774	0.034773	0.0094507	0.45404
4	0.063695	0.063693	0.018043	0.26977
5	0.10222	0.10222	0.024954	0.15918
6	0.15027	0.15027	0.029071	0.18321
7	0.20946	0.20946	0.026935	0.20654
8	0.27631	0.27631	0.070925	0.080617
9	0.35648	0.35648	0.054791	0.17226
10	0.44223	0.44223	0.06923	0.25038

a = 0.6435 | b = 0.12792 | c = 0.59737

SSE = 0.0000019899

Mobile Phone (Introduction year: 1985)

t	x	z	p	q
1	0.00041606	0.000416	0.00038917	0.30099
2	0.0014711	0.001471	0.00094995	0.19762
3	0.0031298	0.00313	0.0009682	0.33325
4	0.005377	0.005377	0.0012688	0.26233
5	0.0091671	0.009167	0.0022032	0.24446
6	0.014472	0.014472	0.002614	0.25995
7	0.022133	0.022133	0.0038477	0.23692
8	0.033105	0.033105	0.0078216	0.15958
9	0.047279	0.047279	0.0074772	0.19848
10	0.068203	0.068203	0.01393	0.15909

a = 0.082819 | b = 0.011368 | c = 0.18118

SSE = 0.00000033947

Video Camera (Introduction year: 1983)

t	x	z	p	q
1	0.0023379	0.002338	0.0022322	0.21794
2	0.0070891	0.00709	0.0045259	0.15864
3	0.014401	0.014402	0.0055248	0.13739
4	0.024628	0.024628	0.0070647	0.20256
5	0.037549	0.037549	0.0081472	0.14412
6	0.053444	0.053443	0.0084806	0.17193
7	0.071983	0.071983	0.0075853	0.1821
8	0.092616	0.092616	0.013273	0.14804
9	0.12157	0.12157	0.020219	0.1318
10	0.15569	0.1557	0.020704	0.15972

a = 0.18798 | b = 0.13099 | c = 0.22516

SSE = 0.0000014402

NEW ZEALAND

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	0.012339	0.012339	0.0056538	0.2684
2	0.036898	0.036898	0.014538	0.51937
3	0.073728	0.073729	0.028978	0.23221
4	0.12296	0.12296	0.02974	0.24075
5	0.18551	0.18551	0.048302	0.17367
6	0.26239	0.26239	0.055729	0.24719
7	0.353	0.353	0.070722	0.26314
8	0.45715	0.45715	0.12774	0.26047
9	0.57501	0.57501	0.17557	0.23976
10	0.70657	0.70657	0.39027	0.27487
a = 0.39005	b = 0.14426	c = 0.73353		
SSE = 0.000001154				

Home Computer (Introduction year: 1984)

t	x	z	p	q
1	0.0035926	0.003593	0.003525	0.38212
2	0.012369	0.012369	0.0086332	0.22537
3	0.026776	0.026776	0.011814	0.16295
4	0.046468	0.046468	0.010502	0.19095
5	0.072849	0.07285	0.023048	0.1577
6	0.10403	0.10403	0.011397	0.26492
7	0.14293	0.14293	0.028516	0.28235
8	0.18793	0.18792	0.014226	0.15675
9	0.24167	0.24167	0.051012	0.1009
10	0.29959	0.29959	0.037963	0.16044
a = 0.36535	b = 0.7655	c = 0.17586		
SSE = 0.0000018884				

Mobile Phone (Introduction year: 1987)

t	x	z	p	q
1	0.00071	0.00071	0.0007695	0.043855
2	0.00365	0.00365	0.0025928	0.36096
3	0.012108	0.012108	0.0074984	0.27997
4	0.027763	0.027763	0.0109	0.38181
5	0.048345	0.048346	0.017748	0.12942
6	0.07664	0.07664	0.013922	0.28258
7	0.11686	0.11686	0.027979	0.20338
8	0.1827	0.1827	0.062189	0.13692
9	0.28165	0.28165	0.10168	0.22894
10	0.41334	0.41334	0.131	0.31065
a = 0.10599	b = 0.11876	c = 0.32604		
SSE = 0.00000089801				

Video Camera (Introduction year: 1981)

t	x	z	p	q
1	0.0013108	0.001311	0.0014448	0.1209
2	0.0086368	0.008636	0.0084527	0.19656
3	0.019413	0.019413	0.0044461	0.20564
4	0.035473	0.035473	0.014221	0.16996
5	0.058402	0.058402	0.015581	0.2318
6	0.086241	0.086241	0.013136	0.22128
7	0.11904	0.11904	0.022453	0.14556
8	0.15809	0.15809	0.025515	0.16925
9	0.20152	0.20152	0.029345	0.15944
10	0.25143	0.25143	0.056175	0.10977
a = 0.54374	b = 0.10019	c = 0.18438		
SSE = 0.0000013572				

NORWAY

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.00043711	0.000437	0.0013312	0.5065
2	0.018671	0.018671	0.0067657	0.21882
3	0.050649	0.050649	0.044651	0.44086
4	0.10333	0.10333	0.037242	0.25426
5	0.17843	0.17843	0.021783	0.095854
6	0.2739	0.2739	0.11132	0.29919
7	0.39418	0.39418	0.67861	0.67152
8	0.5353	0.53531	0.46179	0.52902
9	0.7111	0.7111	0.60863	0.59062

a = 0.53155 | b = 0.49529 | c = 0.39103

SSE = 0.00000074575

Home Computer (Introduction year: 1984)

t	x	z	p	q
1	0.0042948	0.004295	0.006468	0.26438
2	0.014571	0.014571	0.0049768	0.33461
3	0.030945	0.030945	0.018451	0.21045
4	0.053861	0.05386	0.017439	0.22664
5	0.082659	0.082659	0.013968	0.12453
6	0.11801	0.11801	0.029468	0.19687
7	0.15967	0.15967	0.026139	0.33742
8	0.20911	0.20911	0.069973	0.11957
9	0.26651	0.26651	0.023548	0.18802
10	0.34337	0.34337	0.10276	0.10669

a = 0.26448 | b = 0.15928 | c = 0.31399

SSE = 0.0000011336

Mobile Phone (Introduction year: 1985)

t	x	z	p	q
1	0.01085	0.01085	0.010885	0.22878
2	0.031808	0.031808	0.021067	0.30448
3	0.060606	0.060606	0.025551	0.24102
4	0.096822	0.096822	0.026911	0.16861
5	0.1367	0.1367	0.039471	0.15793
6	0.18324	0.18324	0.038764	0.22578
7	0.2383	0.2383	0.041384	0.23431
8	0.30452	0.30452	0.068853	0.16021
9	0.39081	0.39081	0.12336	0.17491
10	0.52677	0.52677	0.36034	0.20536

a = 0.15194 | b = 0.054227 | c = 0.28214

SSE = 0.0000013481

Video Camera (Introduction year: 1984)

t	x	z	p	q
1	0.0025855	0.002585	0.0031285	0.4829
2	0.0082228	0.008223	0.0032062	0.31661
3	0.017643	0.017643	0.0098939	0.18405
4	0.030146	0.030146	0.00914	0.22326
5	0.046829	0.04683	0.010405	0.10624
6	0.06618	0.06618	0.015441	0.15498
7	0.087069	0.087069	0.021992	0.15031
8	0.11983	0.11983	0.017434	0.26659
9	0.16737	0.16737	0.031988	0.16883
10	0.22161	0.22161	0.038174	0.17479

a = 0.43953 | b = 0.11062 | c = 0.39661

SSE = 0.0000009694

PAKISTAN

Compact Disc Player (Introduction year: 1987)

t	x	z	p	q
1	0.00053757	0.00053757	0.0013913	0.15104
2	0.0015738	0.0015738	0.0021684	0.34471
3	0.0031034	0.0031033	0.0023933	0.32615
4	0.0052206	0.0052206	0.0044037	0.15483
5	0.0078381	0.007838	0.0051788	0.11625
6	0.011	0.011	0.0052316	0.17001
7	0.014574	0.014574	0.006122	0.13242
8	0.018431	0.018431	0.0042747	0.1283
9	0.022497	0.022497	0.0041677	0.12698
10	0.026837	0.026837	0.0084247	0.082973
a = 0.34743	b = 0.11312	c = 0.13108		
SSE = 0.00000011766				

Home Computer (Introduction year: 1990)

t	x	z	p	q
1	0.00017165	0.00017125	0.00040811	0.1627
2	0.00057414	0.00057393	0.00042285	0.16636
3	0.0011701	0.0011696	0.00067637	0.50636
4	0.0020286	0.0020293	0.001894	0.16215
5	0.0030692	0.0030718	0.00078879	0.062427
6	0.0044625	0.0044614	0.0011052	0.10303
7	0.0059962	0.0059966	0.0091095	0.22205
8	0.0077525	0.0077534	0.1029	0.39776
9	0.0097171	0.009718	0.0018161	0.065751
10	0.011984	0.011984	0.026851	0.17915
a = 1.5388	b = 1.8058	c = 0.13533		
SSE = 0.0000032932				

Mobile Phone (Introduction year: 1989)

t	x	z	p	q
1	1.3187e-005	1.2978e-005	3.6729e-005	0.12943
2	3.102e-005	3.1012e-005	4.5559e-005	0.070848
3	0.00010552	0.00010572	0.00014227	0.29679
4	0.00022178	0.00022155	0.00031381	0.11789
5	0.00035566	0.00035569	0.00032737	0.094691
6	0.00056866	0.00056862	0.0002756	0.17884
7	0.00091193	0.00091228	0.0005864	0.14955
8	0.0014186	0.0014186	0.0011677	0.13622
9	0.0022532	0.0022532	0.0014378	0.27924
10	0.037816	0.037816	0.09727	0.041903
a = 0.93985	b = 0.082346	c = 0.13819		
SSE = 0.00000058589				

Video Camera (Introduction year: 1977)

t	x	z	p	q
1	1.6468e-005	1.6368e-005	5.6827e-005	0.11317
2	6.5764e-005	6.569e-005	0.00016429	0.054291
3	0.00011507	0.00011512	0.00016424	0.034656
4	0.00016461	0.00016453	0.00015887	0.032291
5	0.00024664	0.00024668	0.00022713	0.086627
6	0.00031197	0.0003121	0.00020321	0.030251
7	0.00040957	0.00040967	0.00020788	0.10243
8	0.00049048	0.00049043	0.00012819	0.090589
9	0.00058667	0.00058669	0.00022559	0.053484
10	0.00066635	0.00066632	0.00016492	0.0464
a = 0.048801	b = 0.026776	c = 0.05288		
SSE = 0.00000023484				

POLAND

Compact Disc Player (Introduction year: 1988)

t	x	z	p	q
1	0.0015914	0.0015915	0.0020711	0.48344
2	0.0081482	0.0081481	0.007598	0.23939
3	0.019779	0.019779	0.0080976	0.29359
4	0.036215	0.036215	0.011897	0.31084
5	0.058128	0.058129	0.019373	0.18254
6	0.081425	0.081425	0.015023	0.22303
7	0.10765	0.10765	0.024233	0.12221
8	0.13934	0.13934	0.050053	0.042421
9	0.17657	0.17657	0.051517	0.093229
10	0.21823	0.21823	0.055927	0.10983

a = 0.16676 | b = 0.077226 | c = 0.19358

SSE = 0.0000012074

Home Computer (Introduction year: 1987)

t	x	z	p	q
1	0.0023782	0.002378	0.00305	0.39555
2	0.010758	0.010758	0.012054	0.2118
3	0.023935	0.023935	0.012477	0.30522
4	0.043447	0.043447	0.014874	0.22171
5	0.067608	0.067608	0.022351	0.21293
6	0.09895	0.09895	0.024109	0.21091
7	0.13439	0.13439	0.042496	0.11902
8	0.17164	0.17164	0.040229	0.10988
9	0.2114	0.2114	0.040799	0.13997
10	0.25292	0.25292	0.071641	0.070278

a = 0.30255 | b = 0.040663 | c = 0.21809

SSE = 0.00000046155

Mobile Phone (Introduction year: 1990)

t	x	z	p	q
1	2.864e-005	2.89e-005	4.3058e-005	0.069981
2	7.3396e-005	7.34e-005	4.5862e-005	0.31438
3	0.00014701	0.000147	6.838e-005	0.27305
4	0.00055503	0.000555	0.00039511	0.46474
5	0.001567	0.001567	0.0012194	0.21002
6	0.0035111	0.003511	0.0017747	0.32211
7	0.0091279	0.009128	0.0044841	0.4527
8	0.030143	0.030143	0.024313	0.30848
9	0.080014	0.080014	0.05806	0.31139
10	0.18235	0.18235	0.13756	0.29173

a = 0.039389 | b = 0.0069543 | c = 0.028219

SSE = 0.00000034086

Video Camera (Introduction year: 1986)

t	x	z	p	q
1	6.3897e-005	6.4114e-005	9.9321e-005	0.12896
2	0.0004549	0.00045502	0.00043819	0.49712
3	0.0013969	0.001397	0.0011786	0.25425
4	0.002511	0.0025109	0.0013276	0.14775
5	0.0039412	0.003941	0.0010484	0.22571
6	0.0077237	0.0077241	0.0021258	0.42605
7	0.01368	0.01368	0.0058589	0.20579
8	0.020551	0.020551	0.0051702	0.2101
9	0.027751	0.027751	0.0031406	0.21169
10	0.035495	0.035495	0.0074422	0.10017

a = 0.076931 | b = 0.010338 | c = 0.24948

SSE = 0.00000053061

PORTUGAL

Compact Disc Player (Introduction year: 1987)

t	x	z	p	q
1	0.0014843	0.001484	0.0029066	0.41631
2	0.0048519	0.004852	0.0061978	0.2913
3	0.0093439	0.009344	0.0085576	0.16738
4	0.01597	0.01597	0.014825	0.15127
5	0.033445	0.033445	0.029785	0.36588
6	0.062216	0.062216	0.06485	0.28464
7	0.10157	0.10157	0.071807	0.32343
8	0.15467	0.15467	0.1438	0.27386
9	0.21729	0.21729	0.17442	0.25702
10	0.28125	0.28125	0.27668	0.37192
ạ = 0.18575	b = 0.15952	c = 0.13317		
SSE = 0.00000069715				

Home Computer (Introduction year: 1987)

t	x	z	p	q
1	9.0998e-005	9.08e-005	0.00020105	0.10299
2	0.0056641	0.005664	0.011985	0.2526
3	0.015484	0.015484	0.013149	0.39724
4	0.031256	0.031256	0.034107	0.23076
5	0.050931	0.050931	0.045471	0.16795
6	0.078186	0.078186	0.078699	0.15406
7	0.10809	0.10809	0.024142	0.3429
8	0.14411	0.14411	0.061874	0.27693
9	0.18107	0.18107	0.089361	0.13444
10	0.21903	0.21903	0.090457	0.21346
ạ = 0.28168	b = 0.20512	c = 0.30714		
SSE = 0.00000049933				

Mobile Phone (Introduction year: 1989)

t	x	z	p	q
1	0.00028014	0.00028	0.00065837	0.30914
2	0.00093482	0.000935	0.001338	0.35349
3	0.0022111	0.002211	0.0022625	0.34402
4	0.0059879	0.005988	0.007041	0.38929
5	0.016252	0.016252	0.026191	0.13715
6	0.033792	0.033792	0.037744	0.24349
7	0.068179	0.068179	0.051396	0.34414
8	0.13511	0.13511	0.12332	0.42898
9	0.28681	0.28681	0.75695	0.46678
ạ = 0.089997	b = 0.10196	c = 0.068719		
SSE = 0.00000058202				

Video Camera (Introduction year: 1988)

t	x	z	p	q
1	0.0029092	0.002909	0.0074496	0.080643
2	0.0087331	0.008733	0.012205	0.19507
3	0.017568	0.017568	0.017209	0.25989
4	0.029462	0.029462	0.019987	0.25334
5	0.044493	0.044493	0.025527	0.25459
6	0.0629	0.0629	0.036933	0.15978
7	0.083896	0.083896	0.03912	0.17218
8	0.10992	0.10992	0.058476	0.099141
9	0.13665	0.13666	0.034654	0.20249
10	0.16961	0.16961	0.082559	0.15468
ạ = 0.24385	b = 0.13284	c = 0.14168		
SSE = 0.00000065783				

RUSSIAN FEDERATION

Compact Disc Player (Introduction year: 1988)

t	x	z	p	q
1	0.00053402	0.000534	0.00068334	0.13124
2	0.0019133	0.001913	0.0015491	0.37288
3	0.0057549	0.005755	0.0065791	0.16254
4	0.0094439	0.009444	0.0023101	0.13959
5	0.016781	0.016781	0.0060453	0.18314
6	0.024049	0.024049	0.014669	0.25226
7	0.034852	0.034852	0.0093853	0.15771
8	0.049111	0.049111	0.0083607	0.18491
9	0.070564	0.070564	0.012212	0.19535
10	0.09561	0.09561	0.016515	0.23157

a = 0.83913 | b = 0.042363 | c = 1.5376

SSE = 0.00000072244

Home Computer (Introduction year: 1988)

t	x	z	p	q
1	0.000142	0.000142	0.00019041	0.03836
2	0.0019102	0.00191	0.0025022	0.19521
3	0.0050468	0.005047	0.0054035	0.18017
4	0.0096851	0.009685	0.0024826	0.18557
5	0.015582	0.015582	0.0039249	0.18759
6	0.023237	0.023237	0.014574	0.36501
7	0.031612	0.031612	0.0060211	0.17051
8	0.04235	0.04235	0.0073136	0.13103
9	0.053235	0.053235	0.010763	0.045371
10	0.067663	0.067663	0.018037	0.065227

a = 0.97 | b = 0.042812 | c = 1.3126

SSE = 0.00000053815

Mobile Phone (Introduction year: 1991)

t	x	z	p	q
1	1.9879e-006	2.02e-006	1.422e-006	0.13526
2	4.2417e-005	4.25e-005	4.159e-005	0.11878
3	0.00010982	0.00011	0.00039441	0.20179
4	0.00029694	0.000297	0.00026427	0.10401
5	0.00089572	0.000896	0.00065179	0.090314
6	0.0024739	0.002474	0.00096012	0.3854
7	0.0057701	0.00577	0.0032584	0.37698
8	0.010861	0.010861	0.0033275	0.46075
9	0.020228	0.020228	0.0073007	0.12262
10	0.042647	0.042647	0.021941	0.21034

a = 1.3718 | b = 0.04367 | c = 1.7526

SSE = 0.00000050082

Video Camera (Introduction year: 1991)

t	x	z	p	q
1	0.00059689	0.000597	0.00050095	0.31522
2	0.0020012	0.002001	0.0014704	0.15536
3	0.0057589	0.005759	0.0067886	0.24684
4	0.009489	0.009489	0.0029745	0.10562
5	0.016706	0.016706	0.0042152	0.23558
6	0.023963	0.023963	0.0053069	0.13668
7	0.031335	0.031335	0.0047628	0.1525
8	0.042215	0.042215	0.007976	0.18247
9	0.053108	0.053108	0.0086552	0.07194
10	0.066317	0.066317	0.011336	0.096455

a = 0.63458 | b = 0.088278 | c = 0.91251

SSE = 0.00000047609

SINGAPORE

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	0.0024552	0.002456	0.0020423	0.21541
2	0.0076246	0.007624	0.0044525	0.21986
3	0.028078	0.028079	0.012739	0.30412
4	0.06798	0.06798	0.021266	0.24324
5	0.12292	0.12292	0.027995	0.23317
6	0.19985	0.19985	0.046917	0.27786
7	0.28889	0.28889	0.029894	0.25767
8	0.38352	0.38352	0.074097	0.19475
9	0.48489	0.48489	0.096029	0.22849
10	0.59343	0.59343	0.091464	0.15959
a = 0.32813	b = 0.2163	c = 0.30469		
SSE = 0.0000018414				

Home Computer (Introduction year: 1985)

t	x	z	p	q
1	0.0052296	0.00523	0.0044925	0.16451
2	0.016815	0.016816	0.0087956	0.14346
3	0.03491	0.03491	0.011593	0.20402
4	0.062872	0.062873	0.012936	0.33511
5	0.096401	0.096401	0.022134	0.13404
6	0.13516	0.13517	0.02651	0.14223
7	0.17943	0.17943	0.031489	0.14059
8	0.22994	0.22994	0.029517	0.12799
9	0.28706	0.28706	0.041156	0.10818
10	0.35137	0.35137	0.054035	0.11317
a = 0.15137	b = 0.076901	c = 0.22084		
SSE = 0.000001765				

Mobile Phone (Introduction year: 1988)

t	x	z	p	q
1	0.0042293	0.004229	0.0035216	0.33244
2	0.014257	0.014258	0.0065132	0.30495
3	0.033584	0.033584	0.010102	0.39732
4	0.063554	0.063554	0.012733	0.40071
5	0.10657	0.10658	0.020778	0.2512
6	0.16948	0.16948	0.043448	0.16729
7	0.25068	0.25067	0.043443	0.26276
8	0.35411	0.35411	0.071894	0.23935
9	0.49704	0.49704	0.13931	0.24866
10	0.77311	0.77311	0.53264	0.4912
a = 0.13273	b = 0.06051	c = 0.22592		
SSE = 0.0000013188				

Video Camera (Introduction year: 1983)

t	x	z	p	q
1	0.00071398	0.000714	0.00066556	0.07521
2	0.0027501	0.00275	0.0014999	0.36426
3	0.006058	0.006058	0.0019528	0.25837
4	0.010766	0.010766	0.0027768	0.16888
5	0.016887	0.016887	0.0037832	0.13629
6	0.02449	0.02449	0.0035425	0.20729
7	0.033446	0.033446	0.0057885	0.079472
8	0.043755	0.043755	0.003749	0.17998
9	0.055497	0.055497	0.0053897	0.15398
10	0.068622	0.068622	0.0070739	0.078927
a = 0.14186	b = 0.1198	c = 0.11628		
SSE = 0.00000062529				

SOUTH AFRICA

Compact Disc Player (Introduction

SOUTH AFRICA

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.00013398	0.000134	0.00028324	0.14541
2	0.001772	0.001772	0.0024239	0.37865
3	0.0045109	0.004511	0.0039764	0.26295
4	0.009075	0.009075	0.0060831	0.17321
5	0.014715	0.014715	0.0073146	0.23687
6	0.021188	0.021188	0.0064223	0.19025
7	0.028453	0.028453	0.007688	0.11916
8	0.036392	0.036392	0.0092422	0.13379
9	0.045056	0.045056	0.0092591	0.12059
10	0.054337	0.054337	0.0072984	0.078572
a = 0.16108	b = 0.035083	c = 0.61579		
SSE = 0.00000022217				

Home Computer (Introduction year: 1988)

t	x	z	p	q
1	0.00015387	0.000154	0.00033953	0.12442
2	0.001675	0.001675	0.0021368	0.49517
3	0.0044079	0.004408	0.0020209	0.47165
4	0.008504	0.008504	0.0045506	0.33462
5	0.013762	0.013762	0.0047512	0.27589
6	0.020762	0.020762	0.0035773	0.18083
7	0.027739	0.027739	0.008538	0.069618
8	0.036916	0.036916	0.010689	0.13573
9	0.04731	0.04731	0.0072575	0.13843
10	0.058859	0.058859	0.011054	0.18134
a = 0.656	b = 0.042284	c = 0.80656		
SSE = 0.00000027729				

Mobile Phone (Introduction year: 1989)

t	x	z	p	q
1	0.00011379	0.000114	0.00020205	0.23801
2	0.0002742	0.000274	0.00012933	0.48337
3	0.00046978	0.00047	0.00030976	0.12788
4	0.00080802	0.000808	0.00040967	0.2166
5	0.001866	0.001866	0.00095603	0.31584
6	0.010667	0.010667	0.011647	0.30801
7	0.02422	0.02422	0.017678	0.30061
8	0.047989	0.047989	0.019642	0.3825
9	0.087414	0.087414	0.07314	0.23336
10	0.14805	0.14805	0.094481	0.28163
a = 0.72109	b = 0.013688	c = 0.42119		
SSE = 0.00000052405				

Video Camera (Introduction year: 1990)

t	x	z	p	q
1	0.00034154	0.000342	0.00053392	0.1994
2	0.0013719	0.001371	0.0010863	0.6857
3	0.0031082	0.003109	0.0026046	0.20984
4	0.0055936	0.005594	0.00037877	0.34028
5	0.0080485	0.008049	0.0023863	0.10507
6	0.012681	0.012682	0.0050043	0.21278
7	0.01736	0.017359	0.0035777	0.1421
8	0.021996	0.021997	0.0034571	0.22127
9	0.026971	0.026971	0.0078829	0.046641
10	0.031915	0.031916	0.0040676	0.091107
a = 1.0643	b = 0.043489	c = 0.75383		
SSE = 0.0000025273				

/ SOUTH KOREA

SOUTH KOREA

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	0.00021261	0.000213	0.00024155	0.065192
2	0.00077976	0.00078	0.00026149	0.39109
3	0.002024	0.002024	0.00085311	0.18007
4	0.0052421	0.005242	0.0024093	0.23236
5	0.014982	0.014982	0.0075088	0.16776
6	0.031055	0.031055	0.00975	0.38199
7	0.05524	0.05524	0.020514	0.36044
8	0.084942	0.084942	0.01247	0.21681
9	0.11722	0.11722	0.032727	0.21758
10	0.15241	0.15241	0.03134	0.18437
a = 0.19734	b = 0.59697	c = 0.26338		
SSE = 0.00000072185				

Home Computer (Introduction year: 1985)

t	x	z	p	q
1	0.0019742	0.001974	0.0016676	0.26851
2	0.0085442	0.008545	0.0050885	0.38647
3	0.020037	0.020037	0.0064106	0.30077
4	0.037069	0.037069	0.015341	0.2137
5	0.060015	0.060015	0.025366	0.2276
6	0.088286	0.088287	0.011698	0.21146
7	0.12201	0.12201	0.031921	0.23943
8	0.16183	0.16183	0.048382	0.13654
9	0.20779	0.20779	0.021122	0.17845
10	0.26023	0.26022	0.026994	0.098415
a = 0.068619	b = 0.55906	c = 0.093765		
SSE = 0.0000012745				

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	0.00017004	0.00017	0.00019854	0.29929
2	0.00041024	0.00041	0.00020204	0.28249
3	0.0008868	0.000887	0.00045749	0.2282
4	0.0018299	0.00183	0.0009081	0.2268
5	0.0036968	0.003697	0.0011105	0.34453
6	0.007535	0.007535	0.00256	0.37514
7	0.01375	0.01375	0.0035482	0.35443
8	0.024425	0.024425	0.0065913	0.27801
9	0.045936	0.045936	0.012758	0.27548
10	0.082331	0.082331	0.03129	0.2156
a = 0.13384	b = 0.093701	c = 0.053187		
SSE = 0.00000052008				

Video Camera (Introduction year: 1982)

t	x	z	p	q
1	0.00068978	0.00069	0.0011261	0.030356
2	0.0044698	0.00447	0.0052702	0.18057
3	0.011592	0.011592	0.0075513	0.27792
4	0.022558	0.022558	0.010707	0.23423
5	0.037715	0.037715	0.012857	0.23124
6	0.057532	0.057532	0.0081907	0.31931
7	0.082576	0.082576	0.011885	0.2774
8	0.1127	0.1127	0.027247	0.15829
9	0.14735	0.14735	0.027602	0.16021
10	0.18647	0.18647	0.032046	0.16148
a = 0.026888	b = 0.031969	c = 0.026731		
SSE = 0.0000006025				

SPAIN

SPAIN

Compact Disc Player (Introduction year: 1986)

t	x	z	p	q
1	0.0017098	0.00171	0.0018293	0.22789
2	0.0052279	0.005228	0.0027412	0.31734
3	0.014177	0.014177	0.0061474	0.42725
4	0.028391	0.028391	0.012291	0.16091
5	0.051628	0.051628	0.019487	0.25761
6	0.082909	0.082909	0.031521	0.14552
7	0.12351	0.12351	0.018313	0.35639
8	0.17179	0.17179	0.033306	0.235
9	0.23053	0.23053	0.064403	0.17001
10	0.29584	0.29585	0.063008	0.18717
a = 0.075425	b = 0.20699	c = 0.083277		
SSE = 0.00000093871				

Home Computer (Introduction year: 1988)

t	x	z	p	q
1	0.002802	0.002802	0.0029206	0.33416
2	0.0091501	0.00915	0.0050668	0.26564
3	0.020373	0.020373	0.010519	0.25183
4	0.034519	0.034519	0.0068153	0.33566
5	0.054654	0.054654	0.017714	0.22457
6	0.078915	0.078915	0.021666	0.14802
7	0.10911	0.10912	0.017142	0.24151
8	0.14272	0.14272	0.028903	0.13423
9	0.17796	0.17796	0.024022	0.15131
10	0.22563	0.22563	0.034081	0.11719
a = 0.14046	b = 0.23784	c = 0.1074		
SSE = 0.00000096776				

Mobile Phone (Introduction year: 1985)

t	x	z	p	q
1	2.6064e-005	2.61e-005	1.4821e-005	0.20782
2	7.0258e-005	7.02e-005	3.0645e-005	0.16325
3	0.00017893	0.000179	5.5093e-005	0.19673
4	0.00047924	0.000479	0.00025008	0.16256
5	0.0012481	0.001248	0.0003128	0.22382
6	0.0026571	0.002657	0.001319	0.31854
7	0.0054351	0.005435	0.0027479	0.12282
8	0.010054	0.010054	0.007409	0.19031
9	0.016636	0.016636	0.0051384	0.25265
10	0.027164	0.027164	0.014829	0.23705
a = 0.09372	b = 1.2091	c = 0.13632		
SSE = 0.00000033079				

Video Camera (Introduction year: 1983)

t	x	z	p	q
1	0.00014327	0.000143	0.00017806	0.15087
2	0.001699	0.001699	0.0019889	0.076422
3	0.0042759	0.004276	0.0028154	0.12157
4	0.0082561	0.008256	0.0040212	0.13418
5	0.013308	0.013308	0.0021145	0.31023
6	0.019816	0.019816	0.0043976	0.19577
7	0.027075	0.027075	0.0056772	0.12108
8	0.036443	0.036443	0.0098995	0.072977
9	0.045863	0.045863	0.011357	0.03071
10	0.058287	0.058287	0.0086713	0.13674
a = 0.065982	b = 0.056461	c = 0.052454		
SSE = 0.00000077272				

SWEDEN

SWEDEN

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	0.0022641	0.002264	0.0024419	0.16599
2	0.030273	0.030273	0.025773	0.41571
3	0.085396	0.085396	0.039164	0.36556
4	0.16641	0.16641	0.06036	0.36149
5	0.27353	0.27353	0.10673	0.19953
6	0.40651	0.40651	0.10539	0.40206
7	0.56585	0.56585	0.22103	0.4113
8	0.75158	0.75158	0.71629	0.45328

a = 0.08897 | b = 0.053588 | c = 0.05564

SSE = 0.00000024045

Home Computer (Introduction year: 1984)

t	x	z	p	q
1	0.0041662	0.004166	0.0041554	0.33721
2	0.013715	0.013715	0.0075683	0.35024
3	0.028498	0.028498	0.012459	0.20301
4	0.048492	0.048492	0.0069311	0.387
5	0.073967	0.073967	0.017588	0.20822
6	0.10434	0.10434	0.020834	0.18224
7	0.14055	0.14055	0.03886	0.084922
8	0.18237	0.18237	0.0339	0.14705
9	0.23928	0.23928	0.040909	0.062227
10	0.32329	0.32329	0.10078	0.13853

a = 0.13448 | b = 0.0014972 | c = 0.090481

SSE = 0.00000048249

Mobile Phone (Introduction year: 1985)

t	x	z	p	q
1	0.013169	0.013169	0.009332	0.46698
2	0.026673	0.026673	0.010983	0.17614
3	0.04729	0.04729	0.010778	0.2397
4	0.076136	0.076136	0.02188	0.19592
5	0.11734	0.11735	0.027	0.22427
6	0.17141	0.17141	0.029939	0.21926
7	0.23753	0.23753	0.067631	0.19144
8	0.31342	0.31342	0.0019235	0.0051244
9	0.40258	0.40258	0.10095	0.13769
10	0.5605	0.5605	0.27484	0.16021

a = 0.44818 | b = 0.086455 | c = 0.29822

SSE = 0.00000041401

Video Camera (Introduction year: 1982)

t	x	z	p	q
1	0.00039926	0.000399	0.00040998	0.46641
2	0.0037292	0.003729	0.002801	0.41556
3	0.0099779	0.009978	0.0049709	0.26001
4	0.018803	0.018803	0.0053061	0.1647
5	0.030845	0.030845	0.0071382	0.28197
6	0.044998	0.044998	0.0053226	0.18584
7	0.06285	0.062849	0.011048	0.17769
8	0.087384	0.087384	0.017591	0.15492
9	0.11591	0.11591	0.012566	0.13124
10	0.14669	0.14669	0.031681	0.13519

a = 0.11273 | b = 0.17223 | c = 0.093817

SSE = 0.0000010037

SWITZERLAND

SWITZERLAND

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.00084798	0.000848	0.001043	0.25022
2	0.010589	0.010589	0.0082268	0.43373
3	0.028345	0.028345	0.016009	0.32585
4	0.055218	0.055218	0.027582	0.39486
5	0.096916	0.096916	0.025594	0.12085
6	0.15127	0.15127	0.040481	0.16707
7	0.22191	0.22192	0.078499	0.4021
8	0.30252	0.30252	0.14958	0.34762
9	0.40296	0.40296	0.24881	0.53418
10	0.5137	0.5137	0.033118	0.032487
a = 0.59723	b = 0.24045	c = 0.3127		
SSE = 0.00000081998				

Home Computer (Introduction year: 1986)

t	x	z	p	q
1	0.0029022	0.002902	0.0031098	0.44476
2	0.019538	0.019538	0.035179	0.3141
3	0.051682	0.051682	0.012634	0.12458
4	0.09685	0.09685	0.026325	0.14986
5	0.15898	0.15898	0.1049	0.36669
6	0.24414	0.24414	0.24508	0.35071
7	0.37534	0.37534	0.75307	0.64906
8	0.53013	0.53013	0.024537	0.024508
a = 0.61646	b = 0.473	c = 0.34028		
SSE = 0.00000036667				

Mobile Phone (Introduction year: 1987)

t	x	z	p	q
1	0.0007702	0.00077	0.00091929	0.46211
2	0.005511	0.005511	0.004872	0.35238
3	0.016587	0.016587	0.010643	0.27332
4	0.035317	0.035317	0.016263	0.42429
5	0.06124	0.06124	0.023928	0.31041
6	0.09266	0.09266	0.028292	0.28255
7	0.13001	0.13001	0.01734	0.038577
8	0.17768	0.17768	0.03621	0.21201
9	0.24136	0.24136	0.058932	0.24928
10	0.33524	0.33524	0.12513	0.2773
a = 0.54495	b = 0.045146	c = 0.89454		
SSE = 0.00000082375				

Video Camera (Introduction year: 1985)

t	x	z	p	q
1	0.0055719	0.005572	0.0066211	0.39217
2	0.018207	0.018206	0.012073	0.41218
3	0.036421	0.036421	0.014897	0.35912
4	0.062152	0.062152	0.019227	0.30922
5	0.090698	0.090698	0.023848	0.2042
6	0.12306	0.12306	0.036283	0.17644
7	0.15037	0.15037	0.025539	0.15037
8	0.16764	0.16764	0.025799	0.049878
9	0.17996	0.17996	0.0091394	0.02725
10	0.20162	0.20162	0.016384	0.092865
a = 0.3825	b = 0.013278	c = 0.099137		
SSE = 0.0000013353				

TAIWAN

TAIWAN

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	0.0022209	0.002221	0.0028926	0.19633
2	0.0084979	0.008498	0.0067281	0.30022
3	0.024973	0.024973	0.020207	0.17099
4	0.056828	0.056828	0.029394	0.24445
5	0.097182	0.097182	0.031068	0.28885
6	0.14689	0.14689	0.039783	0.2502
7	0.20628	0.20628	0.060963	0.22666
8	0.2755	0.2755	0.053831	0.28711
9	0.35443	0.35443	0.1095	0.23421
10	0.44336	0.44336	0.18265	0.21889
a = 0.15623	b = 0.075513	c = 0.12263		
SSE = 0.0000010403				

Home Computer (Introduction year: 1986)

t	x	z	p	q
1	0.0011631	0.001163	0.00083292	0.56161
2	0.0053578	0.005358	0.0043121	0.26125
3	0.012255	0.012255	0.0056526	0.23504
4	0.022988	0.022989	0.011662	0.20224
5	0.039913	0.039914	0.014643	0.24126
6	0.064154	0.064154	0.022387	0.24484
7	0.094296	0.094296	0.027834	0.17934
8	0.12953	0.12953	0.025267	0.17106
9	0.16993	0.16993	0.046321	0.10839
10	0.21981	0.21981	0.033759	0.21773
a = 0.15048	b = 0.26691	c = 0.66029		
SSE = 0.0000013019				

Mobile Phone (Introduction year: 1989)

t	x	z	p	q
1	0.001831	0.001831	0.0025027	0.26055
2	0.0059002	0.0059	0.0044544	0.22816
3	0.01546	0.01546	0.010265	0.31592
4	0.033967	0.033967	0.012525	0.40875
5	0.059639	0.05964	0.019791	0.19234
6	0.087216	0.087216	0.014695	0.23048
7	0.12336	0.12336	0.022564	0.23075
8	0.16842	0.16842	0.031972	0.20128
9	0.23705	0.23705	0.1069	0.37571
10	0.45261	0.45261	0.077877	0.084201
a = 0.47828	b = 0.34704	c = 0.44866		
SSE = 0.00000087915				

Video Camera (Introduction year: 1986)

t	x	z	p	q
1	0.00082806	0.000828	0.00097211	0.21866
2	0.0023323	0.002332	0.0013993	0.32593
3	0.0049132	0.004913	0.002329	0.24864
4	0.0093749	0.009375	0.004586	0.20591
5	0.015165	0.015165	0.0044986	0.22937
6	0.023378	0.023378	0.0062686	0.22477
7	0.034739	0.034739	0.0065782	0.25199
8	0.047025	0.047025	0.0065494	0.19604
9	0.062744	0.062744	0.0098298	0.17974
10	0.079031	0.079032	0.018148	0.075302
a = 0.090184	b = 0.07506	c = 0.081359		
SSE = 0.00000078518				

THAILAND

Compact Disc Player

THAILAND

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.00024692	0.000247	0.0015942	0.1124
2	0.001419	0.001419	0.0047506	0.17419
3	0.0037279	0.003728	0.0080655	0.23965
4	0.0085769	0.008577	0.012472	0.1543
5	0.014102	0.014102	0.016653	0.17506
6	0.020319	0.020319	0.014877	0.19551
7	0.027386	0.027386	0.01513	0.23674
8	0.035113	0.035113	0.031229	0.098903
9	0.043515	0.043515	0.024047	0.16345
10	0.05252	0.05252	0.041567	0.091987
a = 0.060081	b = 0.26336		c = 0.057355	
SSE = 0.00000023687				

Home Computer (Introduction year: 1990)

t	x	z	p	q
1	0.00022193	0.000222	0.0011871	0.065492
2	0.00081803	0.000818	0.0029165	0.025388
3	0.0019031	0.001903	0.0042329	0.24146
4	0.0060671	0.006067	0.019384	0.15513
5	0.011654	0.011654	0.010458	0.2995
6	0.019828	0.019828	0.024353	0.22951
7	0.029817	0.029817	0.031036	0.12698
8	0.042219	0.042219	0.048318	0.10741
9	0.056579	0.056579	0.03617	0.26172
10	0.073215	0.073215	0.083966	0.12112
a = 0.23889	b = 0.36911		c = 0.10451	
SSE = 0.00000019525				

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	1.9149e-005	1.92e-005	9.0549e-005	0.2438
2	0.00013213	0.000132	0.00053081	0.1601
3	0.00046512	0.000465	0.00070092	0.60804
4	0.0011931	0.001193	0.0024883	0.30013
5	0.002326	0.002326	0.0040257	0.20585
6	0.0045289	0.004529	0.0085078	0.18736
7	0.008938	0.008938	0.0092105	0.41835
8	0.016137	0.016137	0.028082	0.18221
9	0.028831	0.028831	0.04632	0.23336
10	0.050977	0.050977	0.071204	0.31734
a = 0.067521	b = 0.04016		c = 0.053429	
SSE = 0.00000027842				

Video Camera (Introduction year: 1983)

t	x	z	p	q
1	0.00042398	0.000424	0.0021664	0.17859
2	0.0011641	0.001164	0.0029242	0.34356
3	0.0022589	0.002259	0.005332	0.049389
4	0.0038439	0.003844	0.0060168	0.14415
5	0.0058419	0.005842	0.0046218	0.18207
6	0.008289	0.008289	0.0050913	0.20763
7	0.011181	0.011181	0.0058905	0.1879
8	0.014637	0.014637	0.011203	0.12709
9	0.018604	0.018604	0.016628	0.068157
10	0.023206	0.023206	0.014938	0.11161
a = 0.047587	b = 0.082352		c = 0.049077	
SSE = 0.00000017977				

TUNISIA

TUNISIA

Compact Disc Player (Introduction year: 1985)

t	x	z	p	q
1	0.00044467	0.000444	0.00076643	0.17541
2	0.001669	0.001669	0.0019298	0.13292
3	0.0035591	0.003559	0.0026754	0.16051
4	0.0063886	0.006388	0.0036303	0.15573
5	0.0097789	0.009779	0.0029379	0.2122
6	0.013629	0.013629	0.0034491	0.15337
7	0.017696	0.017696	0.0031596	0.12469
8	0.022019	0.022019	0.003122	0.13043
9	0.026744	0.026745	0.0057065	0.060395
10	0.031782	0.031781	0.0035814	0.10642
a = 0.042859	b = 0.036208	c = 0.10127		
SSE = 0.0000019719				

Home Computer (Introduction year: 1988)

t	x	z	p	q
1	0.00033791	0.000338	0.00050436	0.29636
2	0.0016069	0.001607	0.0017561	0.12533
3	0.0036061	0.003606	0.0020688	0.22009
4	0.0066429	0.006643	0.0022404	0.26323
5	0.010261	0.010261	0.0019483	0.14805
6	0.014582	0.014582	0.0026027	0.23257
7	0.019754	0.019754	0.0051242	0.11938
8	0.026644	0.026644	0.0053905	0.15538
9	0.034301	0.034301	0.0050589	0.16559
10	0.044515	0.044515	0.006326	0.17319
a = 0.56394	b = 0.18882	c = 0.19323		
SSE = 0.00000056111				

Mobile Phone (Introduction year: 1987)

t	x	z	p	q
1	2.8403e-005	2.84e-005	4.2422e-005	0.32395
2	7.8302e-005	7.83e-005	4.518e-005	0.46412
3	0.000156	0.000156	8.599e-005	0.22917
4	0.00027099	0.000271	6.7546e-005	0.3335
5	0.000418	0.000418	0.00015508	0.15897
6	0.00064901	0.000649	0.00032632	0.065294
7	0.000911	0.000911	0.0003174	0.089355
8	0.001219	0.001219	0.0002053	0.17117
9	0.001577	0.001577	0.00020069	0.16728
10	0.002179	0.002179	0.00050212	0.14817
a = 0.010625	b = 0.01965	c = 0.018216		
SSE = 0.000000012639				

Video Camera (Introduction year: 1985)

t	x	z	p	q
1	0.00012001	0.00012	0.00020643	0.16265
2	0.000706	0.000706	0.00094119	0.14842
3	0.001669	0.001669	0.0012249	0.24232
4	0.003057	0.003057	0.002103	0.085677
5	0.00487	0.00487	0.0015958	0.22779
6	0.007202	0.007202	0.0034941	0.046937
7	0.009826	0.009826	0.0036246	0.047283
8	0.012682	0.012682	0.0031853	0.088786
9	0.015692	0.015692	0.0025238	0.10956
10	0.019342	0.019342	0.0036897	0.085682
a = 0.020025	b = 0.017417	c = 0.10371		
SSE = 0.000000029958				


TURKEY

TURKEY

Compact Disc Player (Introduction year: 1984)

t	x	z	p	q
1	0.001084	0.001084	0.0016996	0.3867
2	0.004422	0.004422	0.004901	0.28646
3	0.009648	0.009648	0.0039538	0.30443
4	0.017098	0.017098	0.0034696	0.17524
5	0.027267	0.027267	0.0075945	0.19579
6	0.037775	0.037775	0.011725	0.086856
7	0.049321	0.049321	0.012177	0.10266
8	0.061189	0.061189	0.0091756	0.11625
9	0.073374	0.073374	0.01101	0.095052
10	0.08611	0.08611	0.0098256	0.11557
a = 0.38878	b = 0.30564		c = 0.26927	
SSE = 0.000000041397				

Home Computer (Introduction year: 1987)

t	x	z	p	q
1	0.000162	0.000162	3.3661e-005	0.6501
2	0.000792	0.000792	2.9629e-005	0.88226
3	0.001657	0.001657	0.0012715	0.064301
4	0.002789	0.002789	0.00049486	0.30807
5	0.004848	0.004848	0.0017536	0.21458
6	0.007939	0.007939	0.002618	0.38216
7	0.011991	0.011991	0.0030847	0.25839
8	0.017162	0.017162	0.003418	0.092577
9	0.0233	0.0233	0.0027142	0.26389
10	0.030713	0.030713	0.00065238	0.24455
a = 0.12089	b = 0.99233		c = 0.055304	
SSE =0. 0000000036025				

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	3.9015e-006	3.9023e-006	1e-006	0.57116
2	0.00010185	0.00010127	0.060281	0.888
3	0.00028525	0.00028528	1e-006	0.98236
4	0.00057022	0.00057058	1e-006	0.65934
5	0.0011425	0.0011425	0.0007816	0.11273
6	0.001988	0.0019878	0.00066506	0.27318
7	0.0030553	0.0030556	0.00028714	0.34712
8	0.0044976	0.0044977	1e-006	0.39299
9	0.0074468	0.0074471	1e-006	0.48795
10	0.014718	0.014718	0.0052218	0.33552
a = 0.10055	b = 0.0035077		c = 0.040228	
SSE = 0.00000085565				

Video Camera (Introduction year: 1983)

t	x	z	p	q
1	0.00046502	0.000465	0.00082628	0.33327
2	0.001493	0.001493	0.00066318	0.73929
3	0.003152	0.003152	0.0029311	0.054492
4	0.005334	0.005334	0.001466	0.32508
5	0.00786	0.00786	0.0017272	0.18134
6	0.011572	0.011572	0.0015267	0.28122
7	0.01554	0.01554	0.0025978	0.18329
8	0.019914	0.019914	0.0030991	0.14456
9	0.024498	0.024498	0.001429	0.17215
10	0.029345	0.029345	0.0020782	0.14084
a = 0.028186	b = 0.073412		c = 0.024206	
SSE = 0.000000084515				

UNITED KINGDOM

Compact Disc Player (Introduction

UNITED KINGDOM

Compact Disc Player (Introduction year: 1983)

t	x	z	p	q
1	0.00089029	0.000891	0.00088041	0.3266
2	0.0067875	0.006787	0.062619	0.30173
3	0.016135	0.016135	0.0050766	0.37688
4	0.031651	0.03165	0.0089673	0.24536
5	0.061739	0.061739	0.018514	0.26649
6	0.1045	0.10451	0.031242	0.21098
7	0.16257	0.16257	0.048514	0.16011
8	0.24388	0.24388	0.079413	0.19255
9	0.34899	0.34899	0.091119	0.24804
10	0.47799	0.47799	0.12711	0.3203
a = 0.37013	b = 0.054426	c = 0.19295		
SSE = 0.0000014608				

Home Computer (Introduction year: 1984)

t	x	z	p	q
1	0.0094657	0.009465	0.049886	0.39932
2	0.032833	0.032834	0.017986	0.31768
3	0.067406	0.067406	0.023106	0.24897
4	0.11761	0.11761	0.021926	0.35794
5	0.17643	0.17643	0.044542	0.19458
6	0.24208	0.24208	0.055821	0.15614
7	0.31737	0.31737	0.065857	0.19689
8	0.39905	0.39905	0.11291	0.095533
9	0.48715	0.48715	0.05742	0.28673
10	0.58162	0.58162	0.12069	0.23553
a = 0.26988	b = 0.047637	c = 0.092823		
SSE = 0.0000015996				

Mobile Phone (Introduction year: 1986)

t	x	z	p	q
1	0.002289	0.002289	0.0017554	0.2183
2	0.0073884	0.007389	0.0038213	0.22373
3	0.017208	0.017208	0.0078096	0.1697
4	0.034242	0.034242	0.010366	0.29709
5	0.05363	0.05363	0.012473	0.27478
6	0.075473	0.075473	0.012911	0.17873
7	0.1015	0.1015	0.015033	0.1818
8	0.14053	0.14053	0.035163	0.12945
9	0.20812	0.20812	0.039612	0.16626
10	0.30617	0.30617	0.054323	0.31211
a = 0.30047	b = 0.20933	c = 0.20314		
SSE = 0.00000086546				

Video Camera (Introduction year: 1979)

t	x	z	p	q
1	0.00040209	0.000402	0.00032193	0.40543
2	0.0022789	0.002279	0.0015812	0.42694
3	0.0053222	0.005322	0.0017058	0.41536
4	0.0095818	0.009582	0.0019806	0.34906
5	0.015186	0.015186	0.0033893	0.22648
6	0.022097	0.022097	0.024323	0.52866
7	0.030418	0.030418	0.0041282	0.16203
8	0.040081	0.040081	0.004534	0.13351
9	0.051143	0.051143	0.005477	0.12583
10	0.063378	0.063378	0.0052754	0.13847
a = 0.27196	b = 0.047795	c = 0.32368		
SSE = 0.0000003795				

UNITED STATES OF AMERICA

Compact Disc Player (Introduction year: 1983)

UNITED STATES OF AMERICA

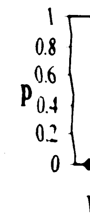
Compact Disc Player (Introduction year: 1983)					Home Computer (Introduction year: 1981)				
t	**x**	**z**	**p**	**q**	**t**	**x**	**z**	**p**	**q**
1	0.0039098	0.00391	0.0016043	0.46804	1	0.0036761	0.003676	0.0087902	0.38243
2	0.016012	0.016012	0.007631	0.50781	2	0.0088749	0.008875	0.0068664	0.14662
3	0.05808	0.05808	0.023266	0.27112	3	0.020888	0.020888	0.0052095	0.10607
4	0.11991	0.11991	0.032705	0.19484	4	0.039326	0.039326	0.015964	0.34764
5	0.2176	0.2176	0.093182	0.10777	5	0.064895	0.064895	0.012349	0.13335
6	0.3275	0.3275	0.080602	0.28571	6	0.097267	0.097267	0.013926	0.14745
7	0.45485	0.45485	0.21033	0.28045	7	0.13732	0.13732	0.034899	0.13903
8	0.59315	0.59315	0.47142	0.39822	8	0.18498	0.18498	0.036184	0.14292
9	0.73706	0.73706	0.95721	0.97914	9	0.24044	0.24044	0.067111	0.21688
10					10	0.30403	0.30403	0.13881	0.24852
a = 1.2219	b = 0.33771	c = 3.03			a = 0.8053	b = 0.80235	c = 0.33369		
SSE = 0.00000041915					SSE = 0.00000036282				
Mobile Phone (Introduction year: 1986)					**Video Camera (Introduction year: 1980)**				
t	**x**	**z**	**p**	**q**	**t**	**x**	**z**	**p**	**q**
1	0.0028561	0.002856	0.0025063	0.37667	1	0.00013553	0.000136	0.00013788	0.24741
2	0.0079631	0.007963	0.0048455	0.26161	2	0.010393	0.010393	0.014719	0.28899
3	0.016471	0.016471	0.0046797	0.38746	3	0.030448	0.030449	0.016412	0.44879
4	0.030769	0.030769	0.010116	0.35896	4	0.060623	0.060624	0.013783	0.2766
5	0.052062	0.052061	0.017356	0.32545	5	0.10029	0.10029	0.039256	0.19464
6	0.08219	0.082191	0.0274	0.1999	6	0.15057	0.15057	0.013369	0.31471
7	0.1257	0.1257	0.025936	0.14474	7	0.21075	0.21075	0.052145	0.13983
8	0.18813	0.18813	0.059342	0.2198	8	0.28253	0.28253	0.067297	0.18326
9	0.2813	0.2813	0.08093	0.26067	9	0.36328	0.36328	0.077656	0.22052
10	0.41046	0.41046	0.14903	0.28114	10	0.45696	0.45697	0.16678	0.21149
a = 0.15453	b = 0.2769	c = 0.14236			a = 0.62625	b = 0.19396	c = 0.43798		
SSE = 0.0000015743					SSE = 0.0000011774				

APPENDI

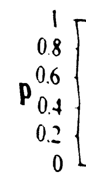
p and *q* Ov

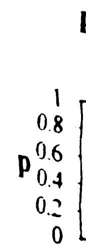
APPENDIX B

p and q Over Time for Each Country and Each Product p for C

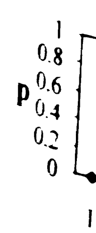


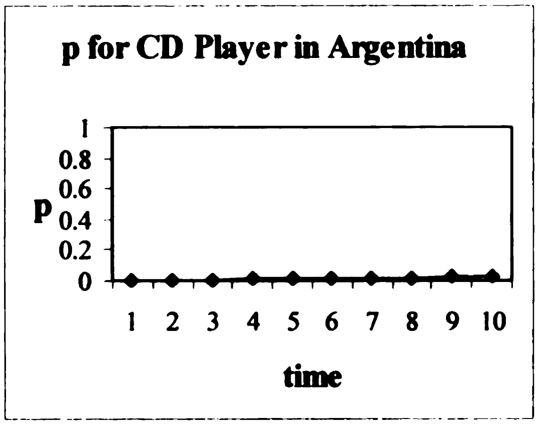
p f

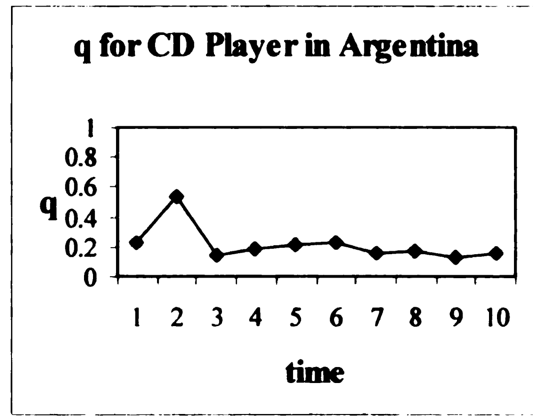


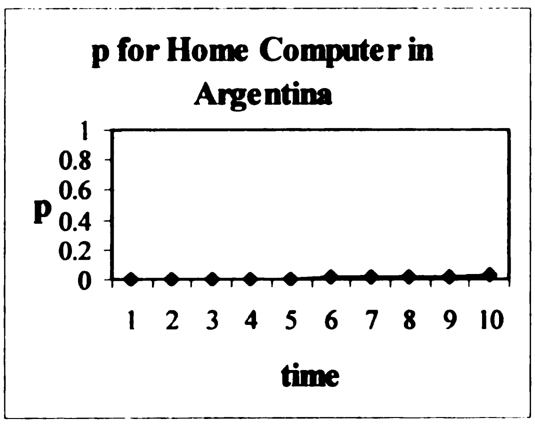


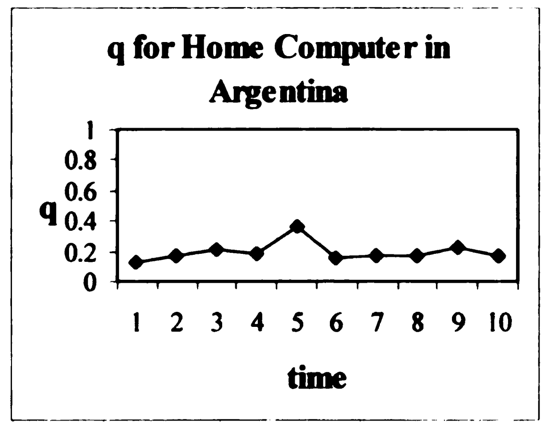
p

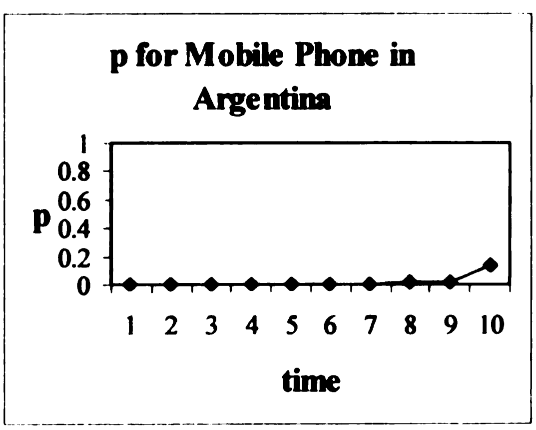


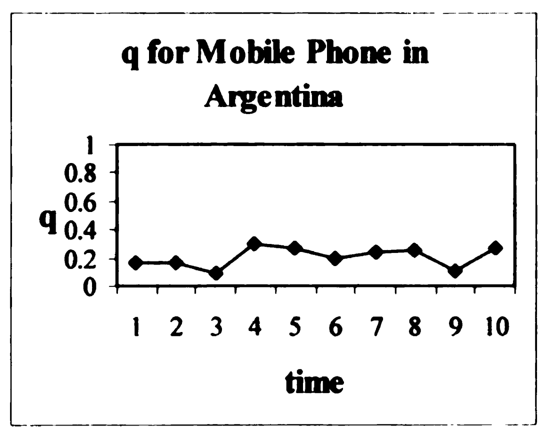

p for CD Player in Argentina
1
0.8
0.6
0.4
0.2
0
p
1 2 3 4 5 6 7 8 9 10
time

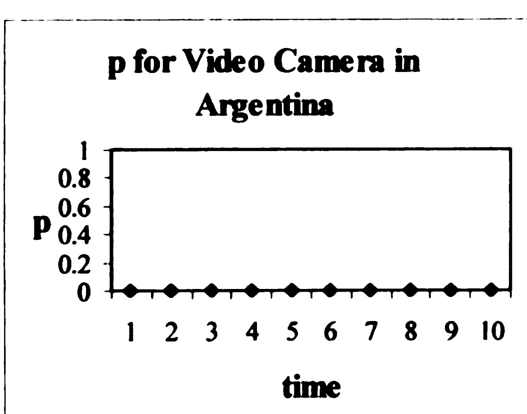

q for CD Player in Argentina
1
0.8
0.6
0.4
0.2
0
q
1 2 3 4 5 6 7 8 9 10
time

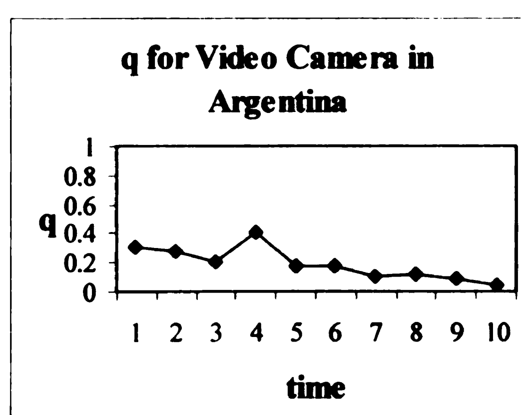

p for Home Computer in Argentina
1
0.8
0.6
0.4
0.2
0
p
1 2 3 4 5 6 7 8 9 10
time

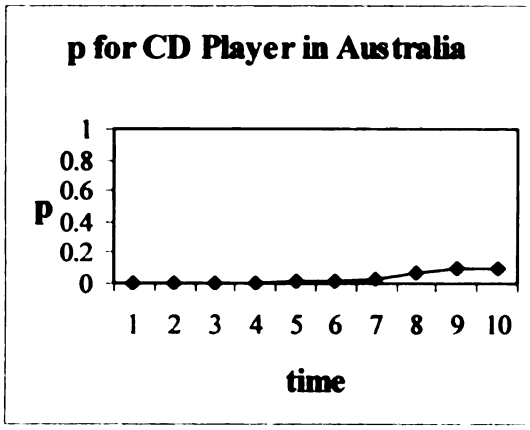

q for Home Computer in Argentina
1
0.8
0.6
0.4
0.2
0
q
1 2 3 4 5 6 7 8 9 10
time

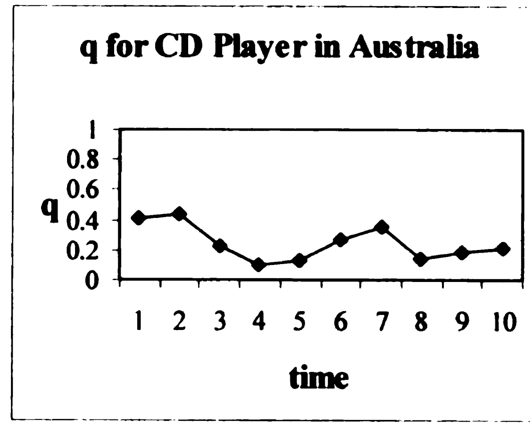

p for Mobile Phone in Argentina
1
0.8
0.6
0.4
0.2
0
p
1 2 3 4 5 6 7 8 9 10
time

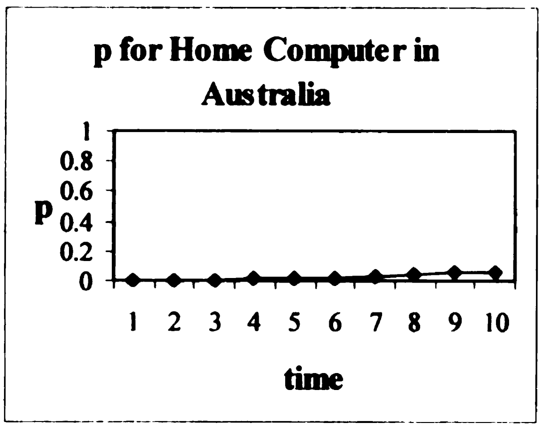

q for Mobile Phone in Argentina
1
0.8
0.6
0.4
0.2
0
q
1 2 3 4 5 6 7 8 9 10
time

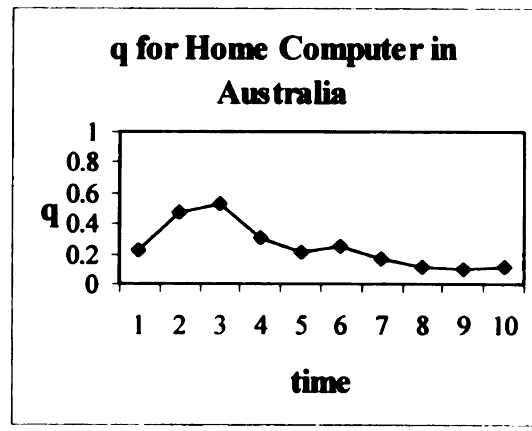

p for Video Camera in Argentina
1
0.8
0.6
0.4
0.2
0
p
1 2 3 4 5 6 7 8 9 10
time


q for Video Camera in Argentina
1
0.8
0.6
0.4
0.2
0
q
1 2 3 4 5 6 7 8 9 10
time


p for CD Player in Australia
p
1
0.8
0.6
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time


q for CD Player in Australia
q
1
0.8
0.6
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time


p for Home Computer in Australia
p
1
0.8
0.6
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time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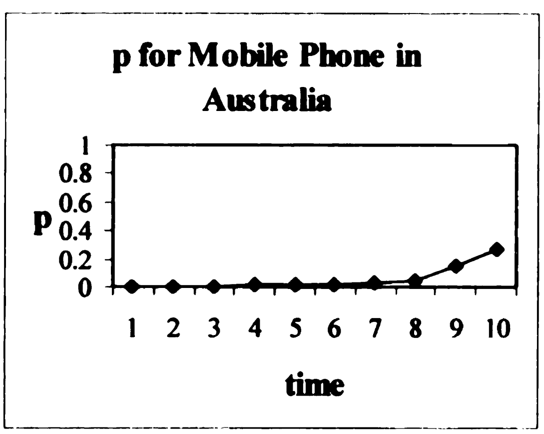
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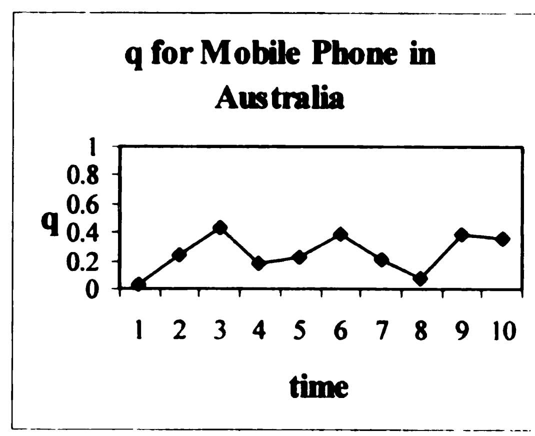
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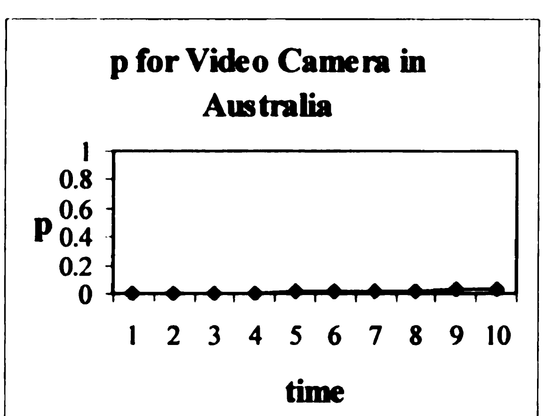
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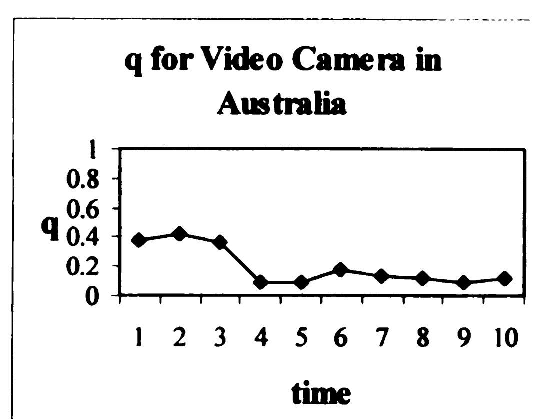
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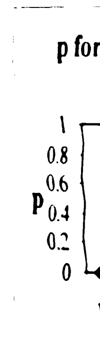
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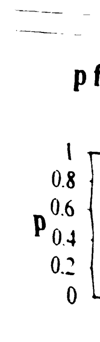
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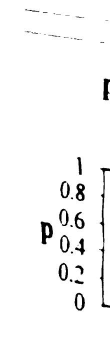
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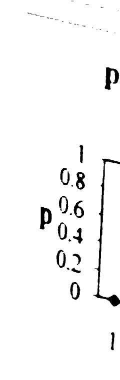
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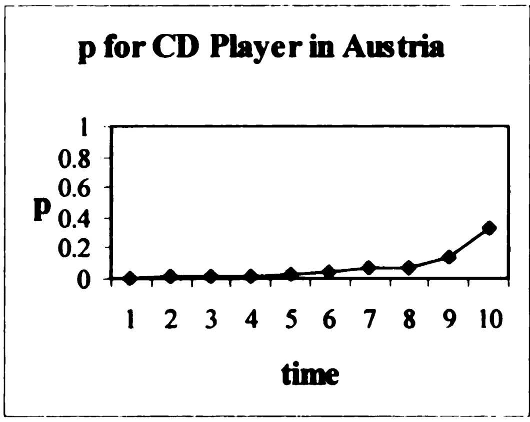
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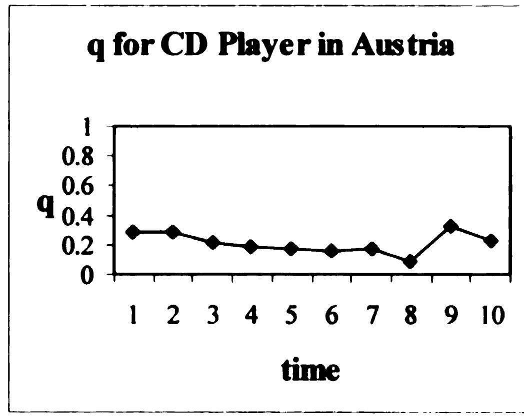
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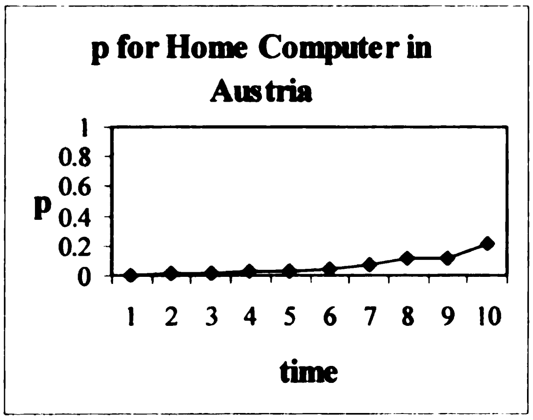
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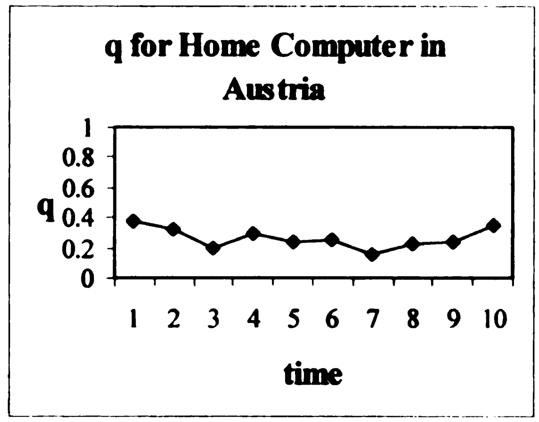
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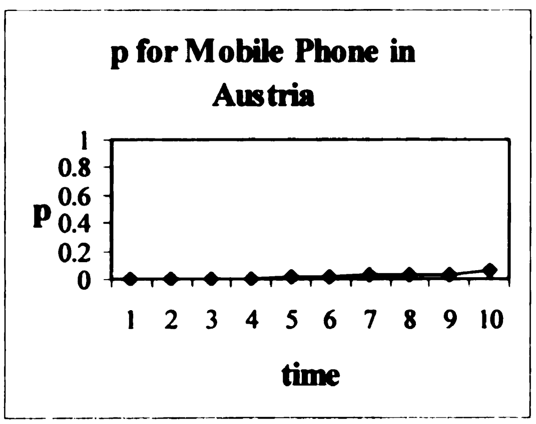
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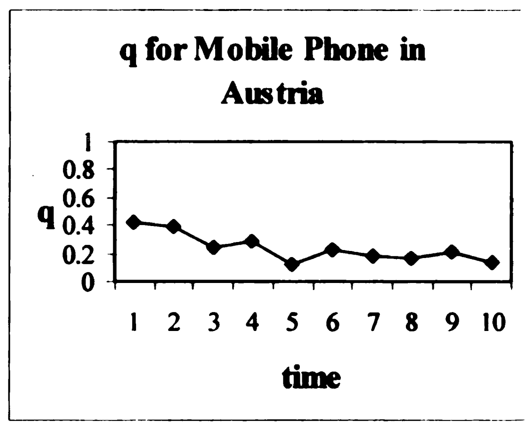
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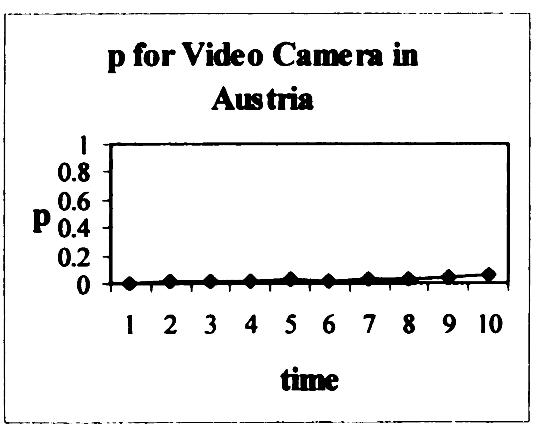
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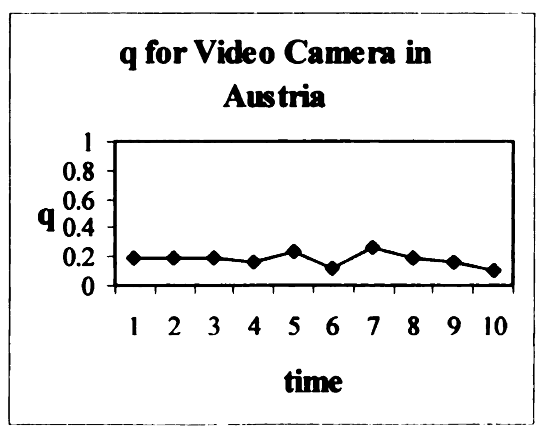
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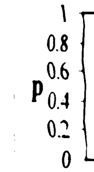

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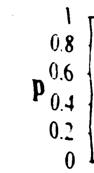

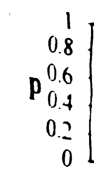

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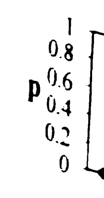

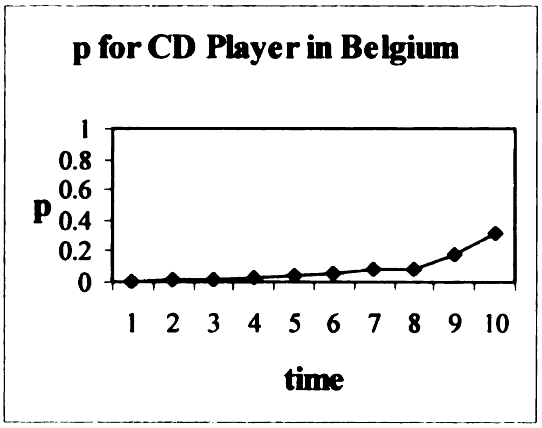
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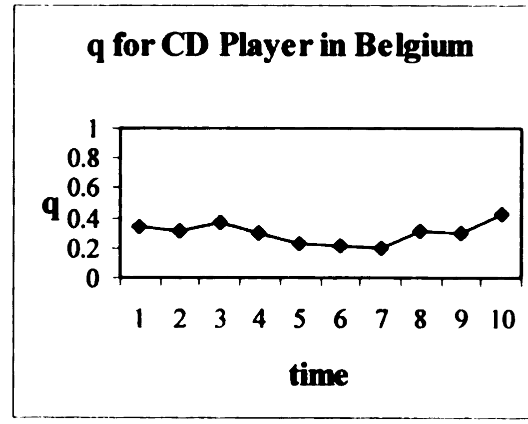
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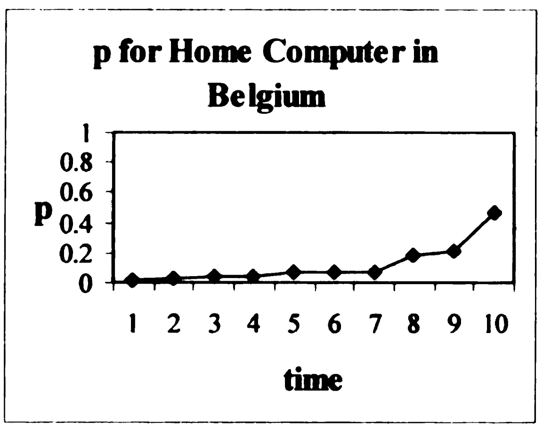
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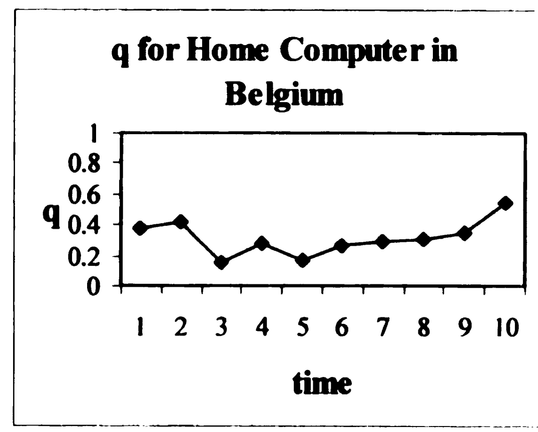
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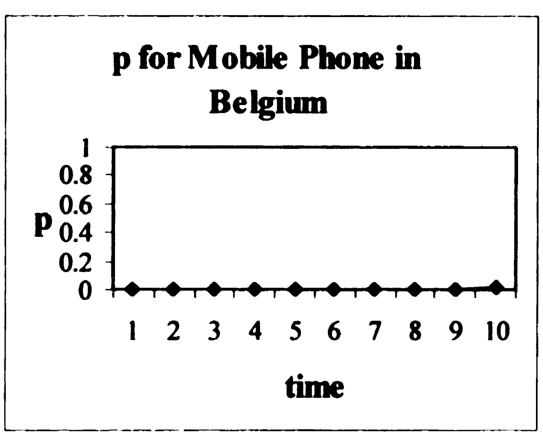
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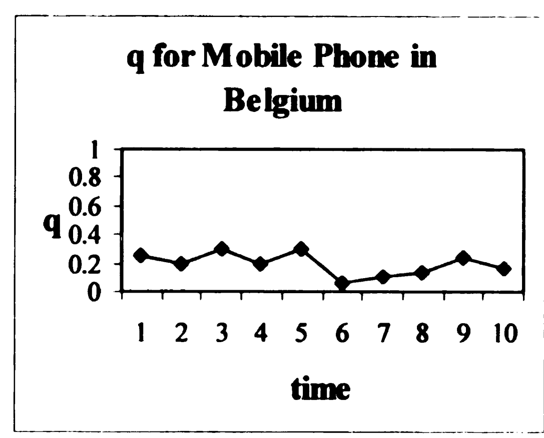
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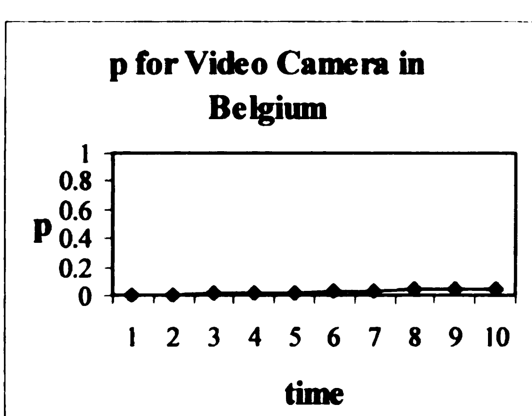
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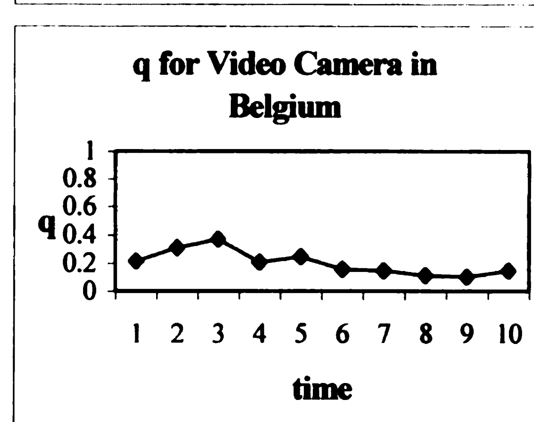
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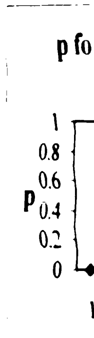
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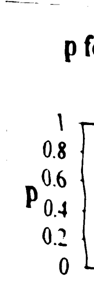
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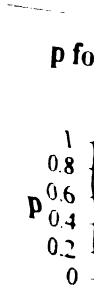
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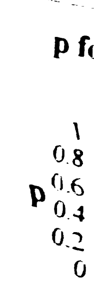
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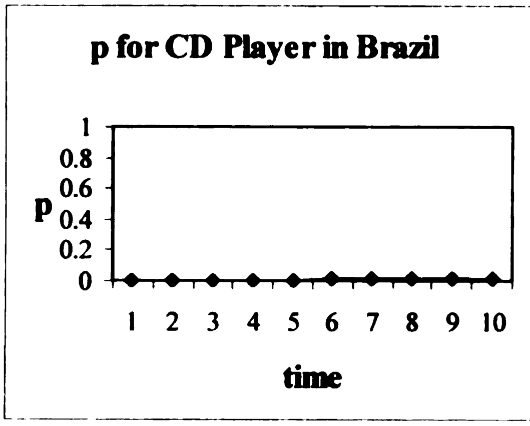
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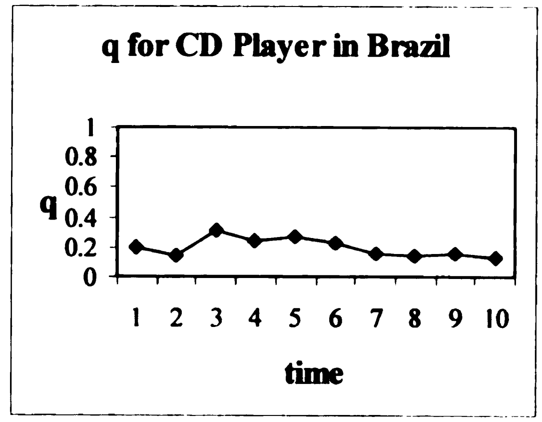
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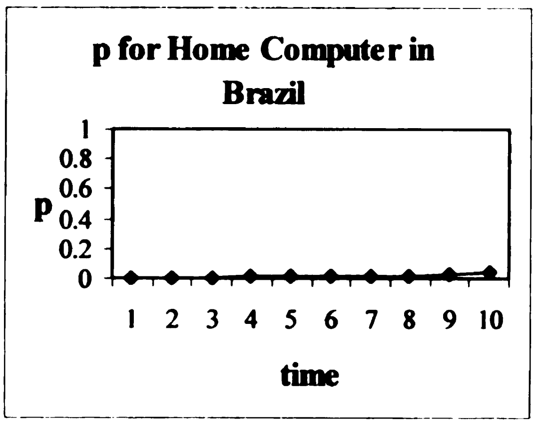
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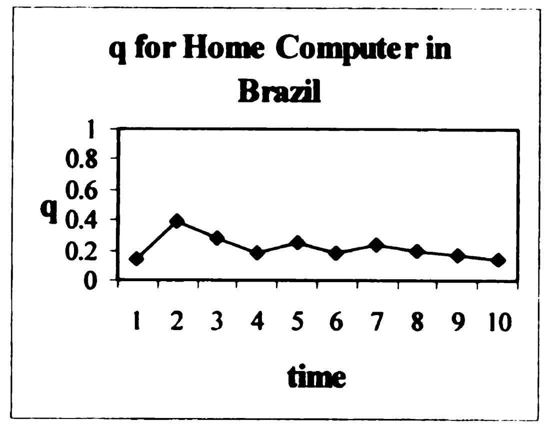
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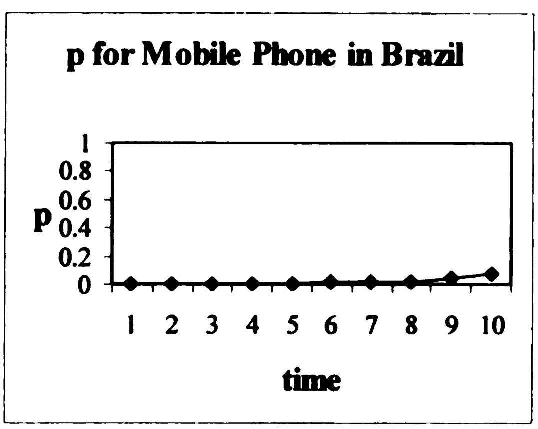
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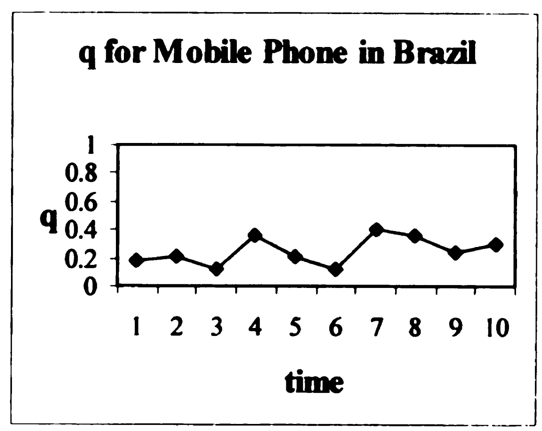
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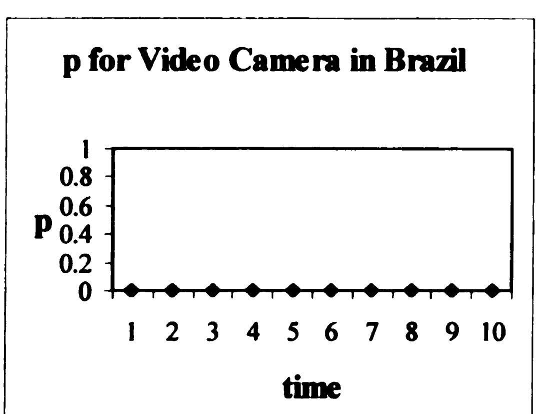
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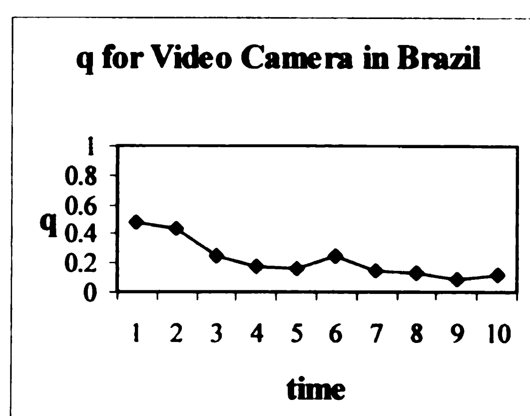
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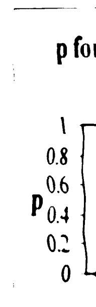
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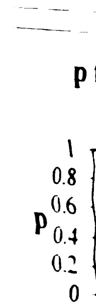
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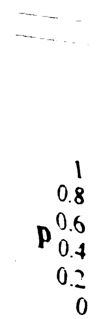
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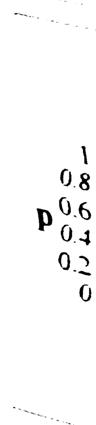
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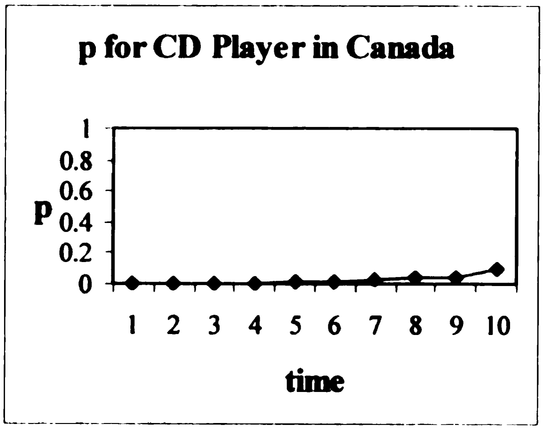
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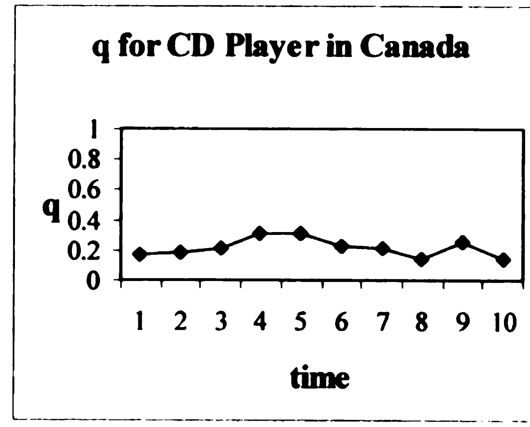
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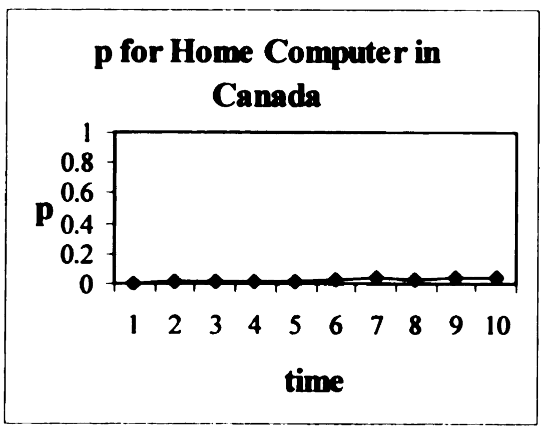
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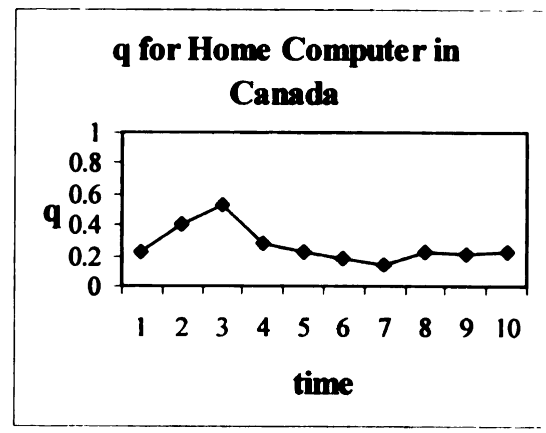
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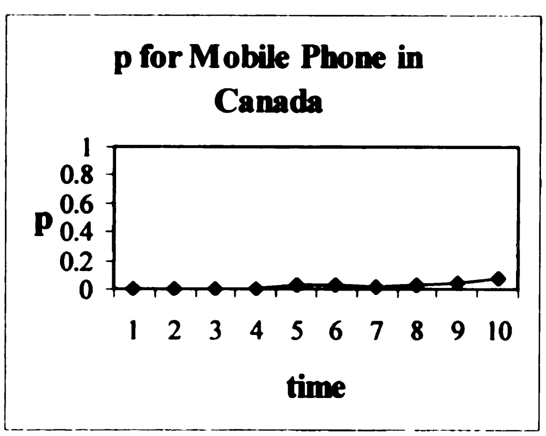
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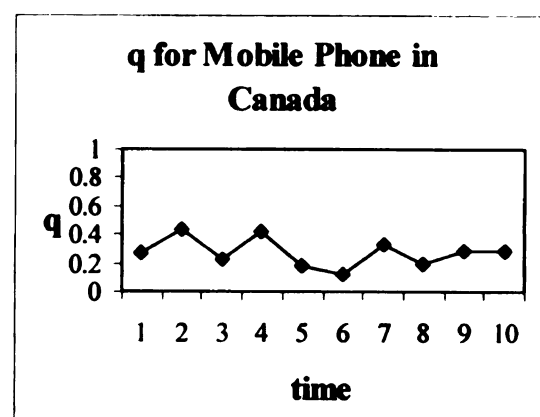
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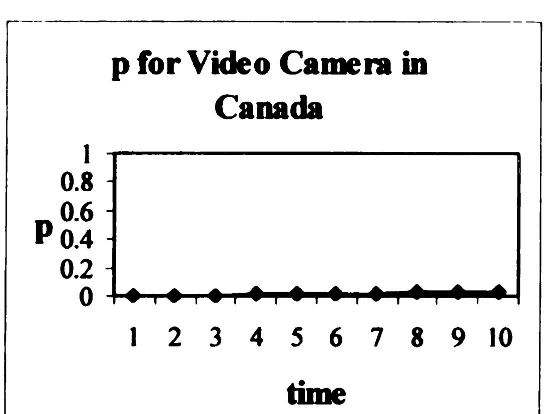
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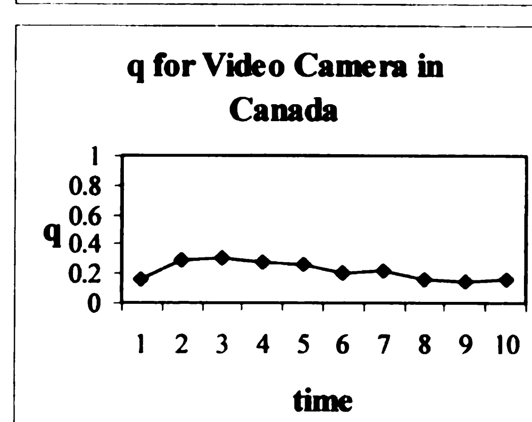
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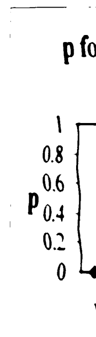
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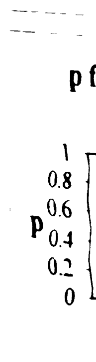
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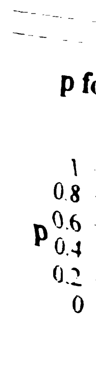
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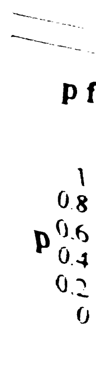
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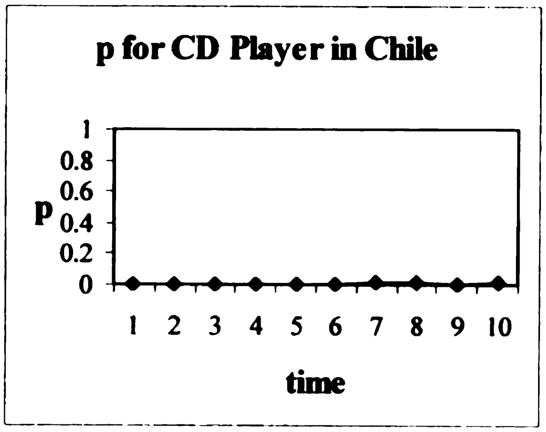
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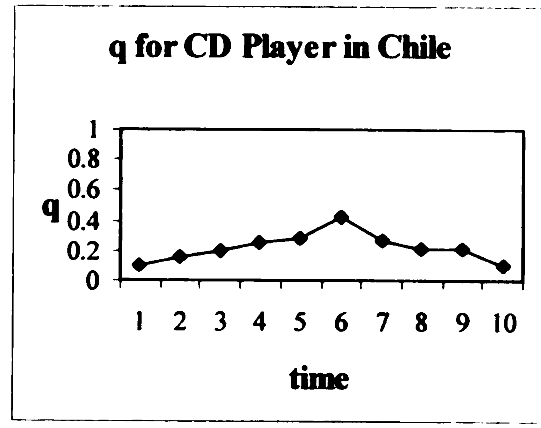
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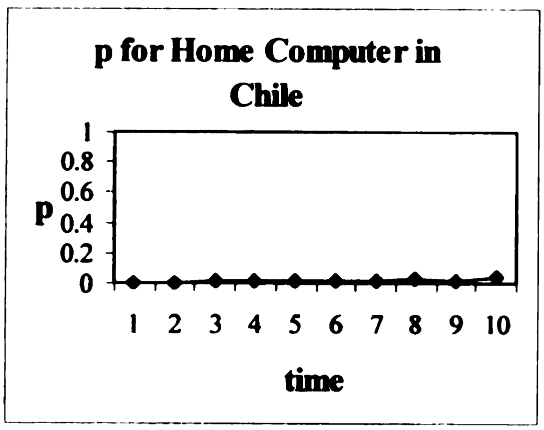
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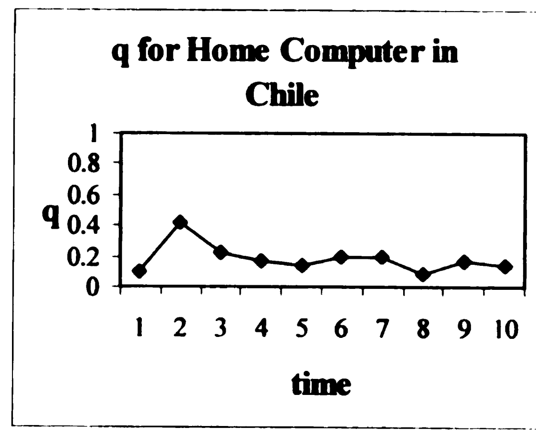
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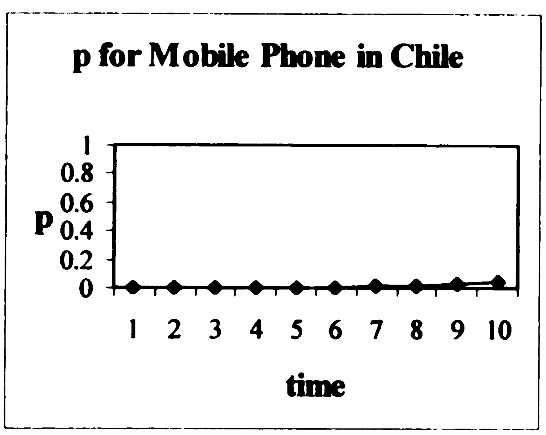
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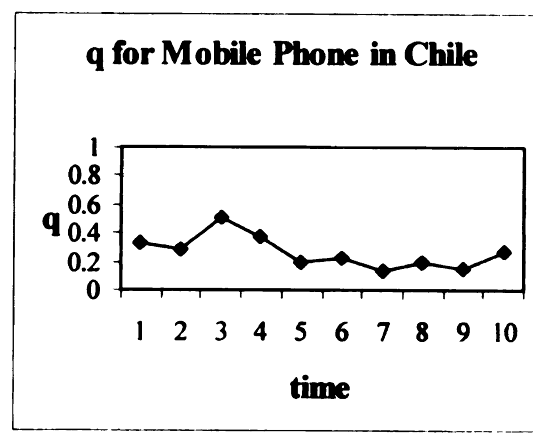
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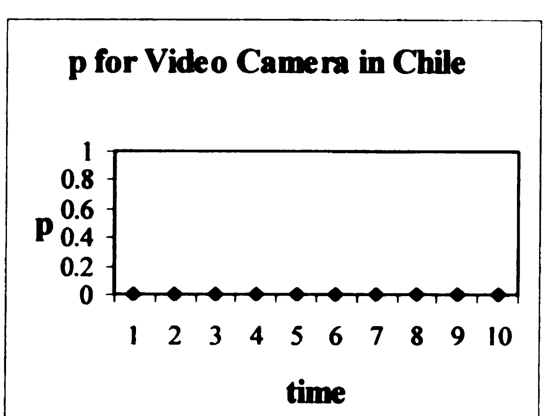
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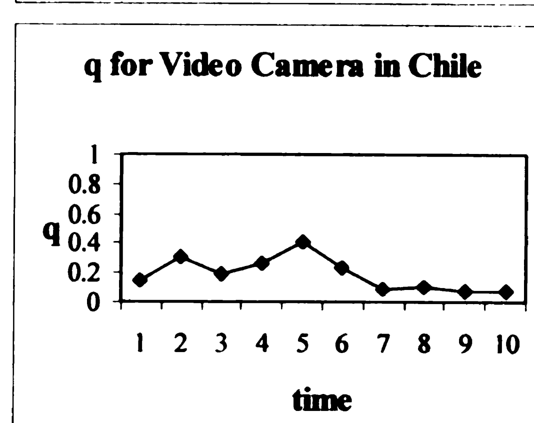
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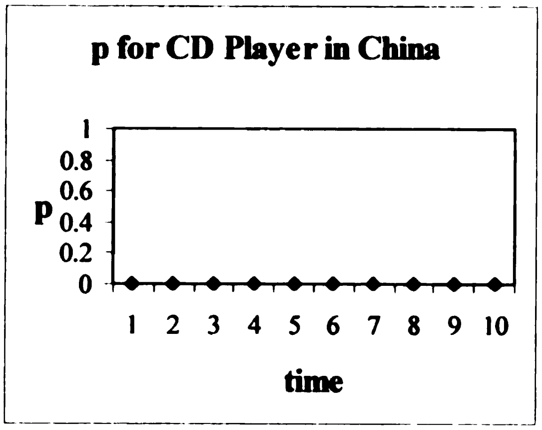
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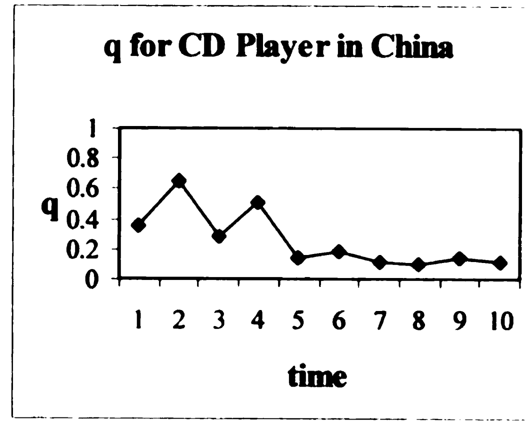
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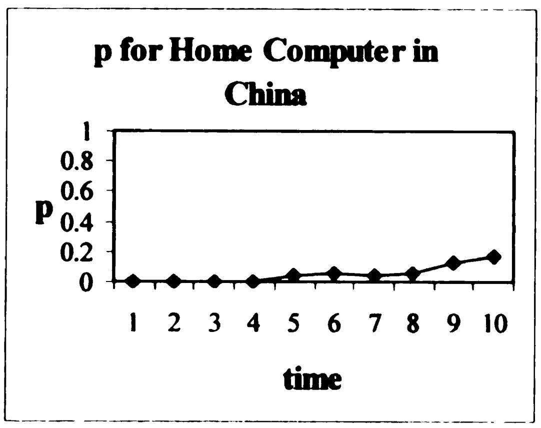
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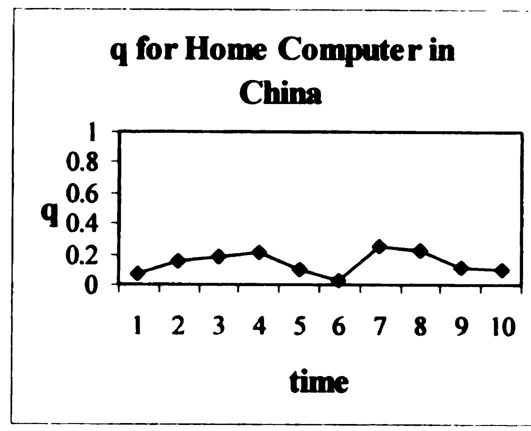
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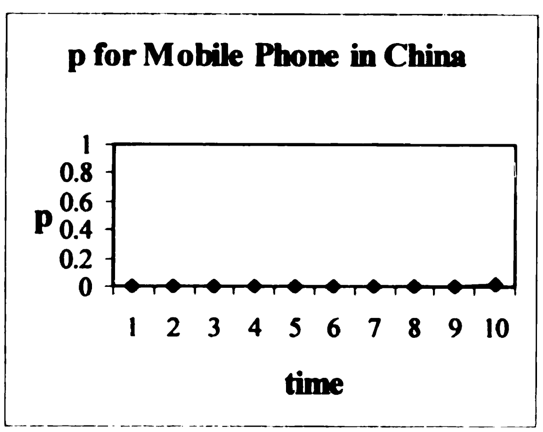
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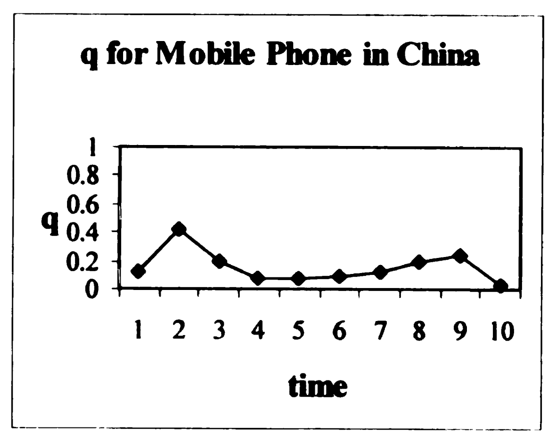
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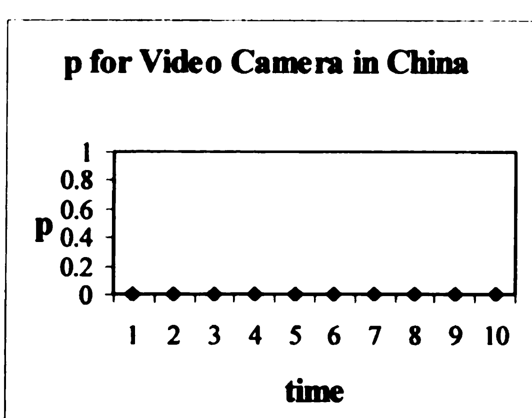
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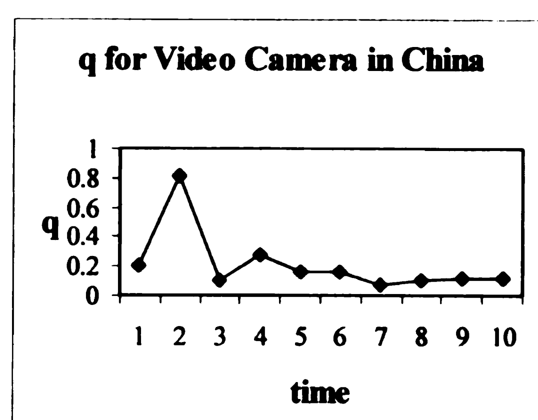
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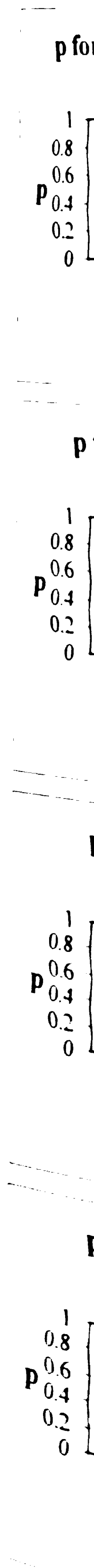

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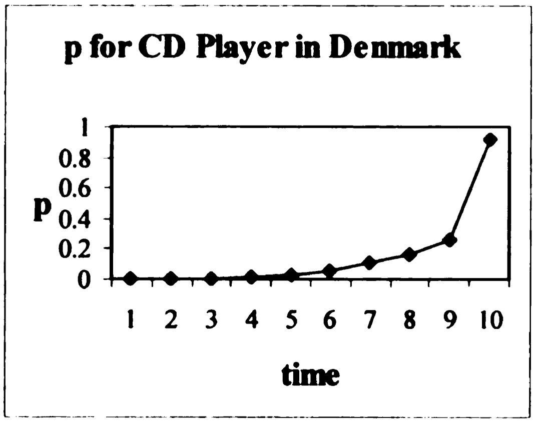
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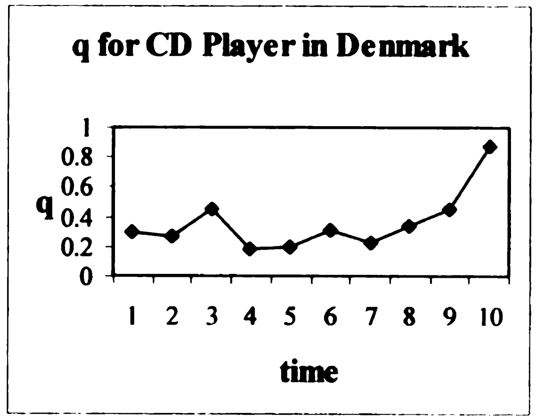
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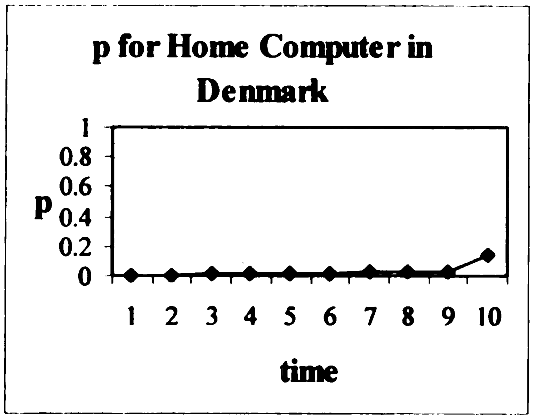
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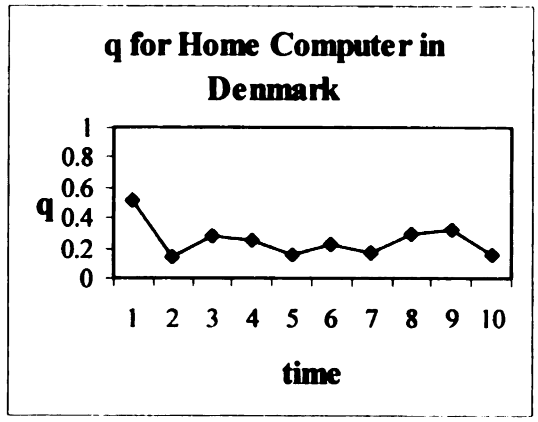
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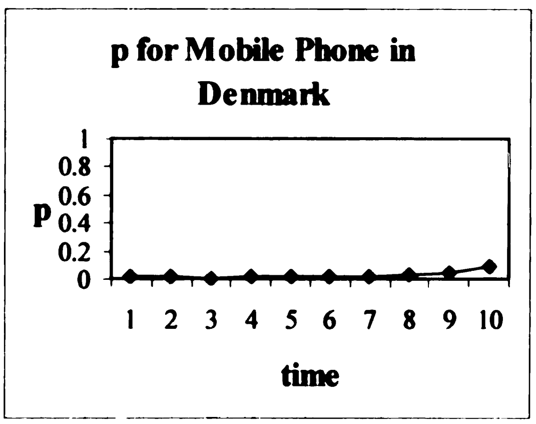
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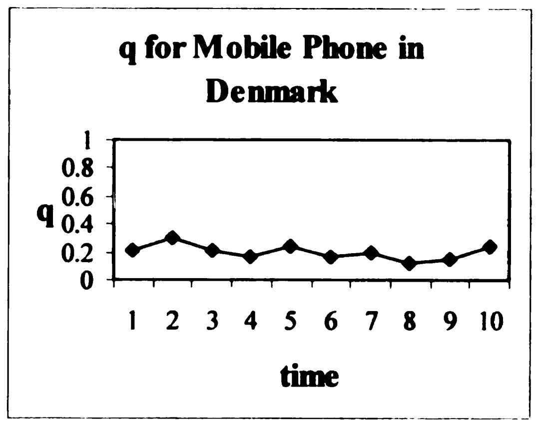
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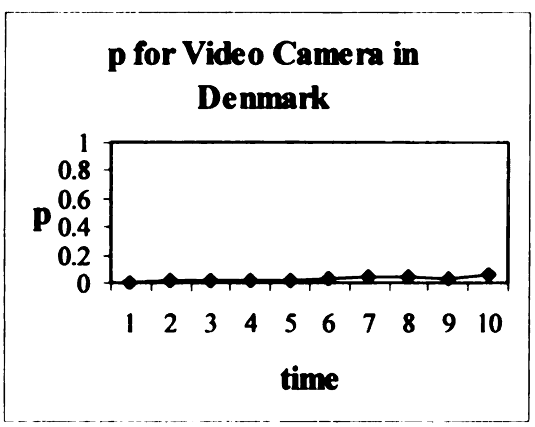
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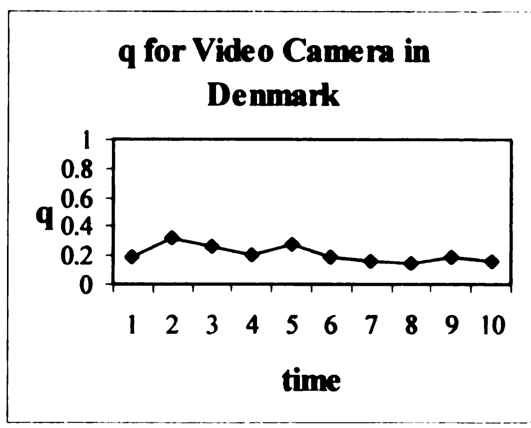
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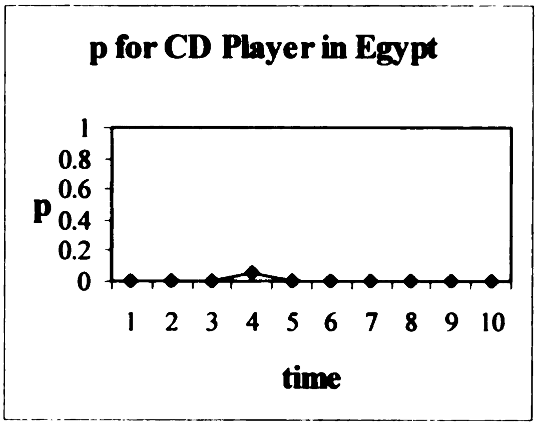
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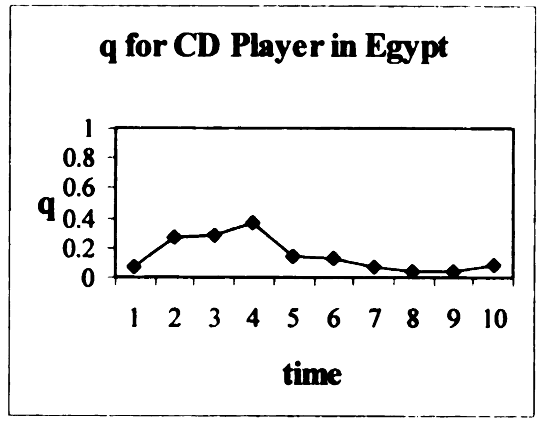
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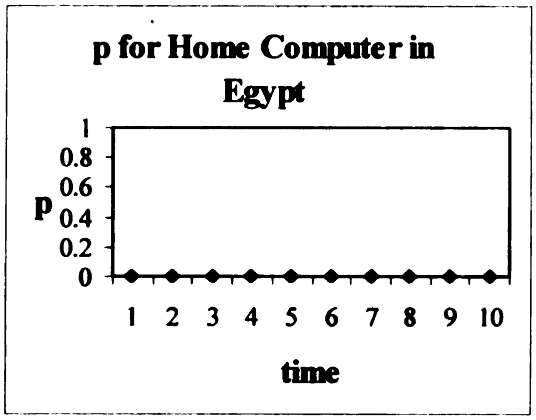
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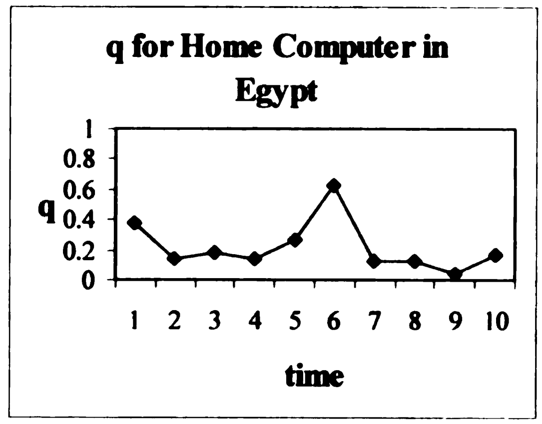
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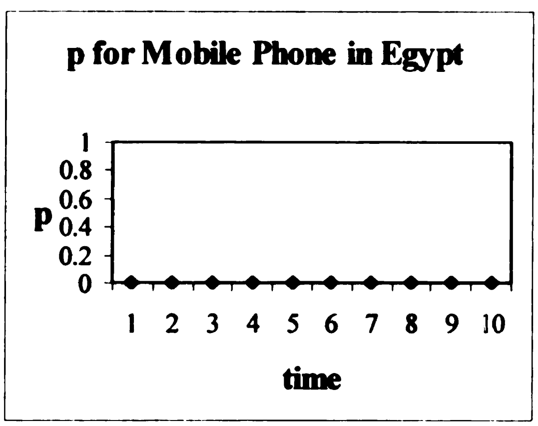
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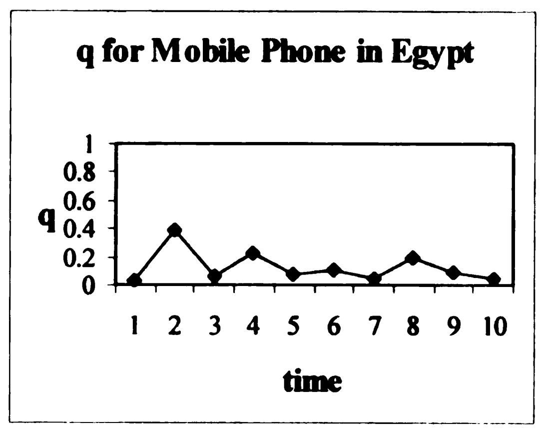
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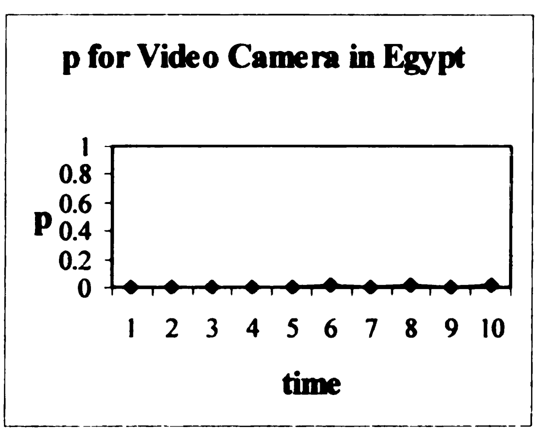
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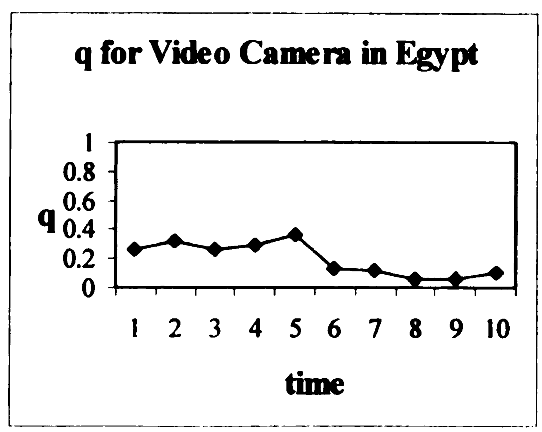
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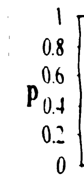

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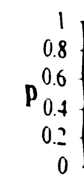

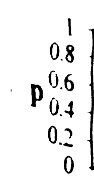

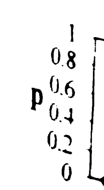

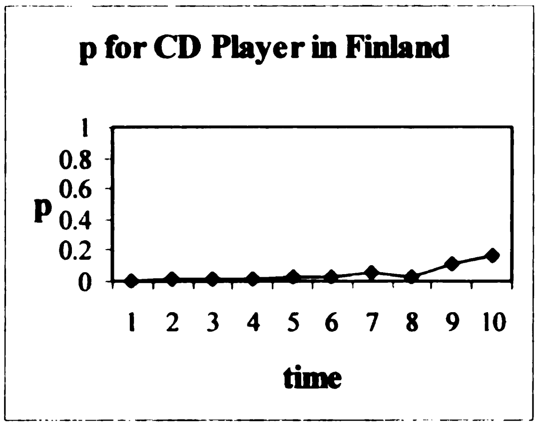
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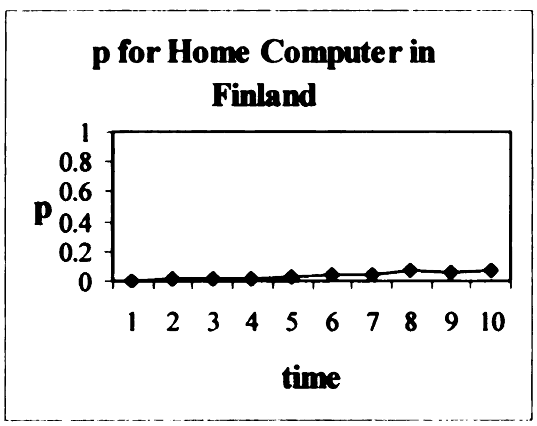
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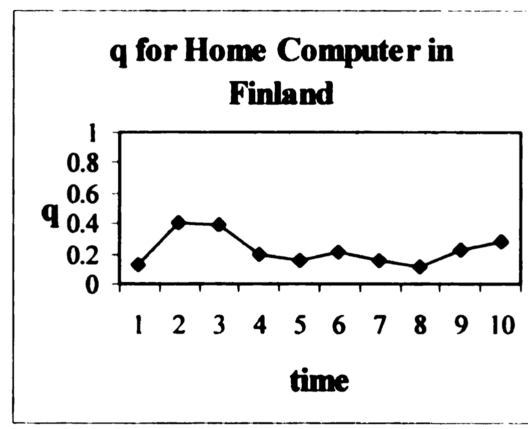
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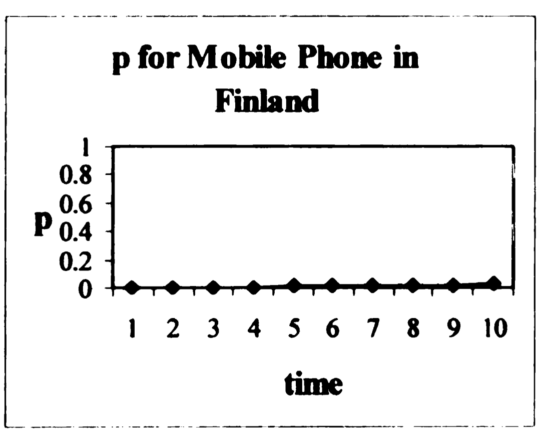
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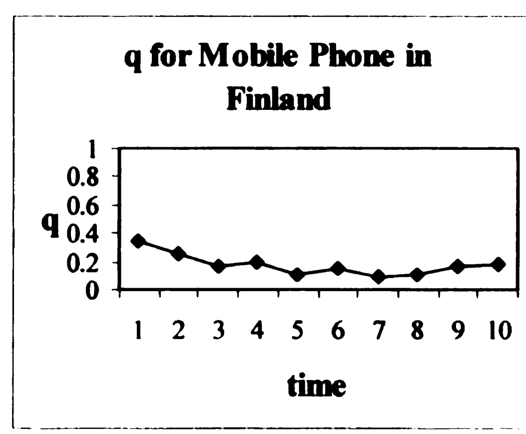
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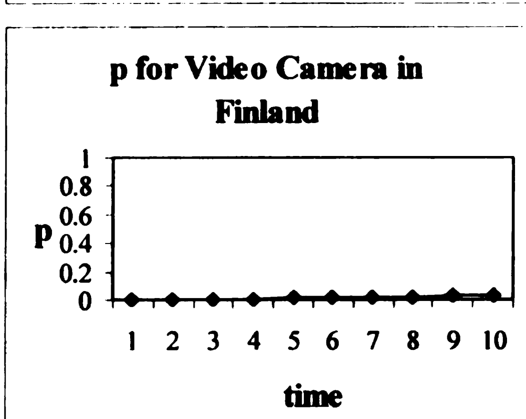
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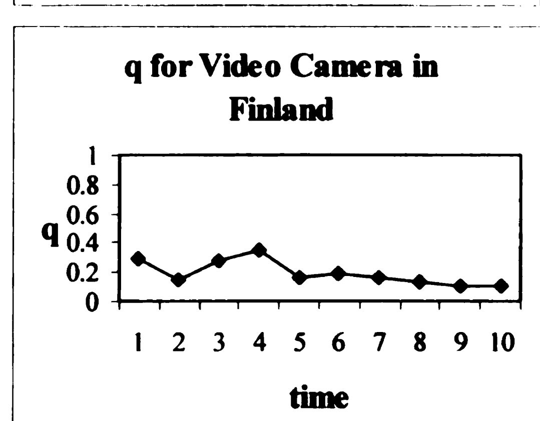
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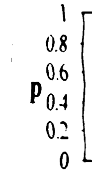

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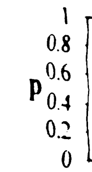

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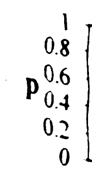

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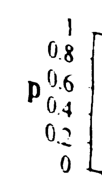

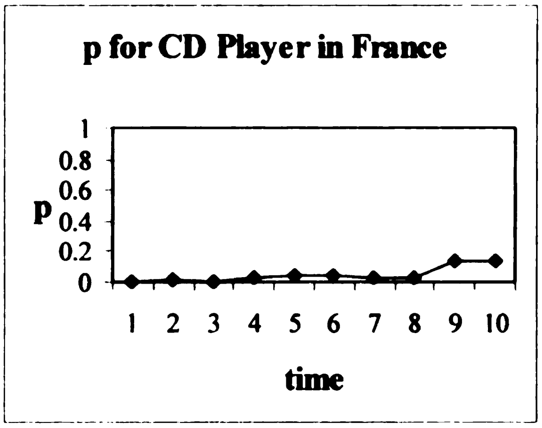
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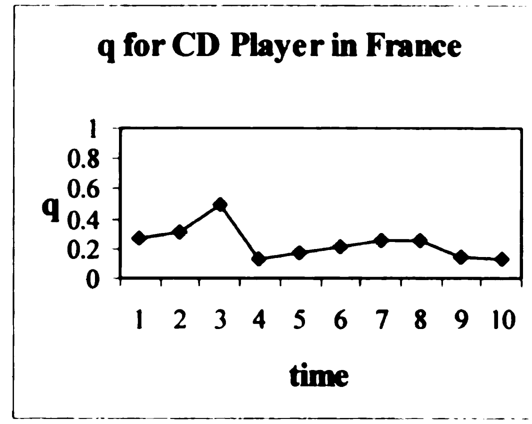
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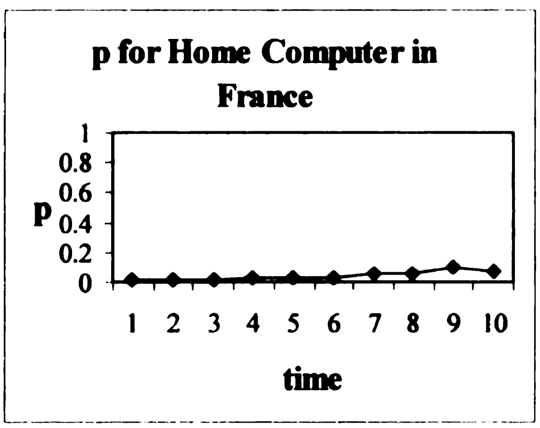
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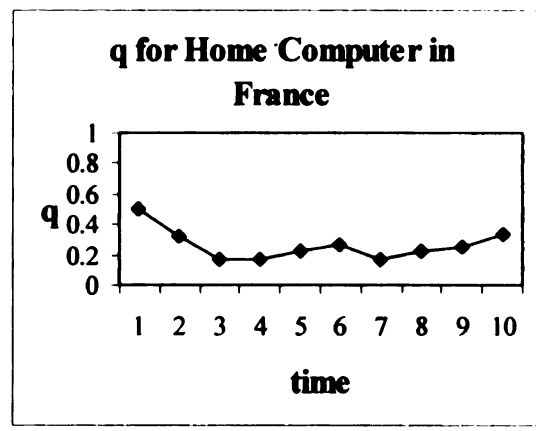
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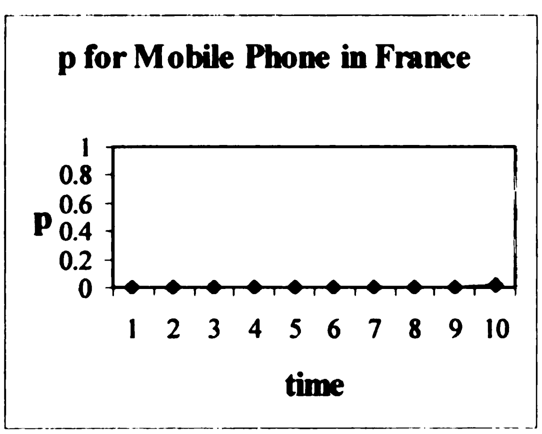
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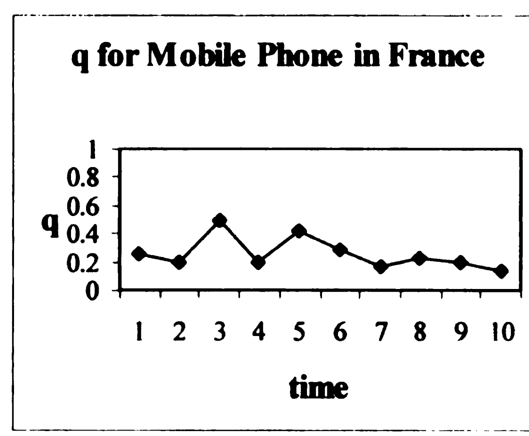
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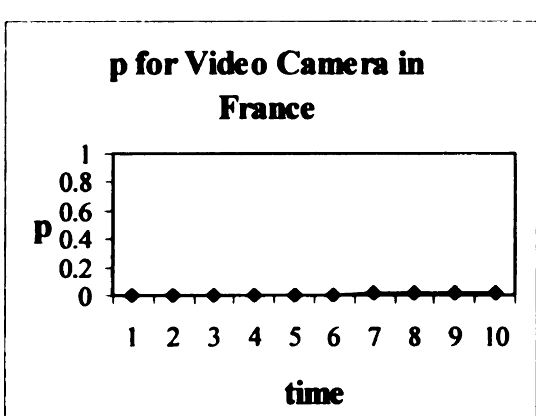
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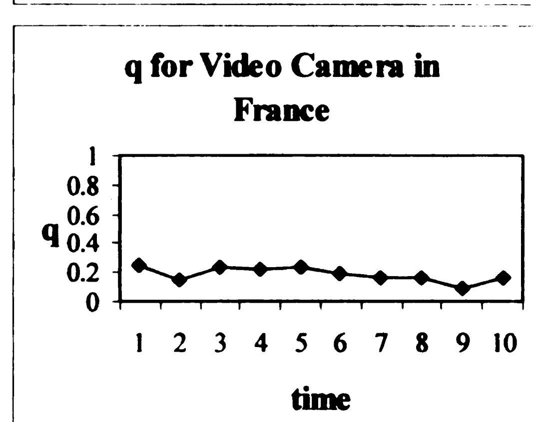
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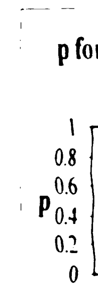
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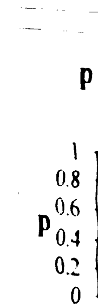
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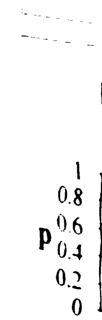
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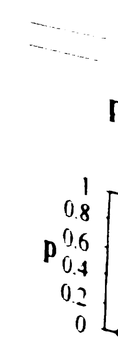
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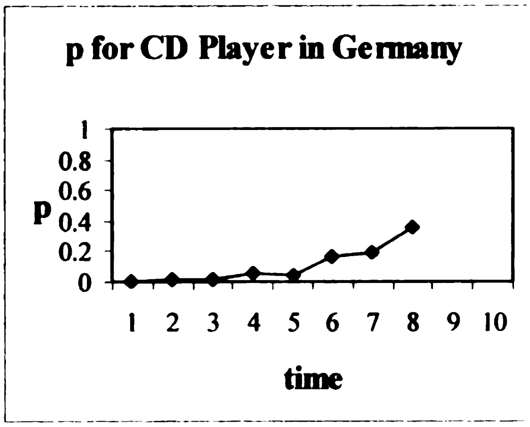
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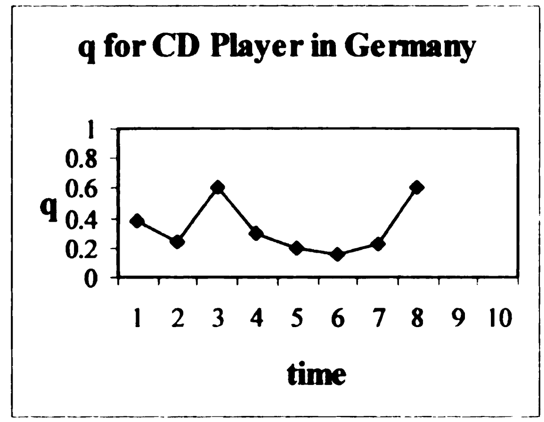
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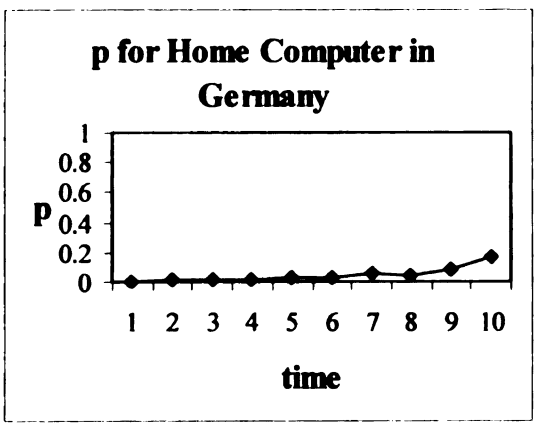
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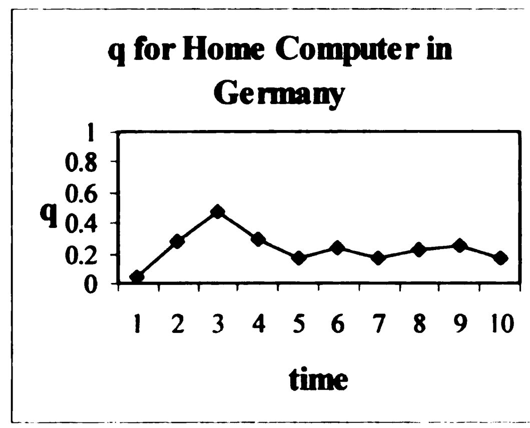
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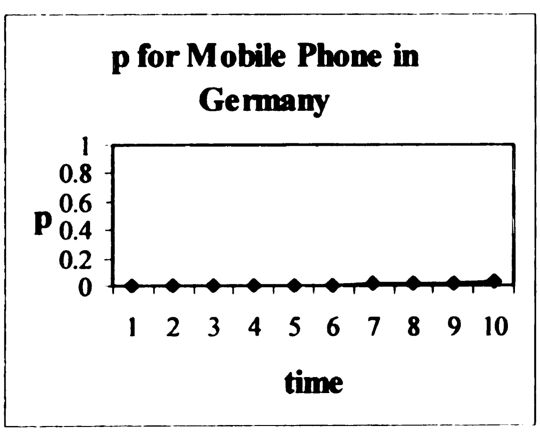
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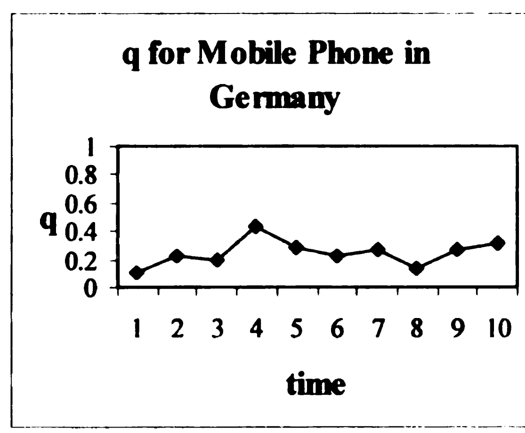
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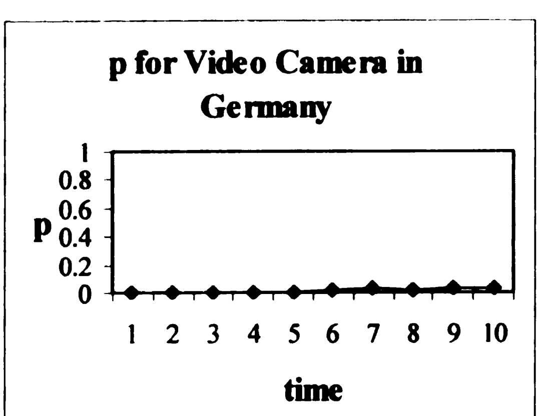
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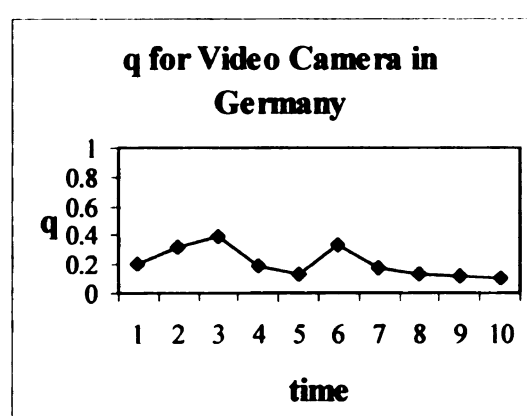
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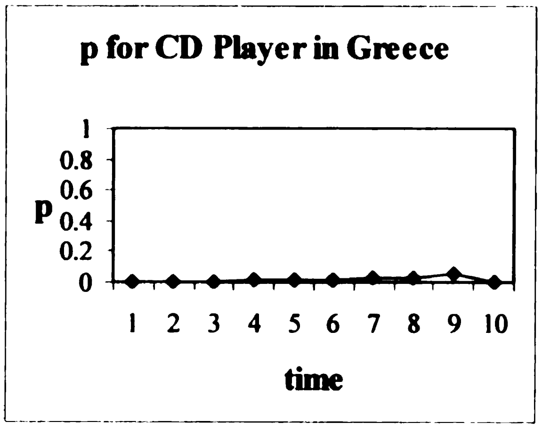

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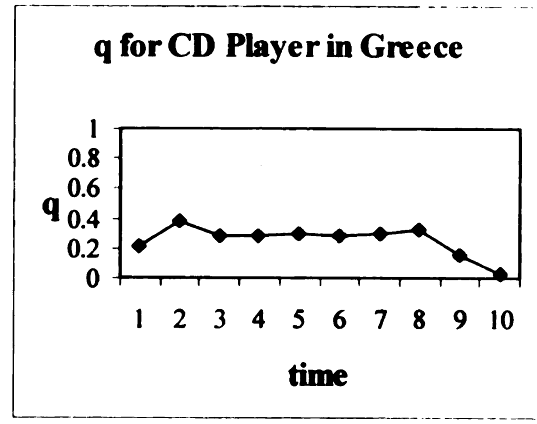

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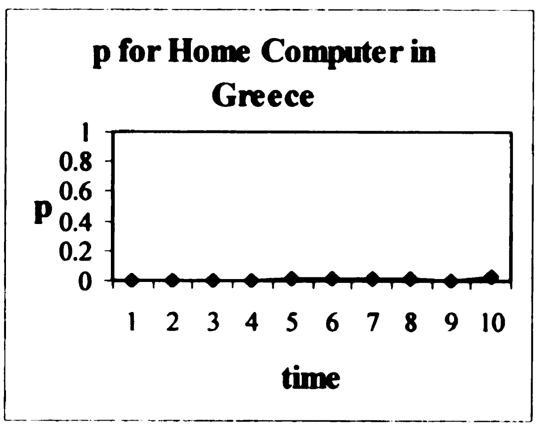

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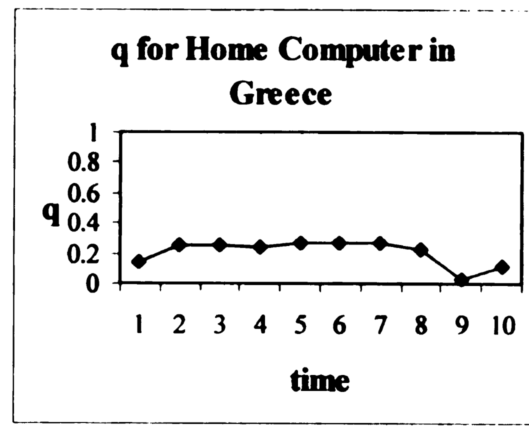

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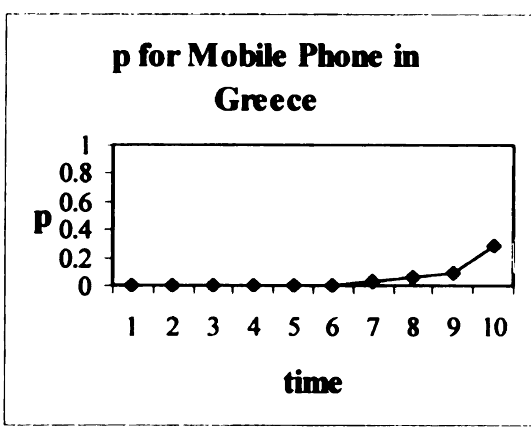

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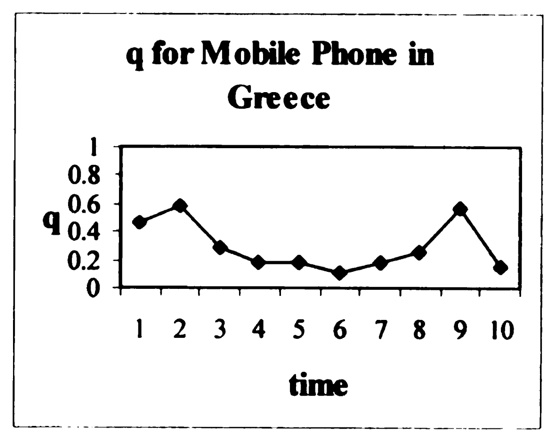

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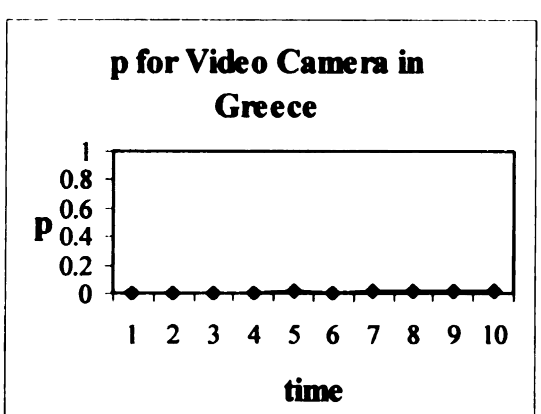

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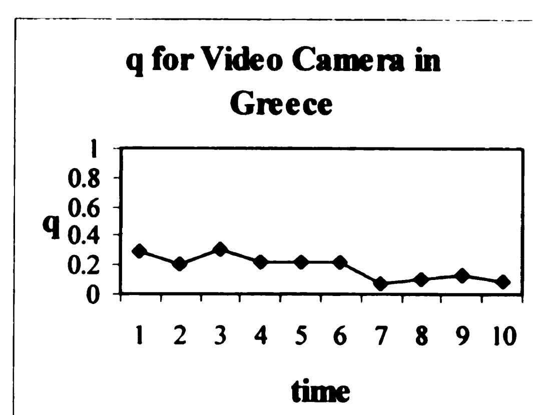

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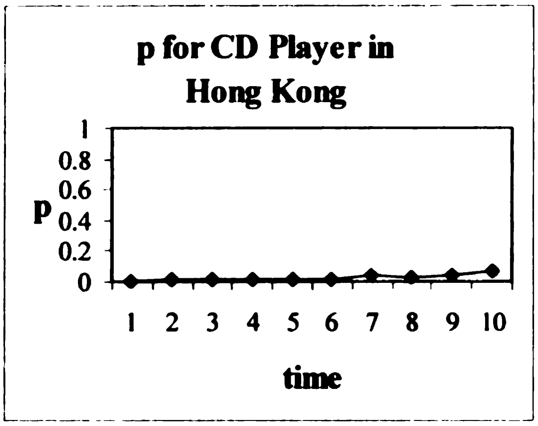
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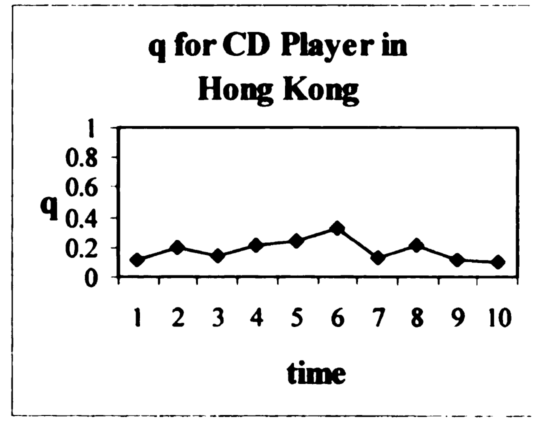
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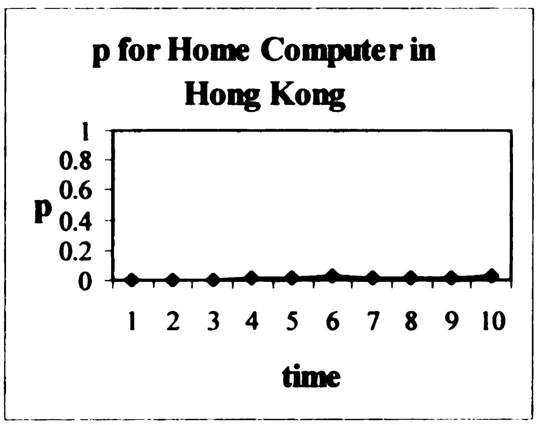
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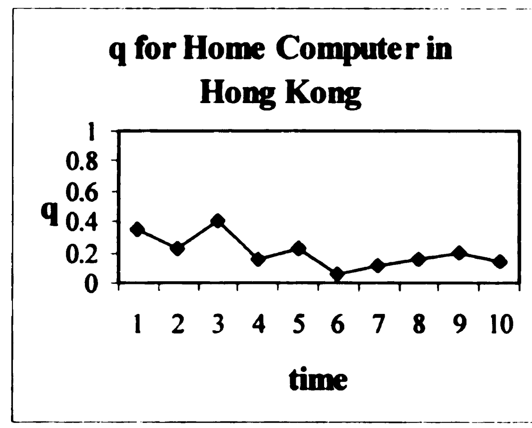
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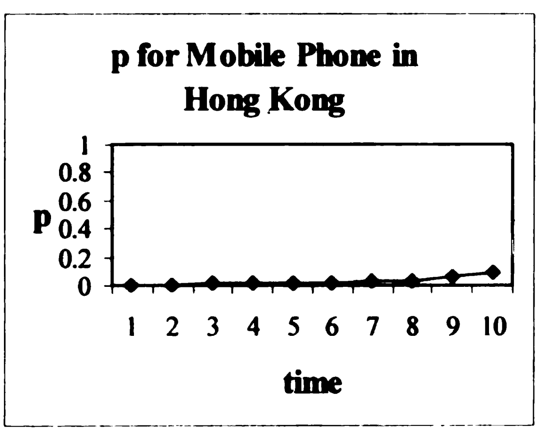
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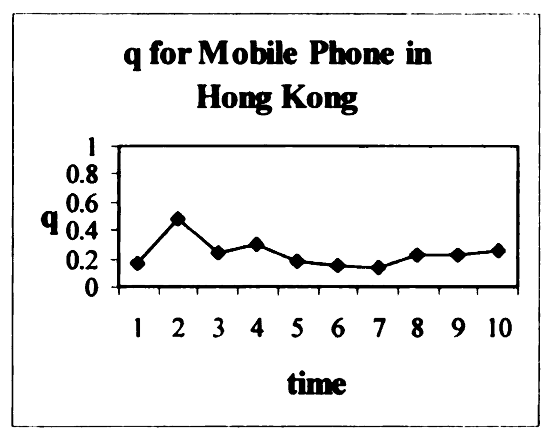
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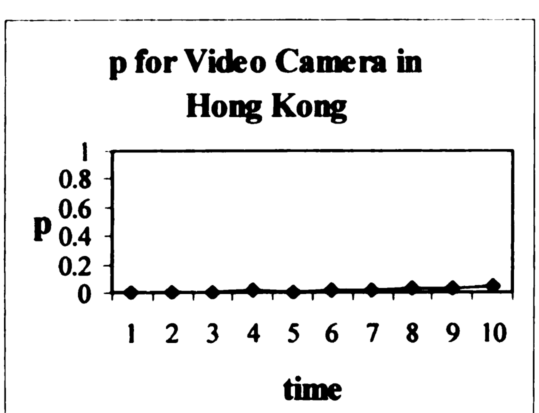
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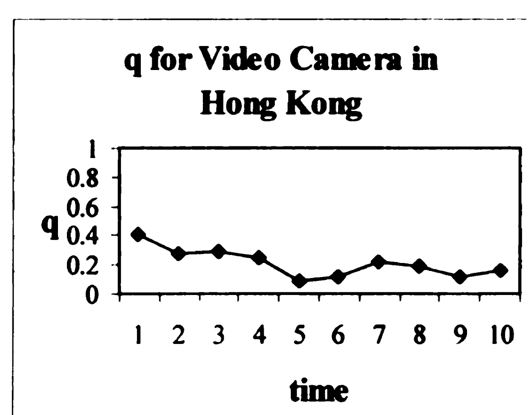
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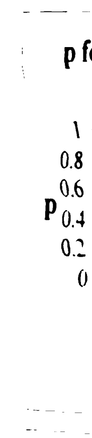
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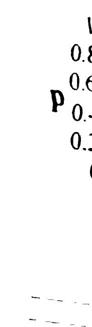

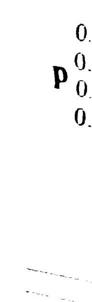

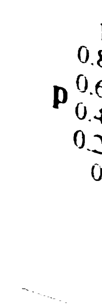

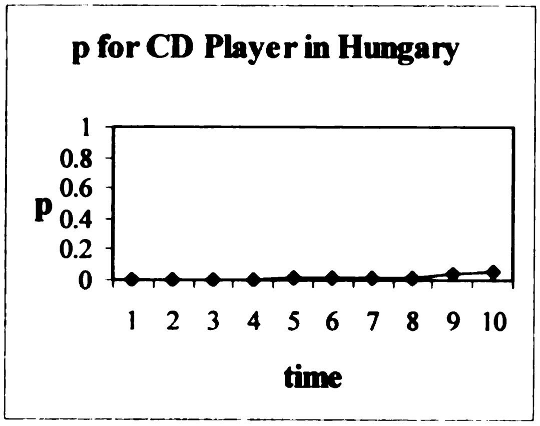
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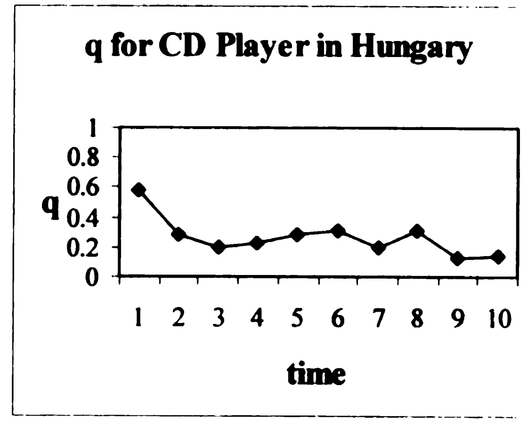
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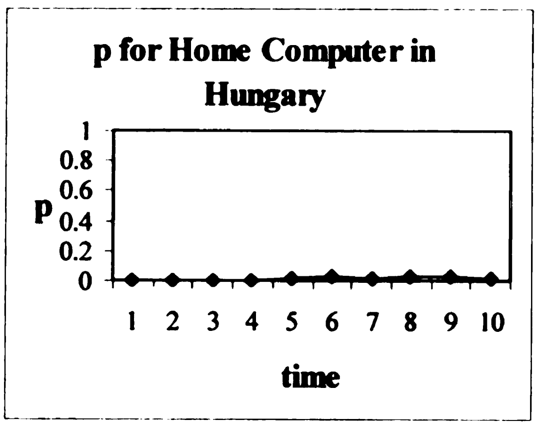
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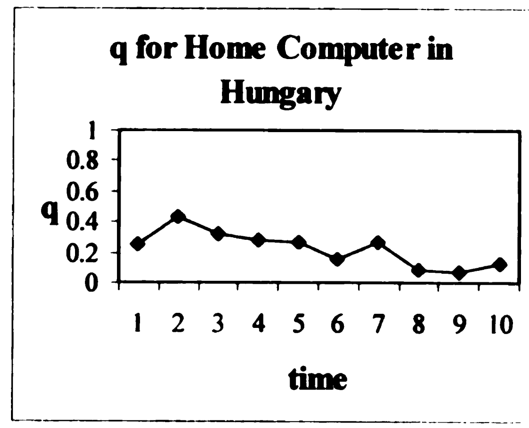
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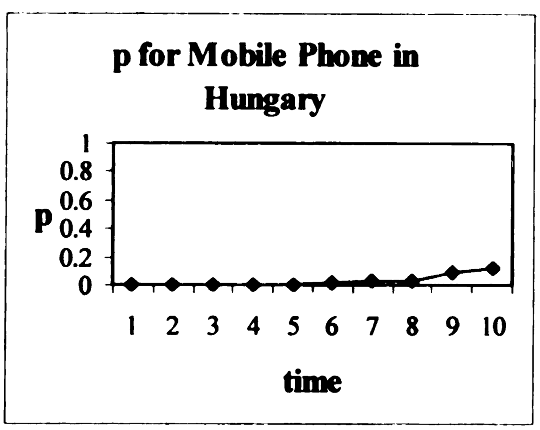
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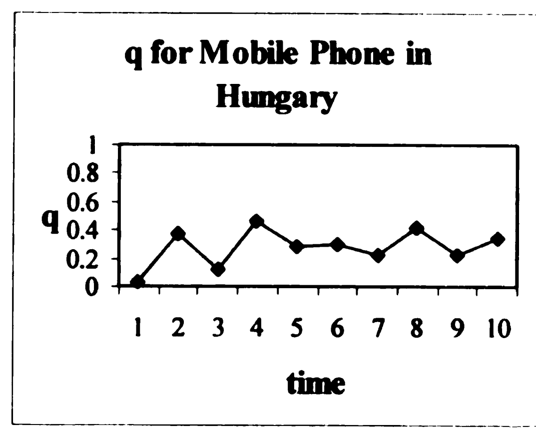
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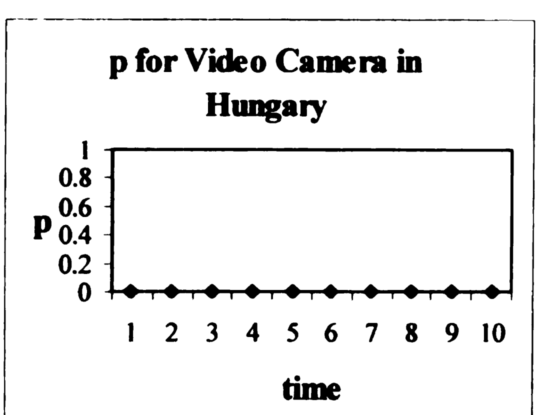
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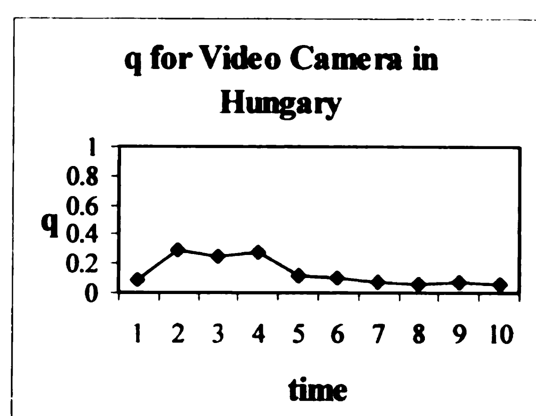
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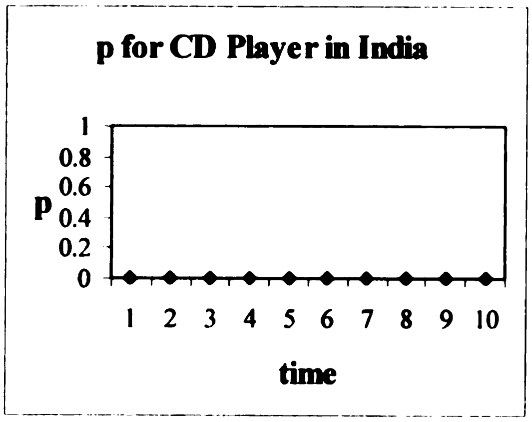
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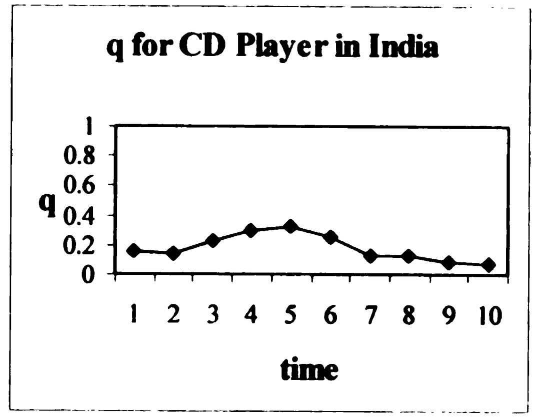
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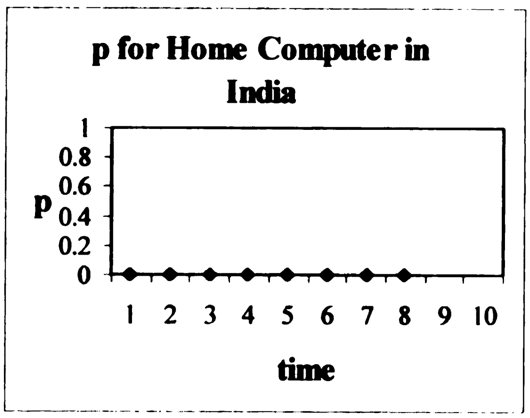
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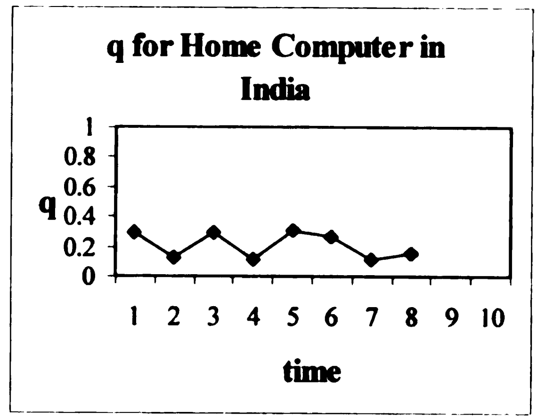
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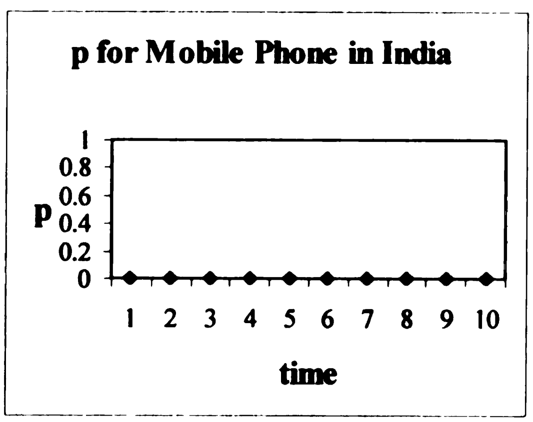
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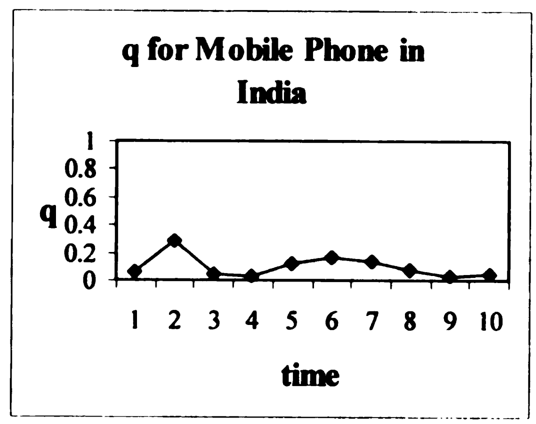
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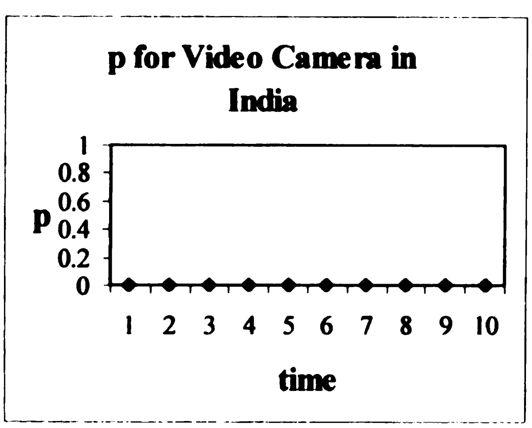
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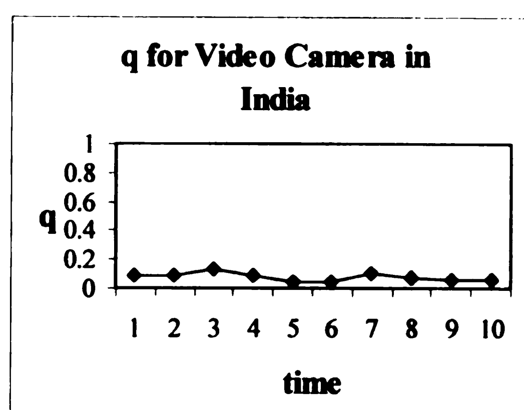
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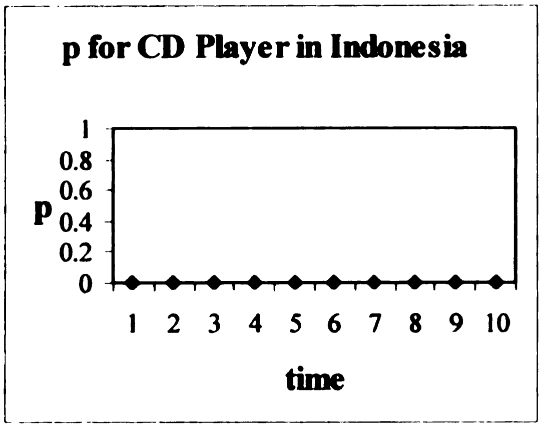
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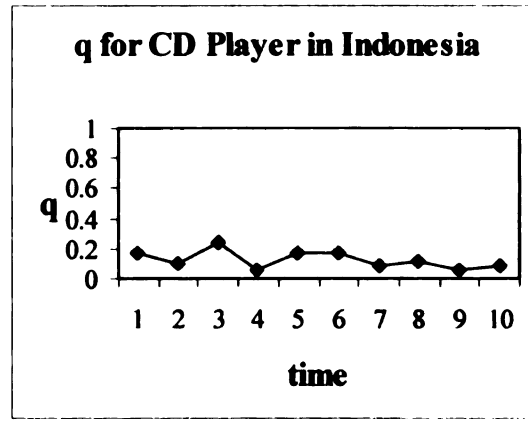
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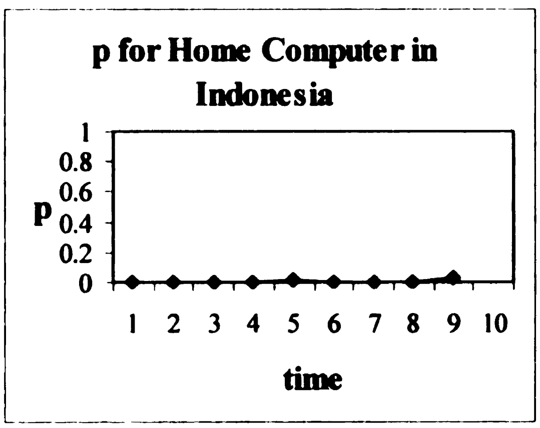
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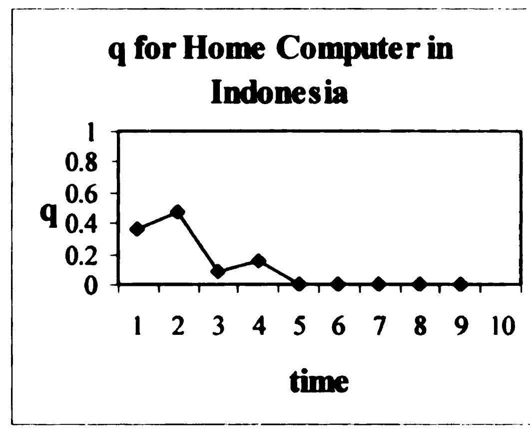
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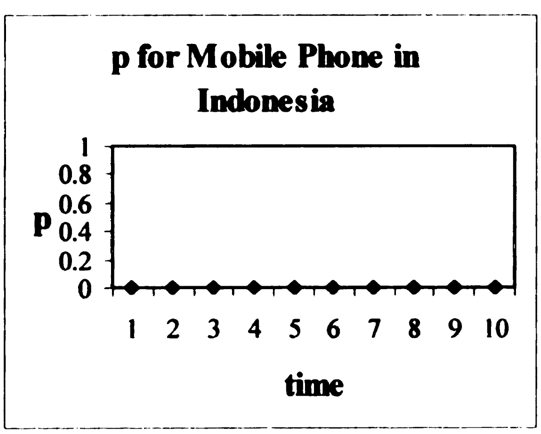
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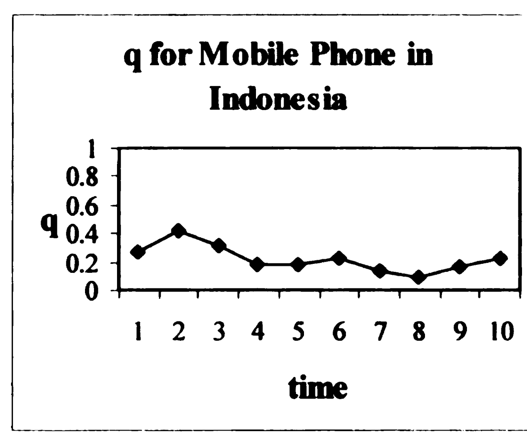
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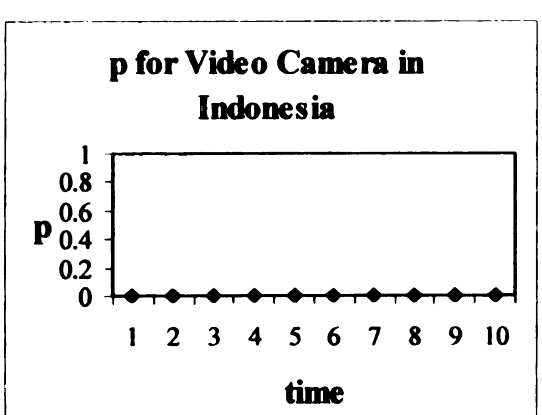
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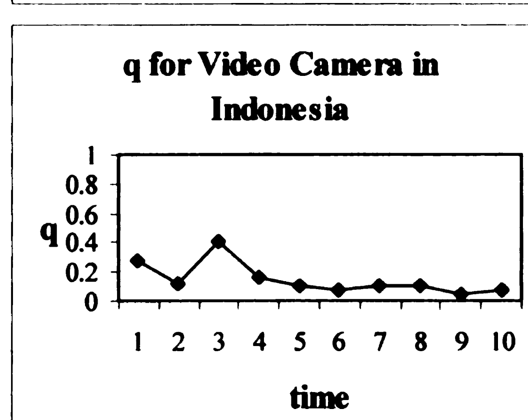
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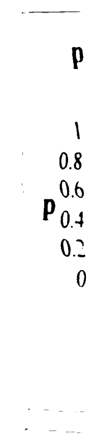
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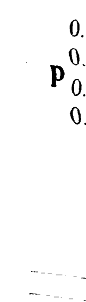
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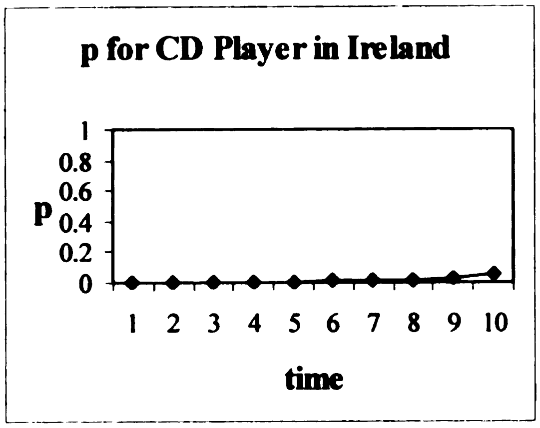
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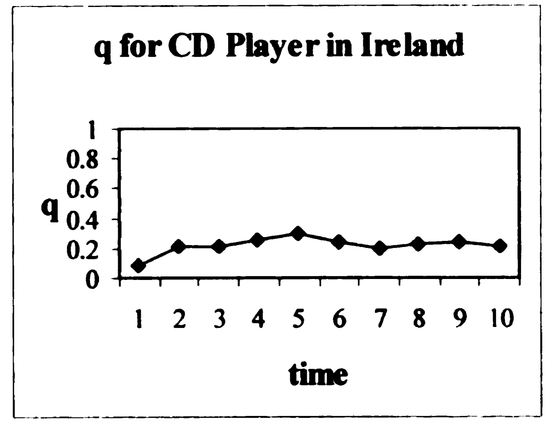
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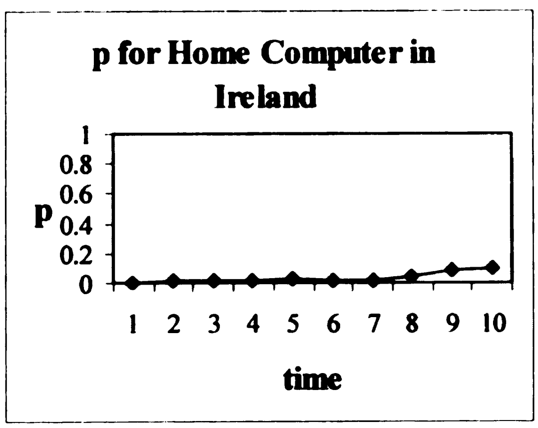
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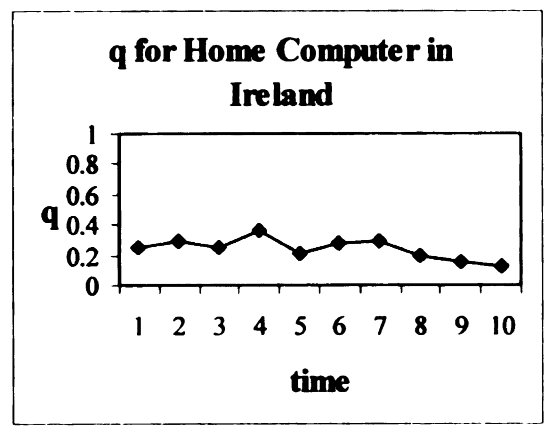
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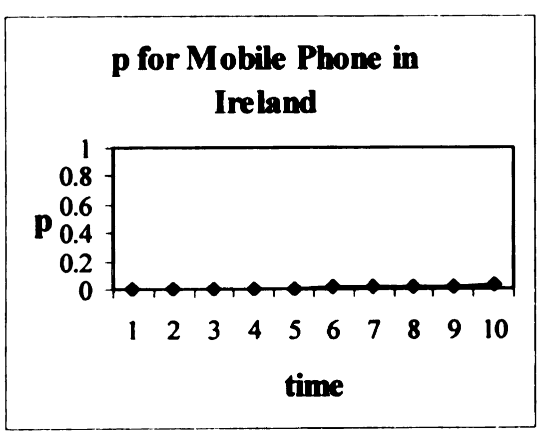
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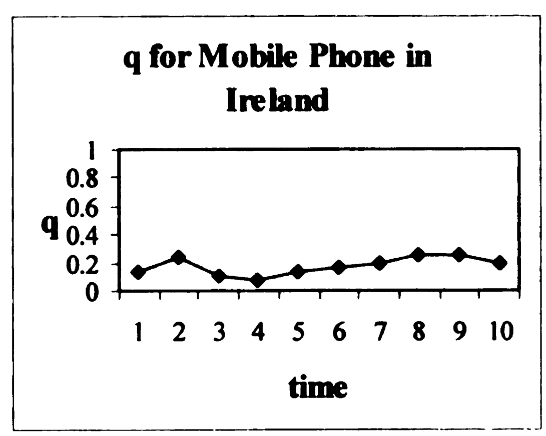
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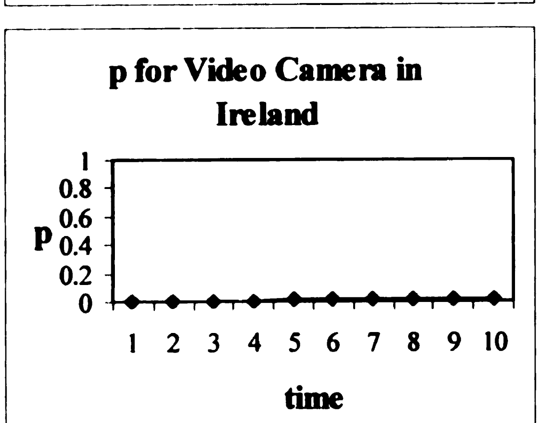
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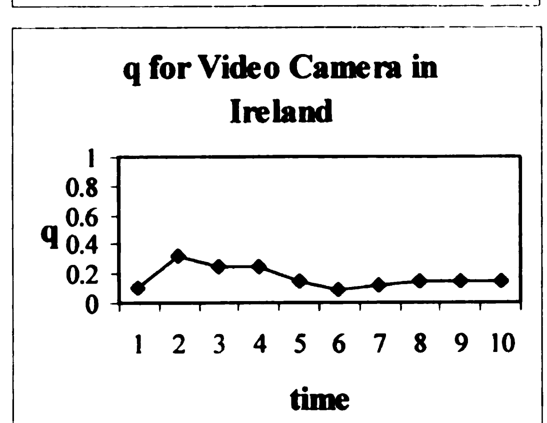
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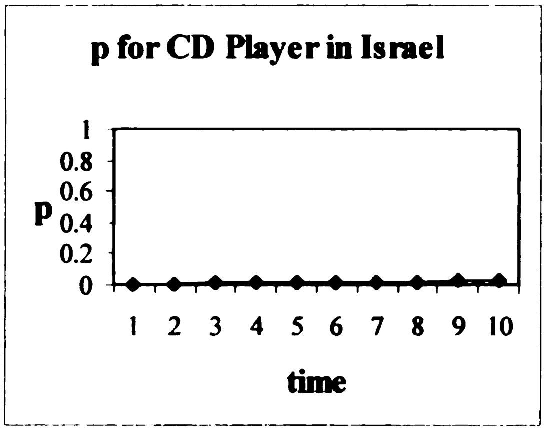
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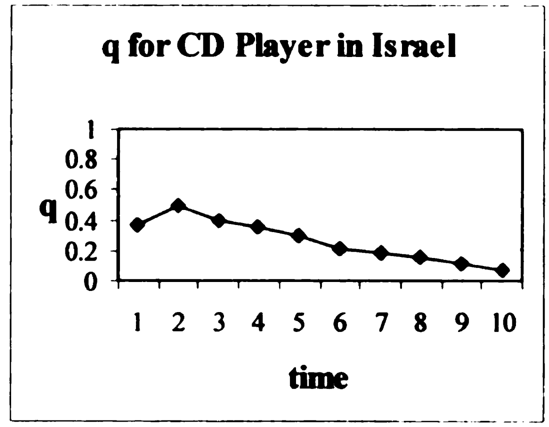
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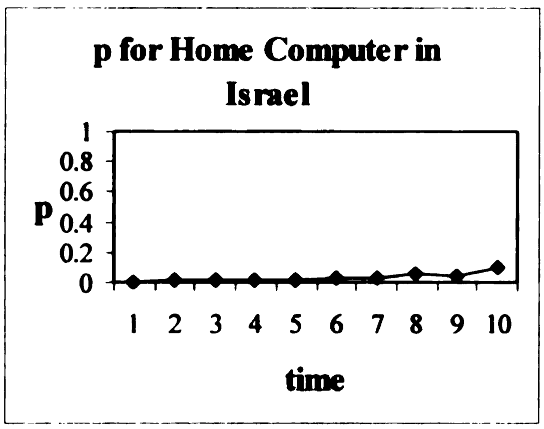
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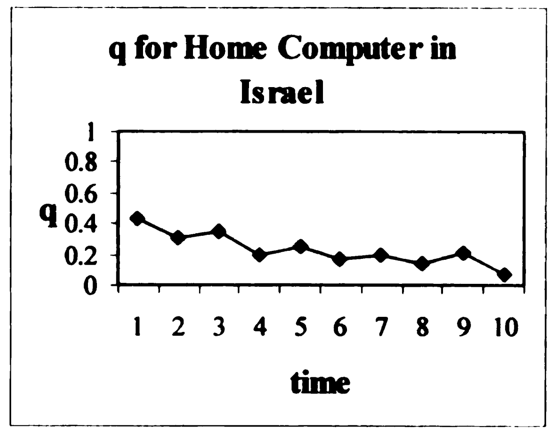
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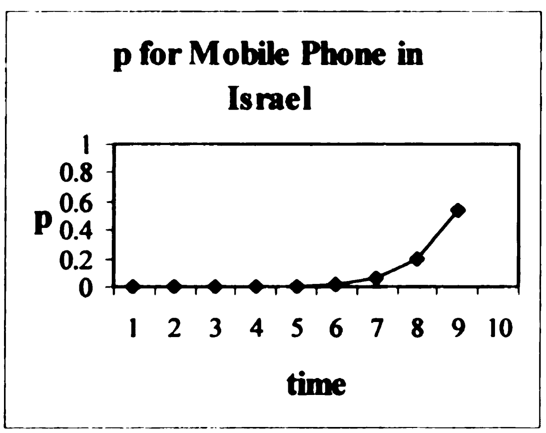
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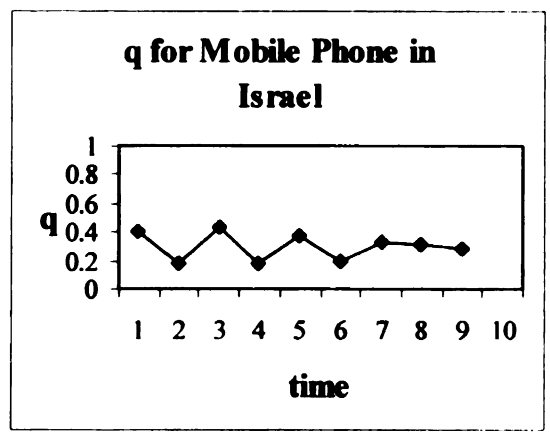
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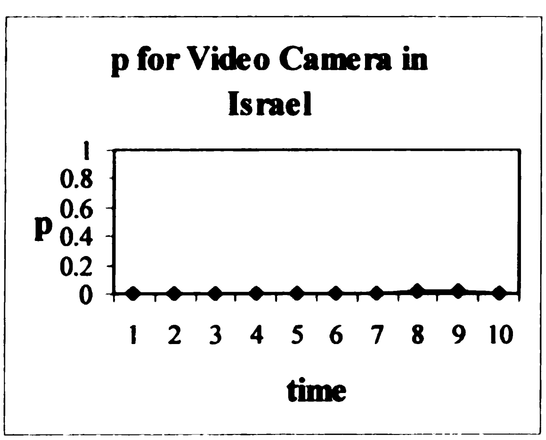
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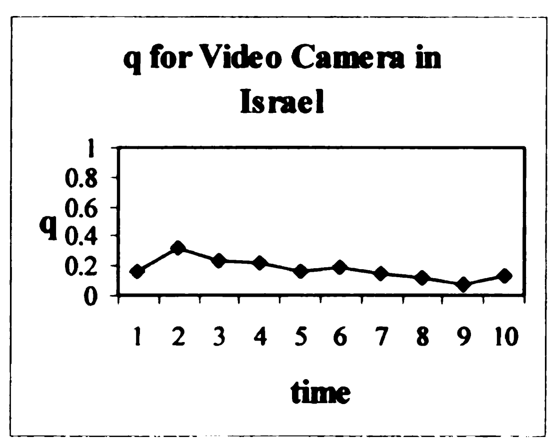
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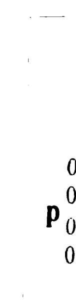

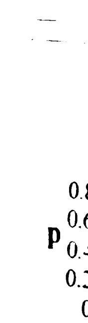

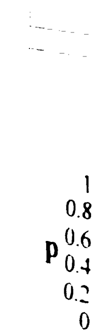
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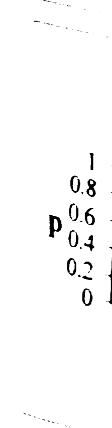
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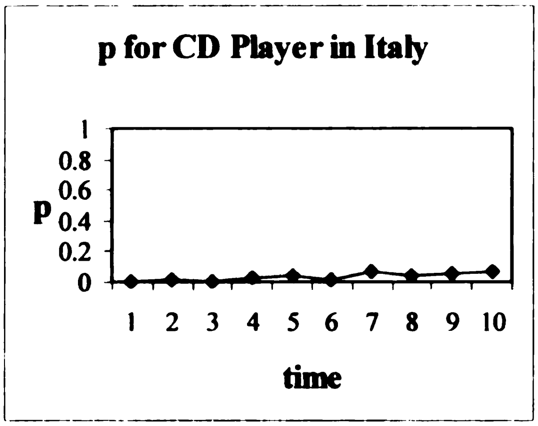
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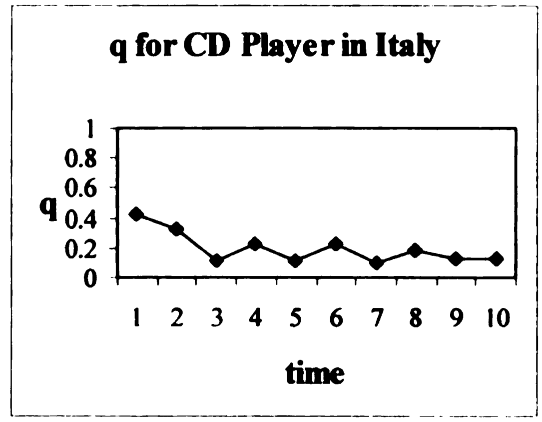
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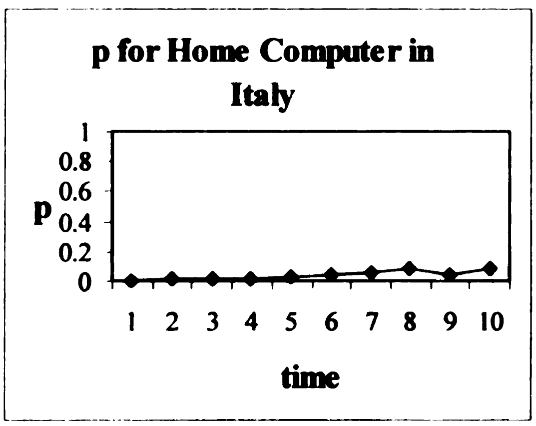
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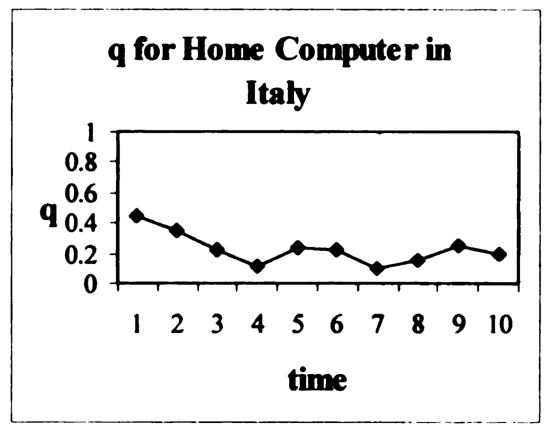
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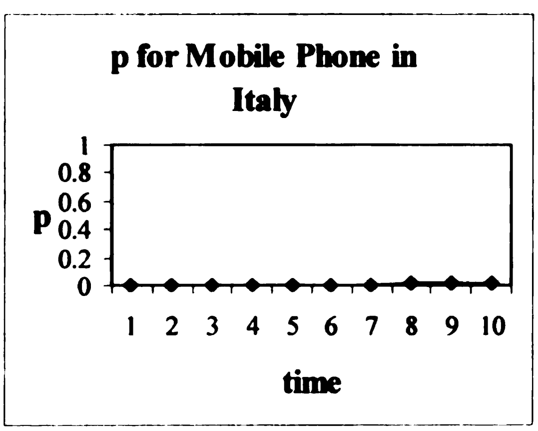
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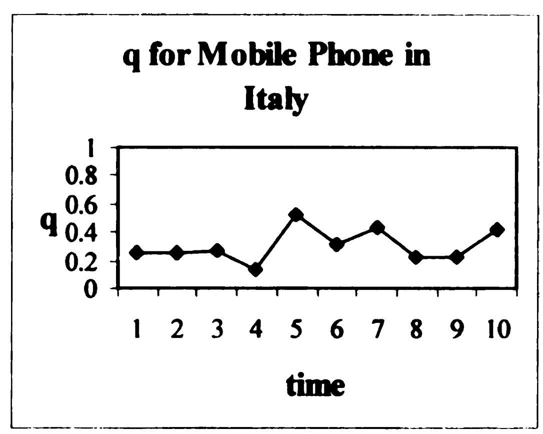
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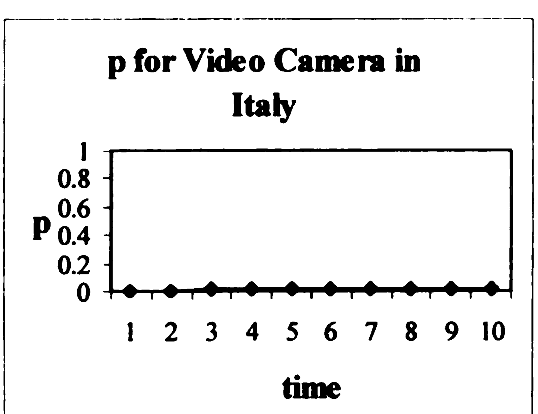
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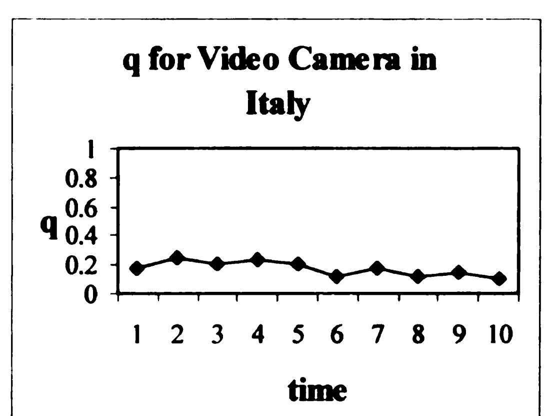
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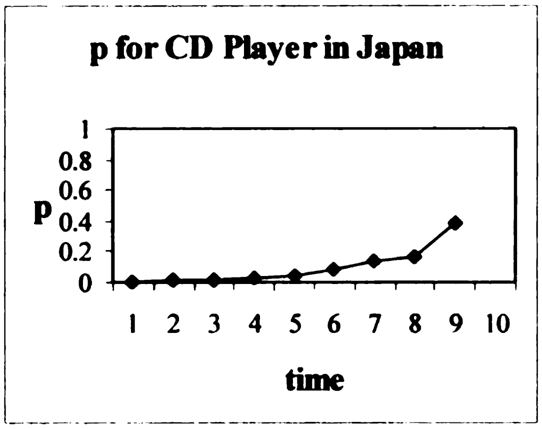
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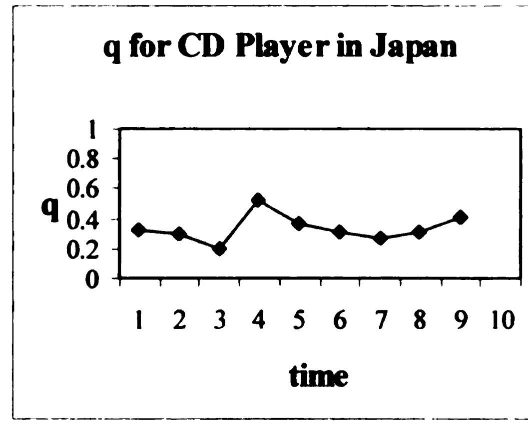
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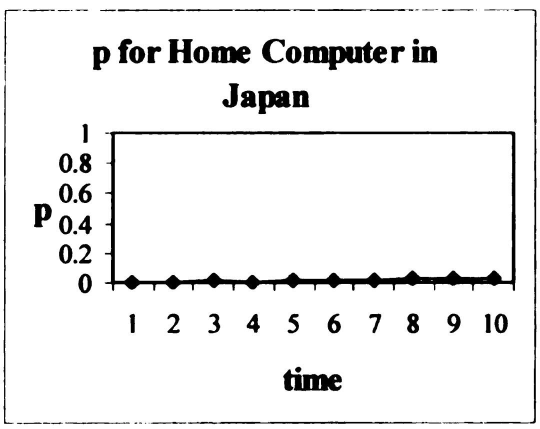
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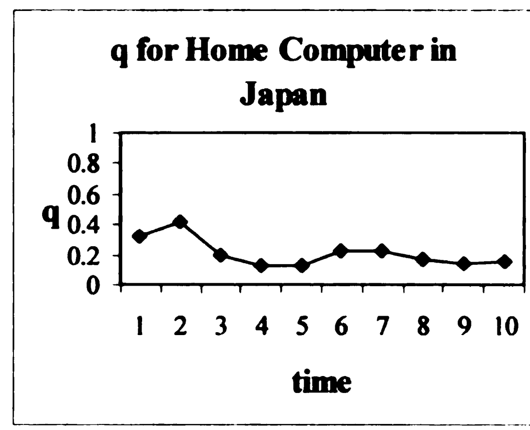
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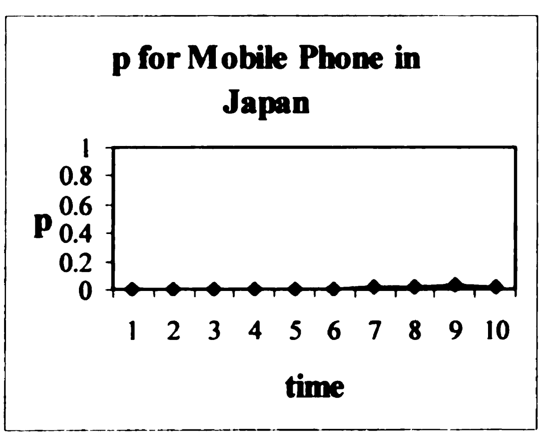
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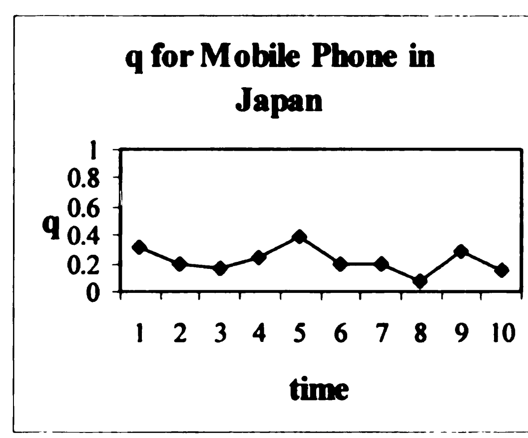
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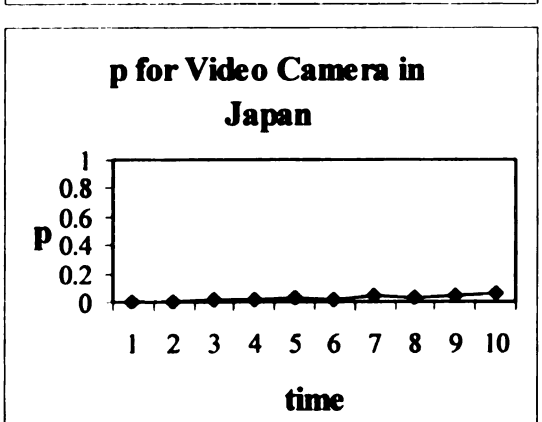
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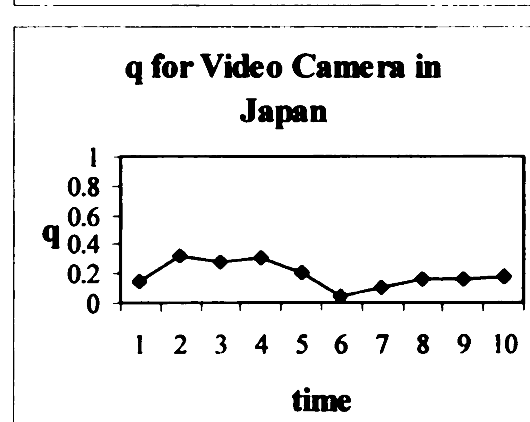
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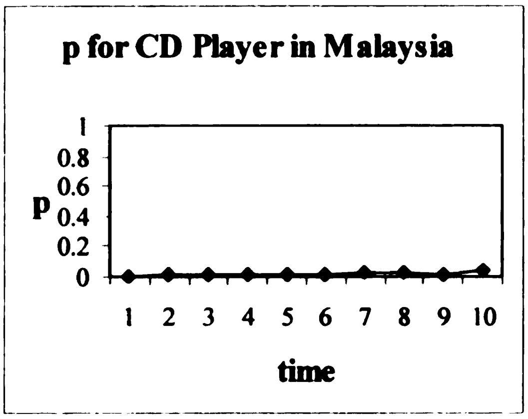
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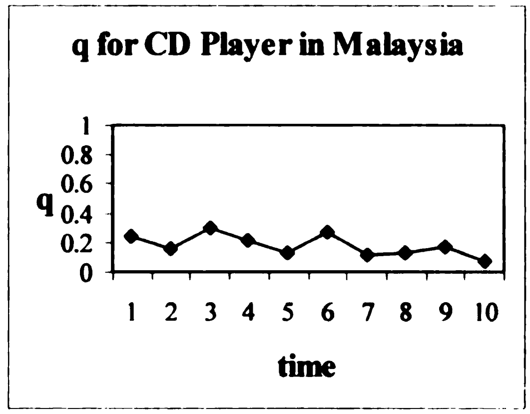
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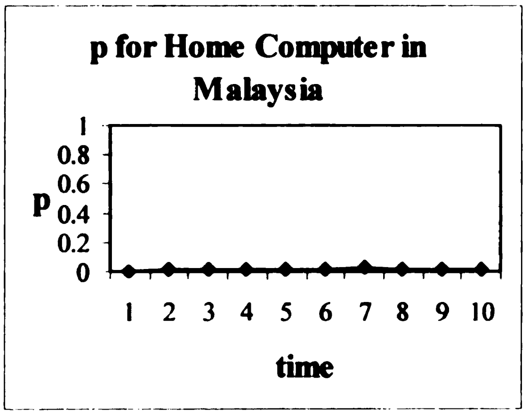
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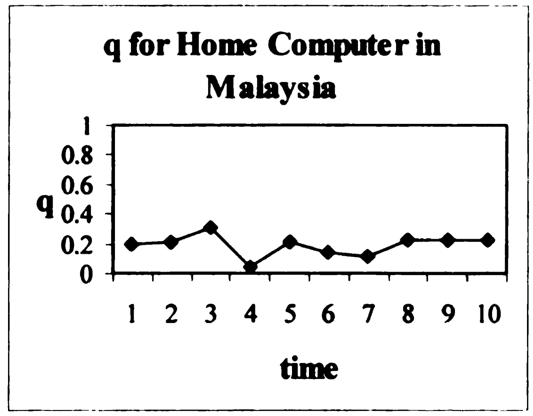
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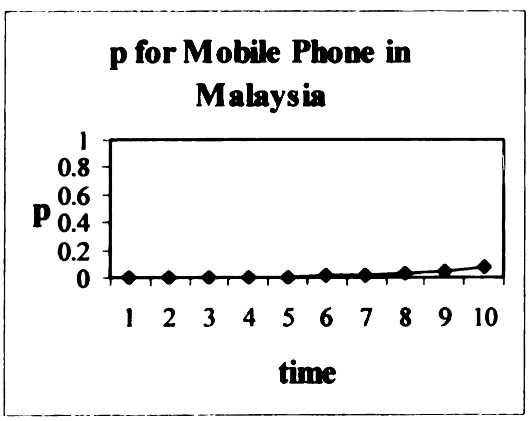
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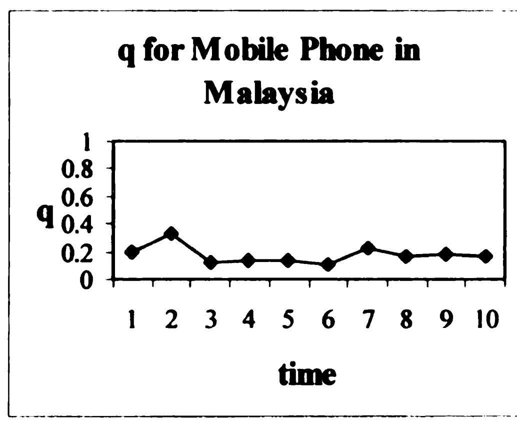
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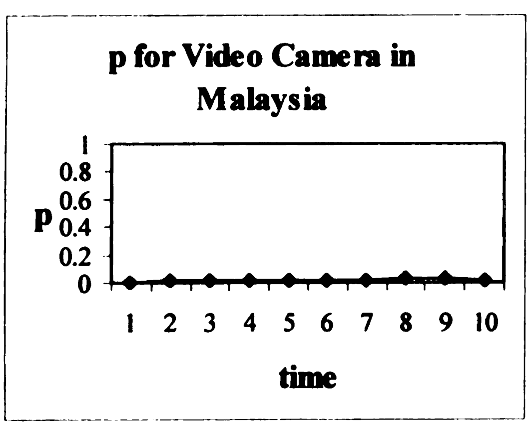
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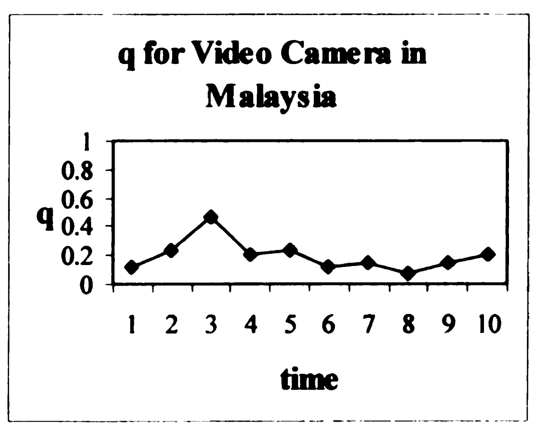
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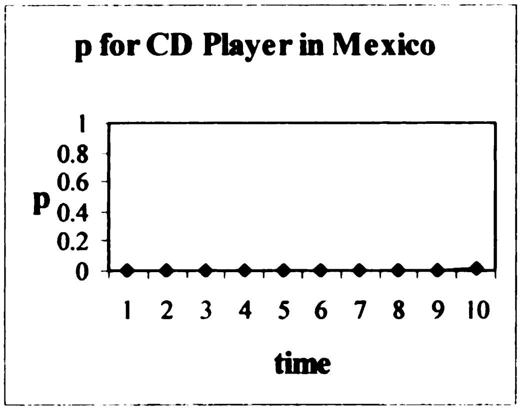
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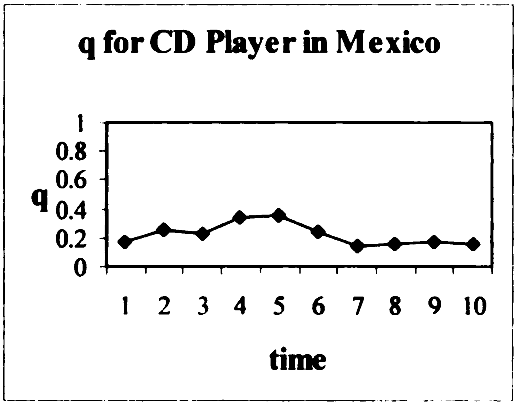
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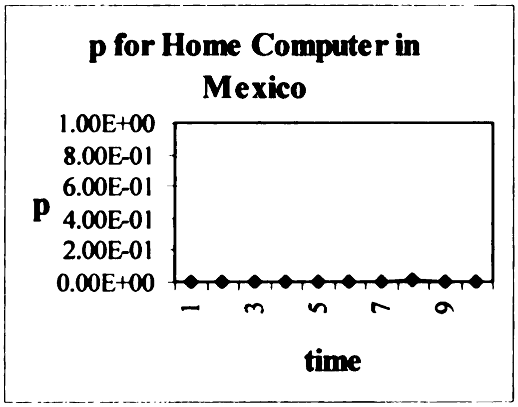
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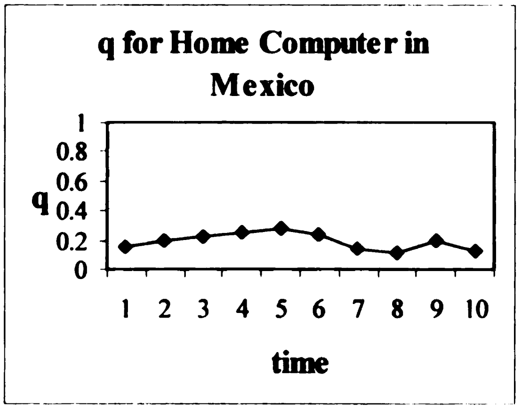
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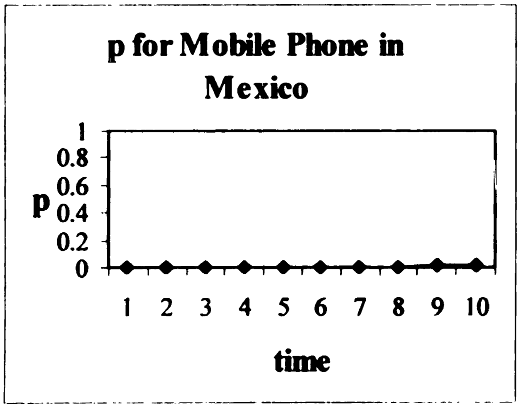
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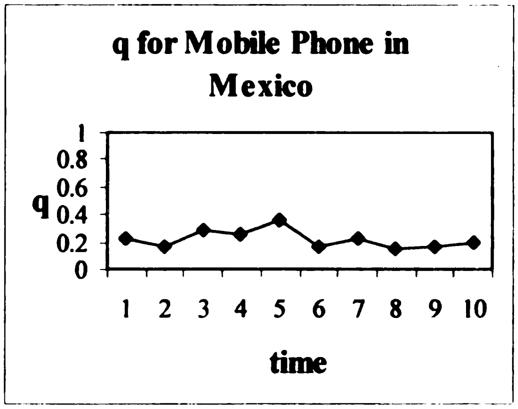
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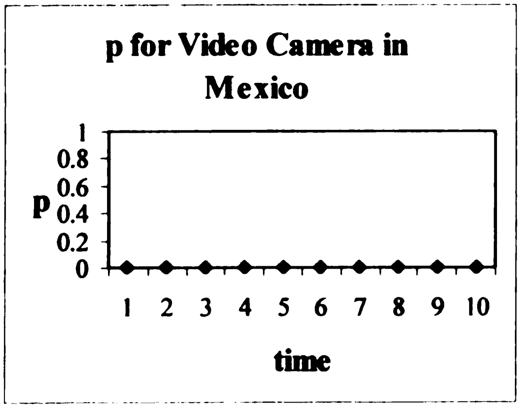
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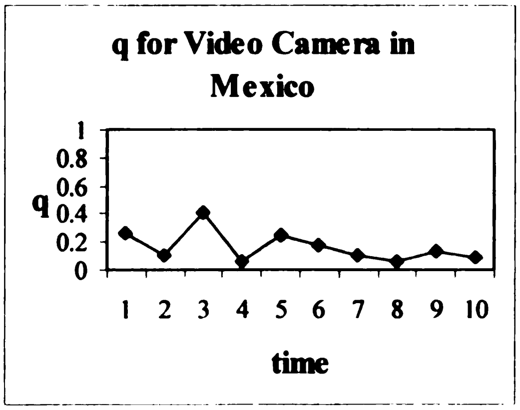
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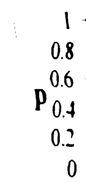
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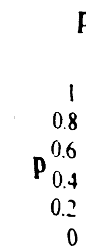
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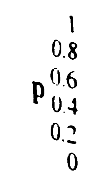
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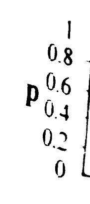
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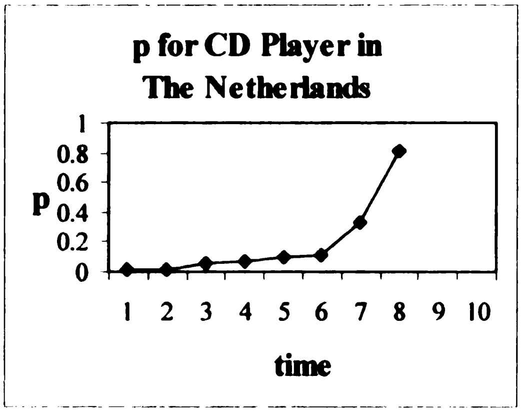
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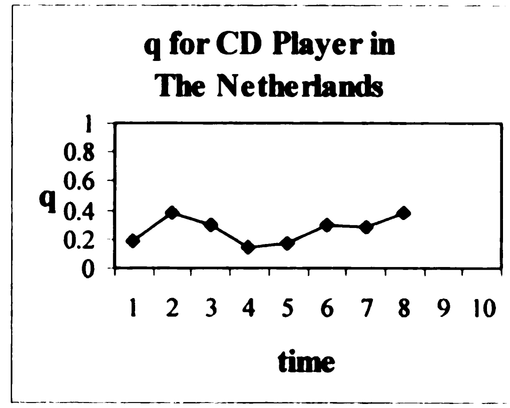
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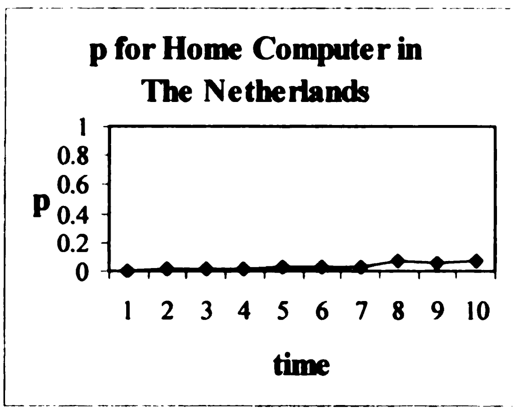
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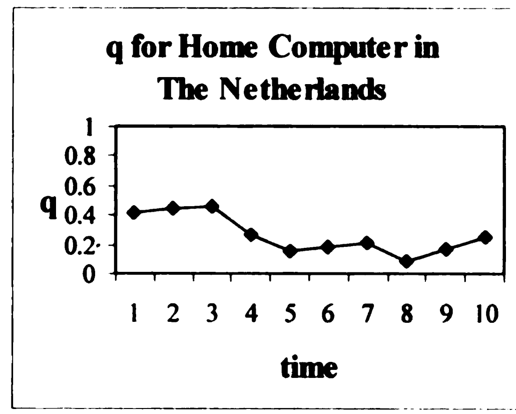
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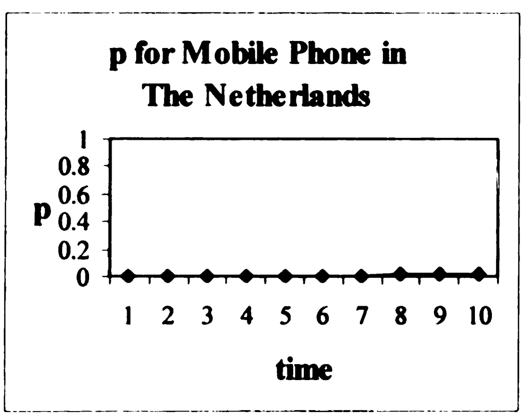
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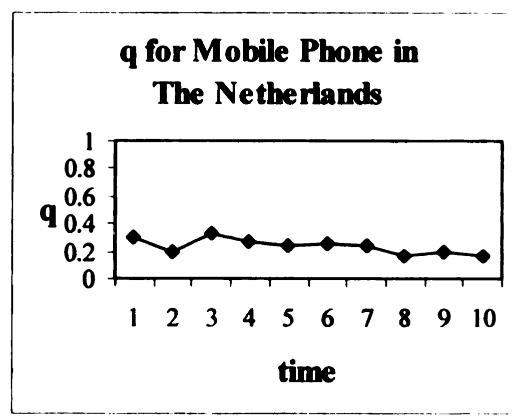
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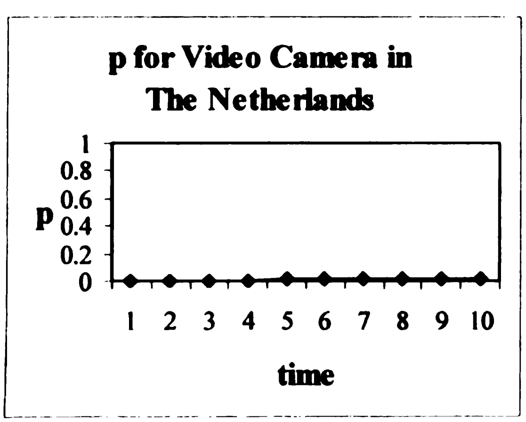
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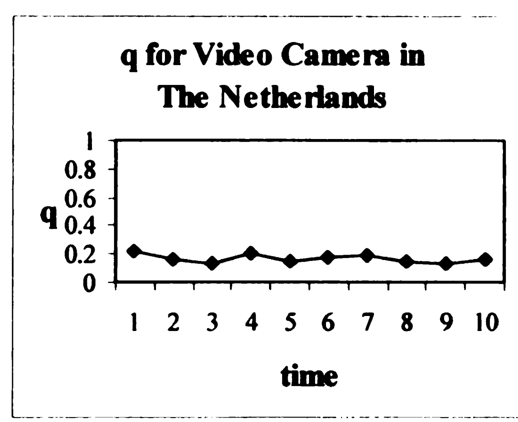
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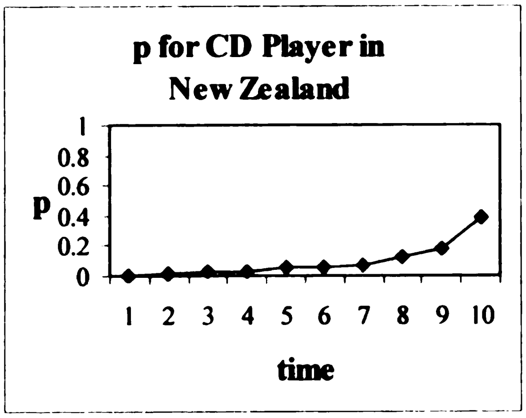
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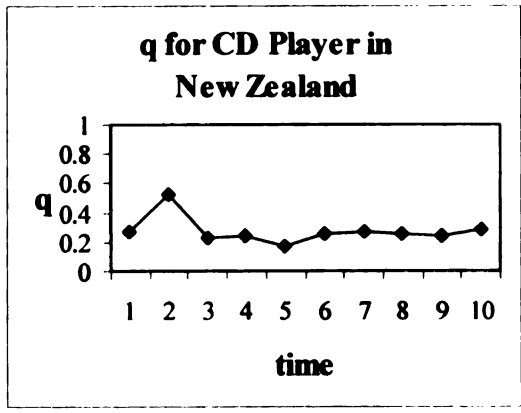
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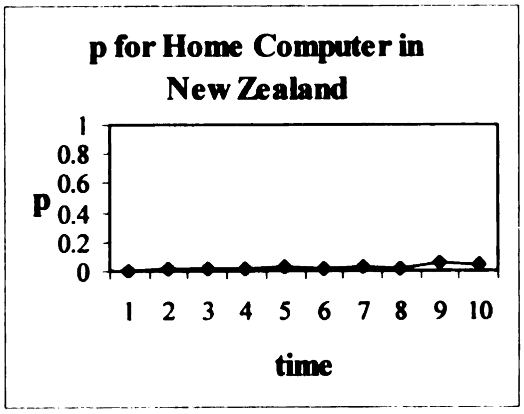
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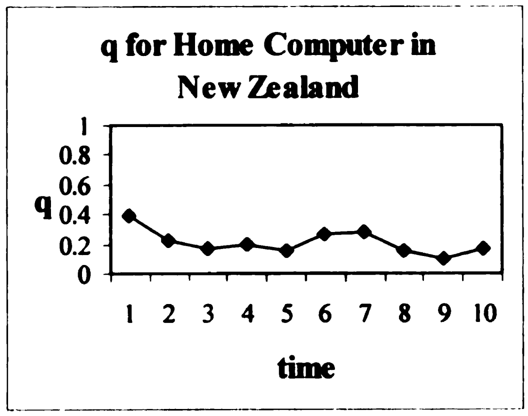
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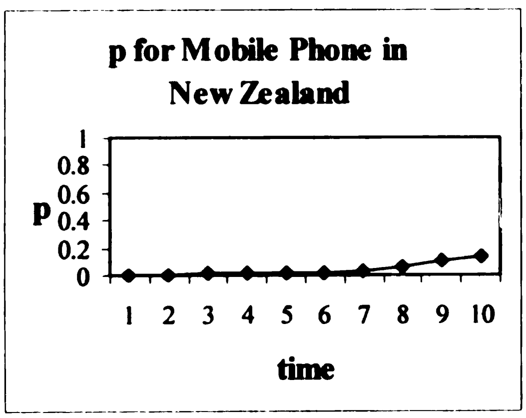
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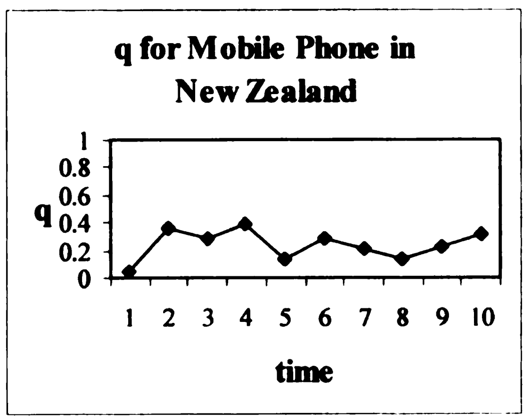
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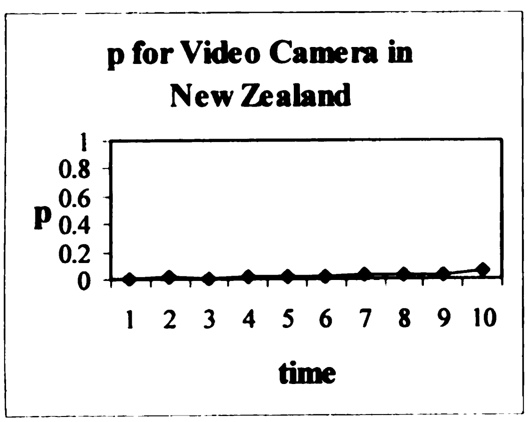
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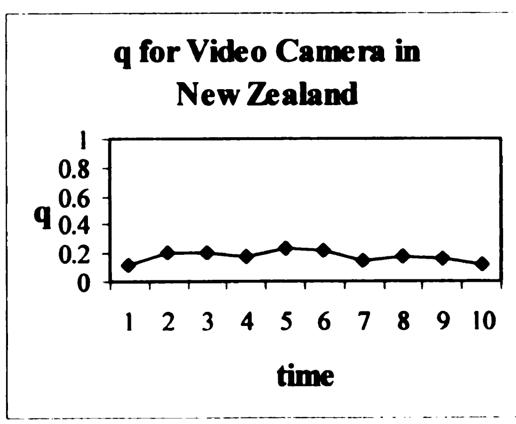
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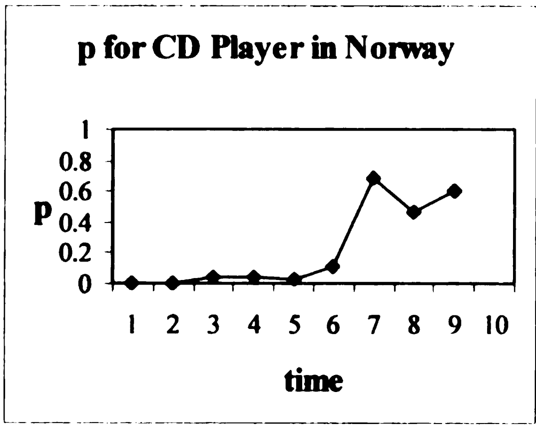
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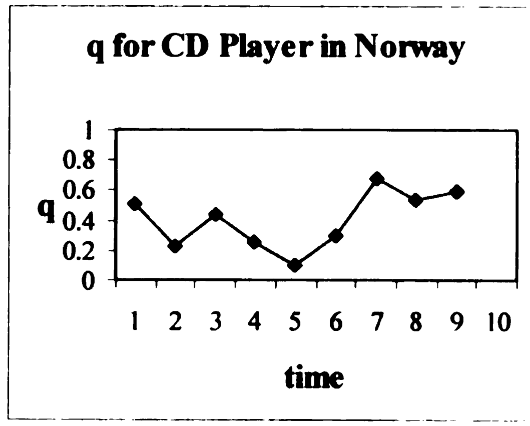
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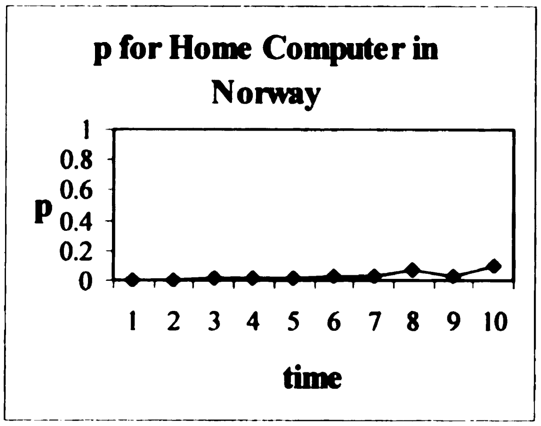
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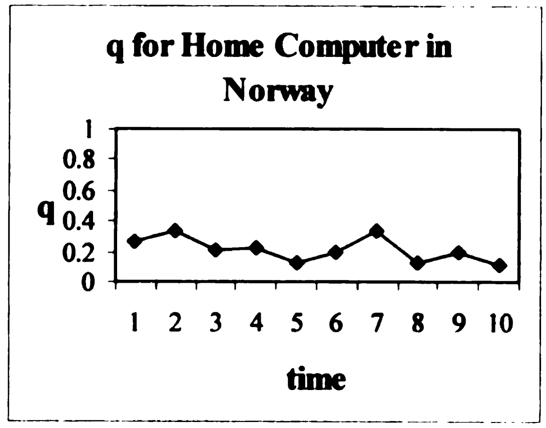
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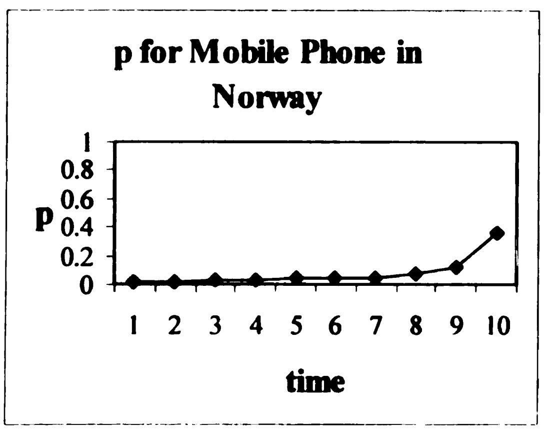
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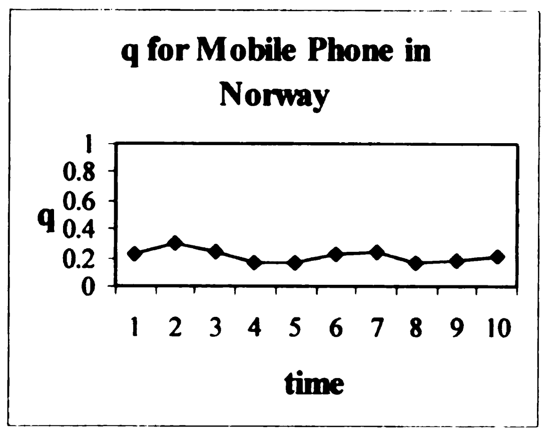
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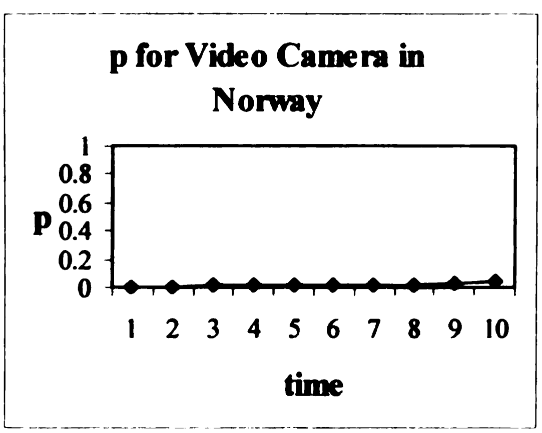
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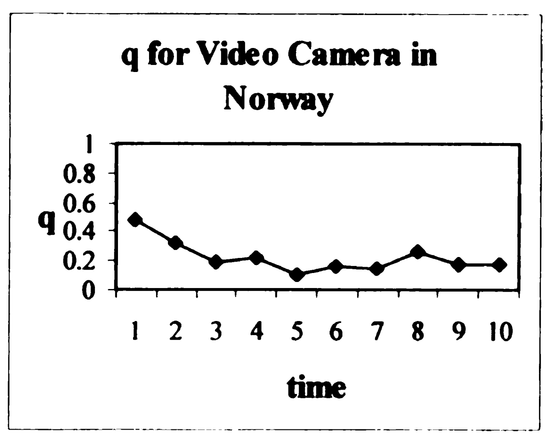
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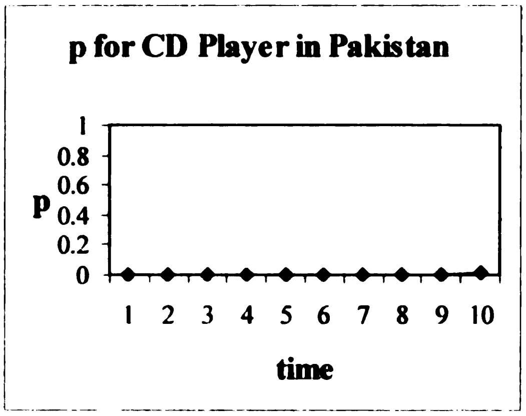
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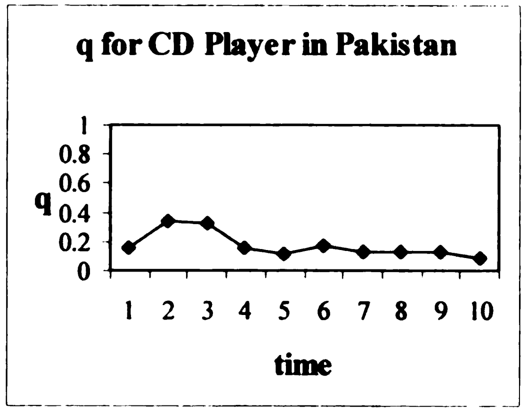
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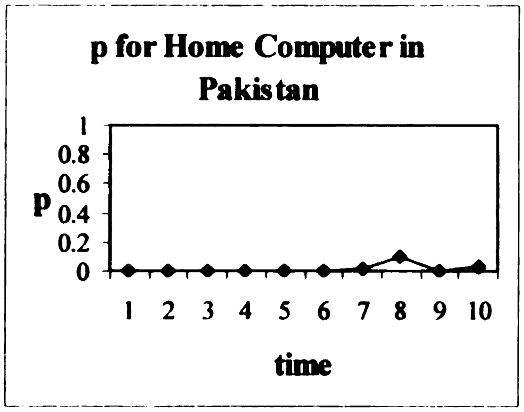
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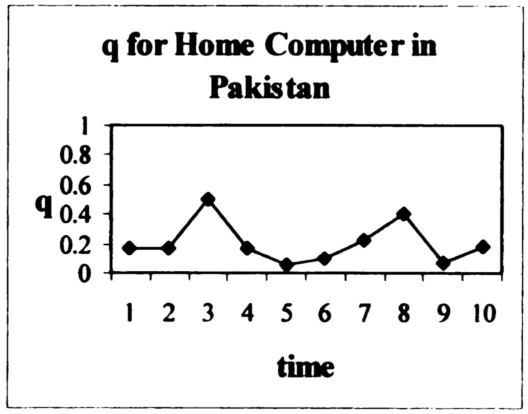
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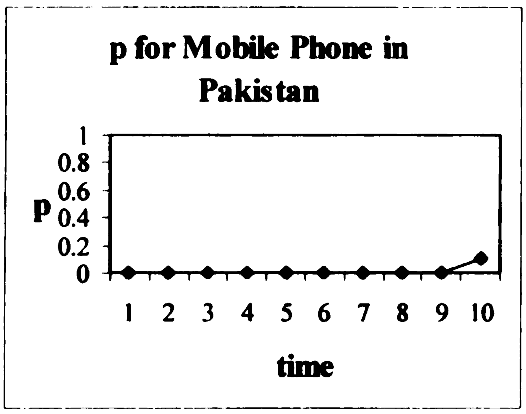
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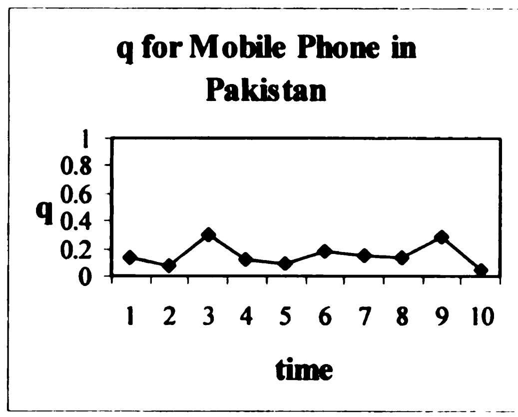
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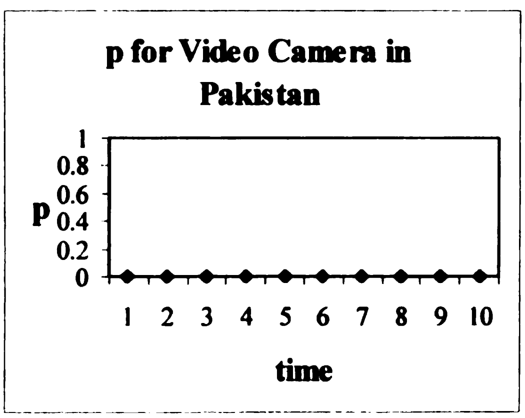
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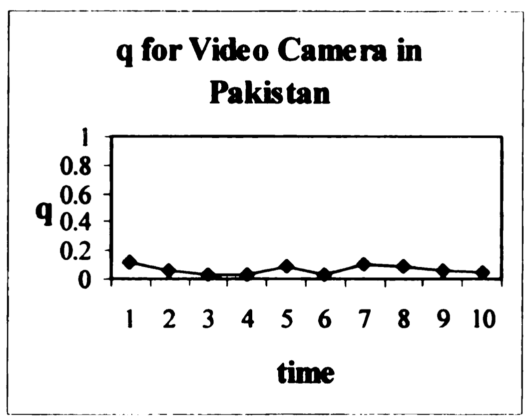
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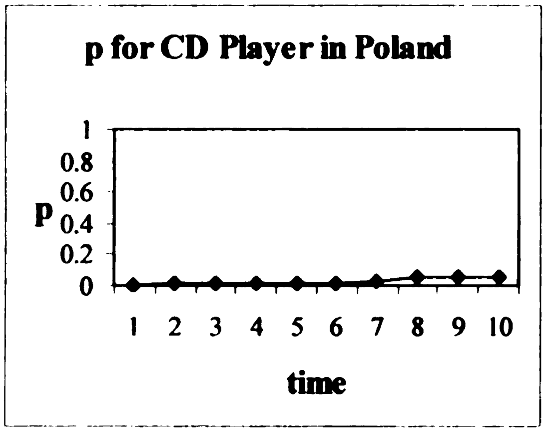
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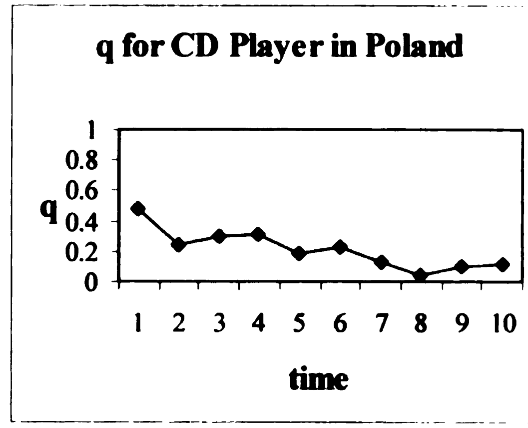
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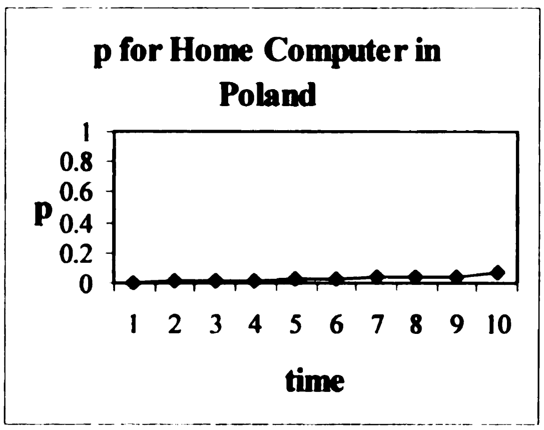
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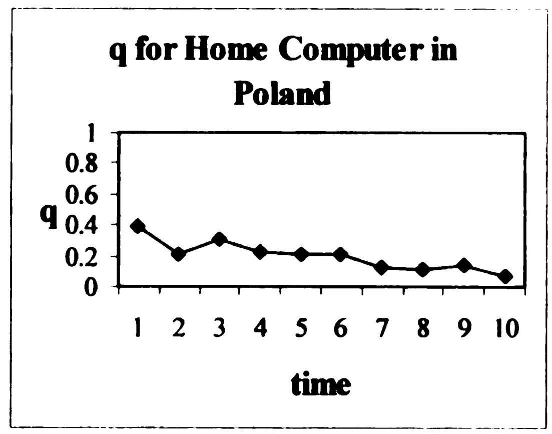
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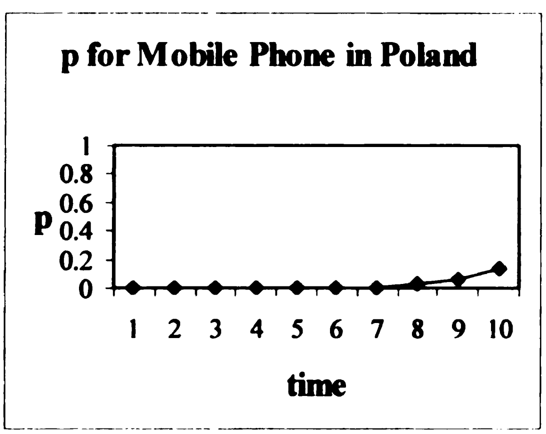
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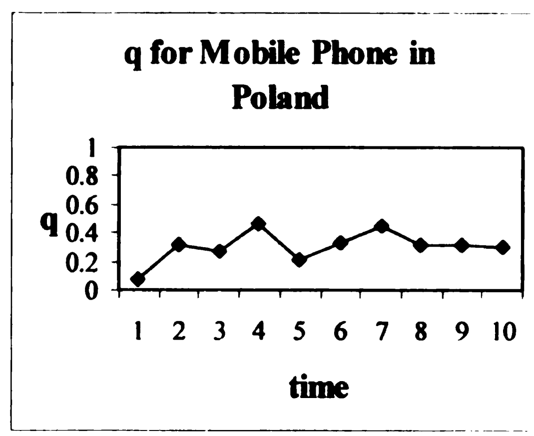
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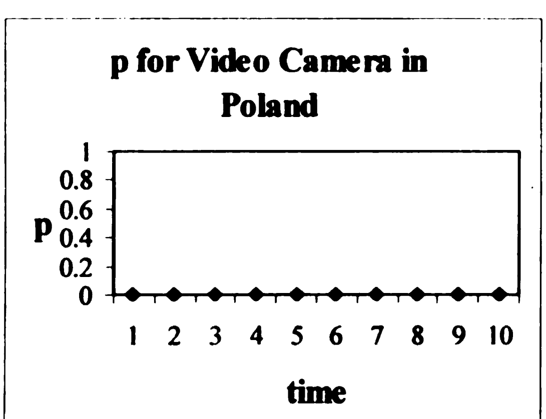
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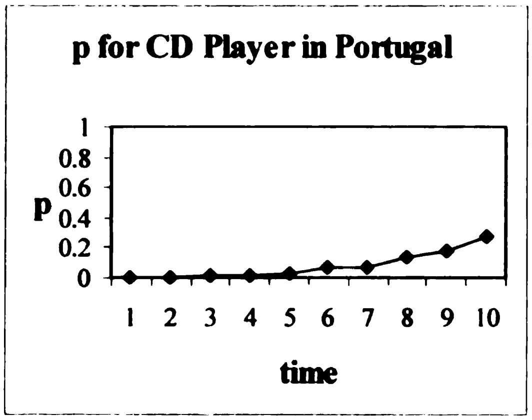
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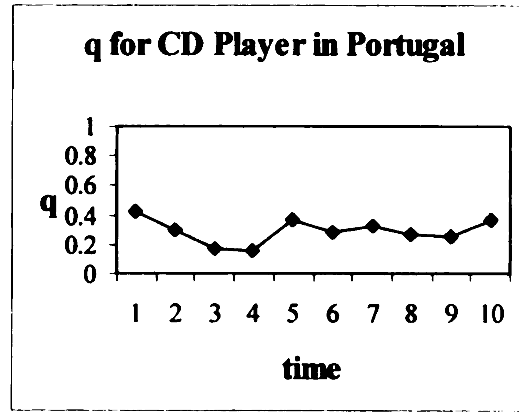
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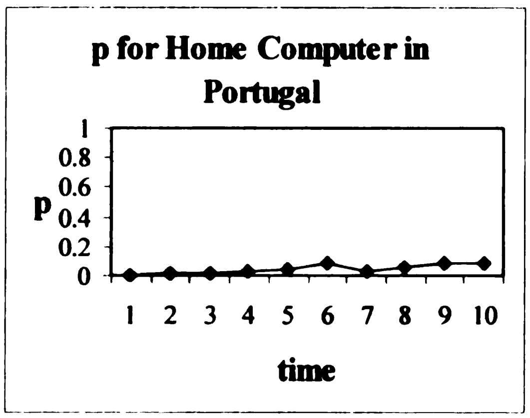
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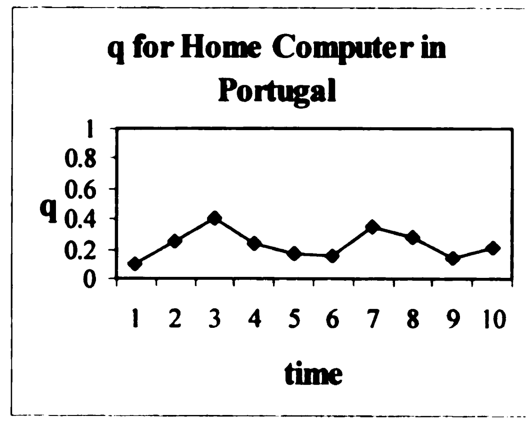
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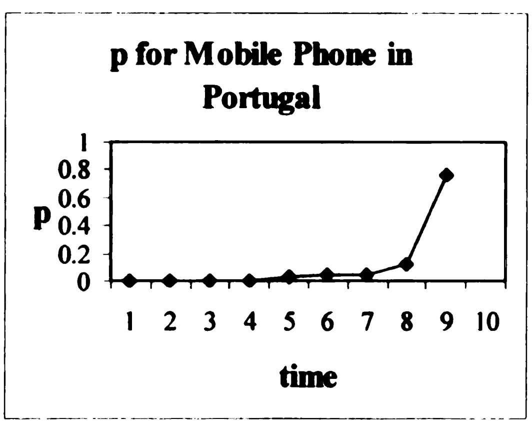
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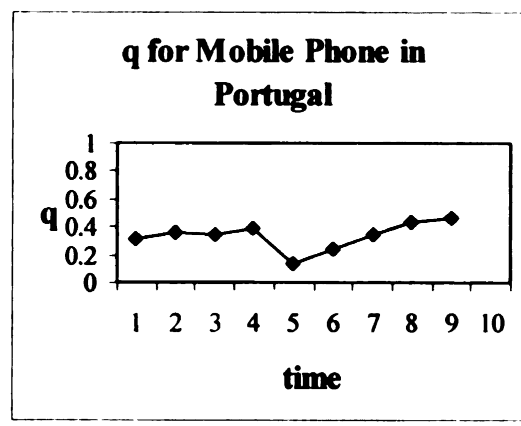
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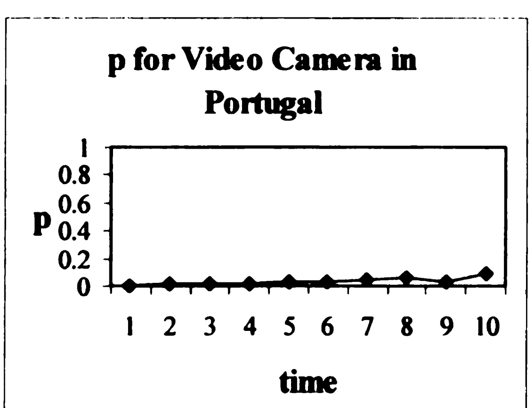
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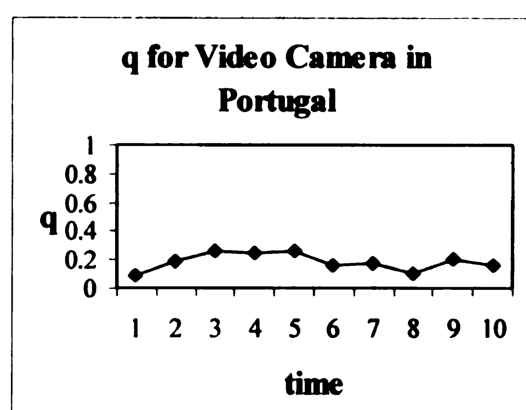
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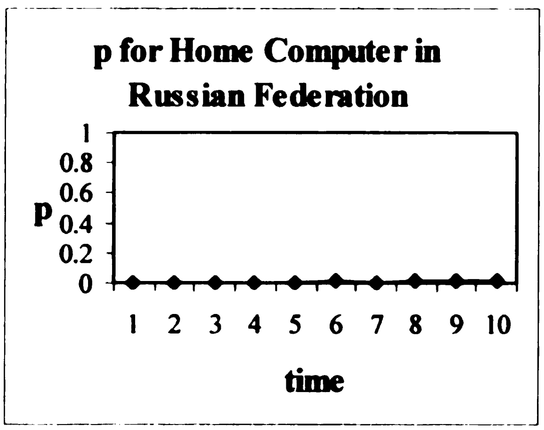
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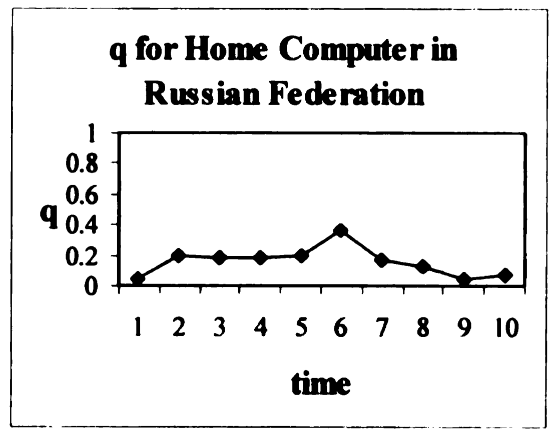
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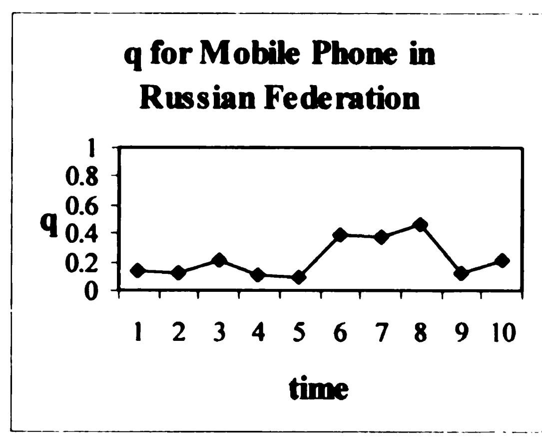
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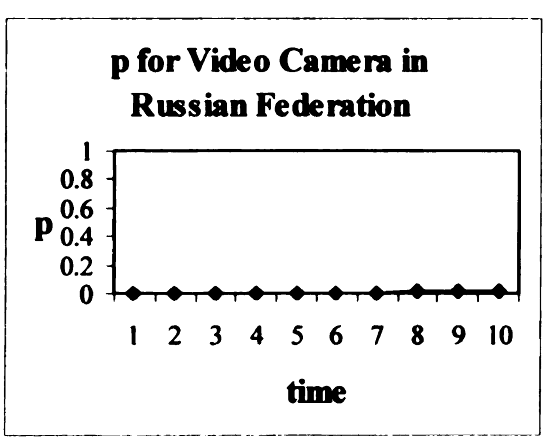
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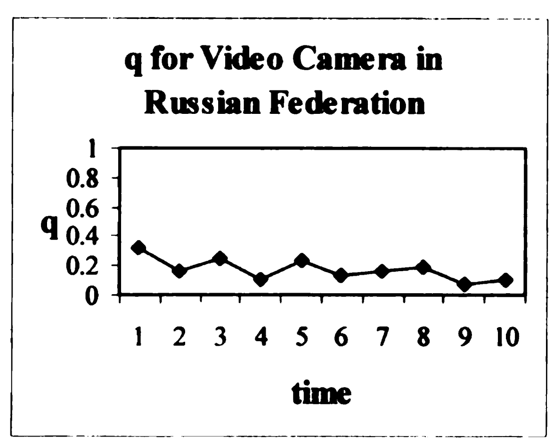
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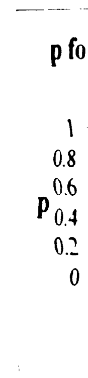
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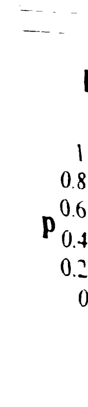
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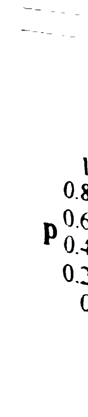
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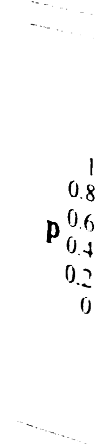
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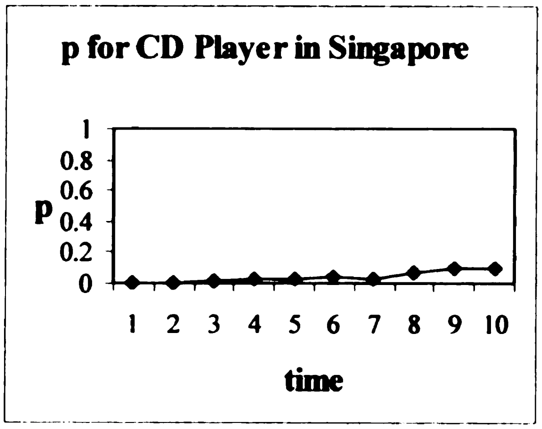
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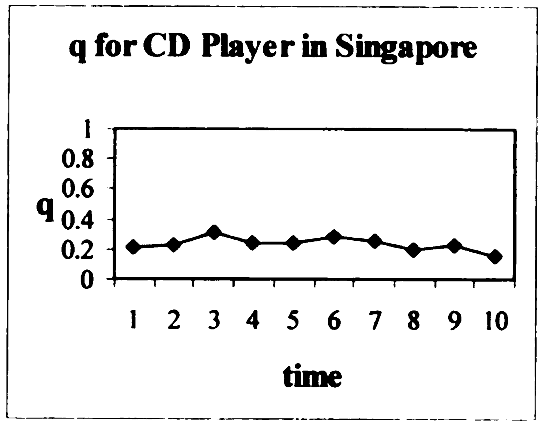
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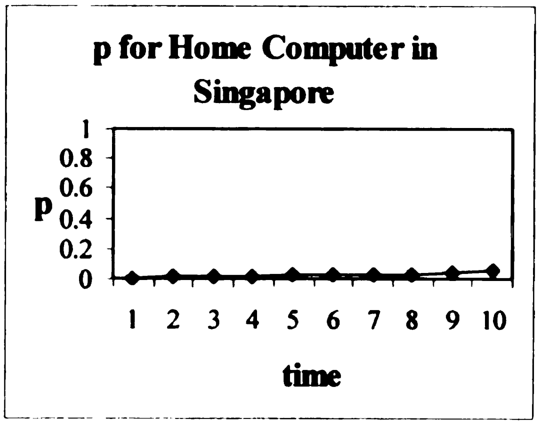
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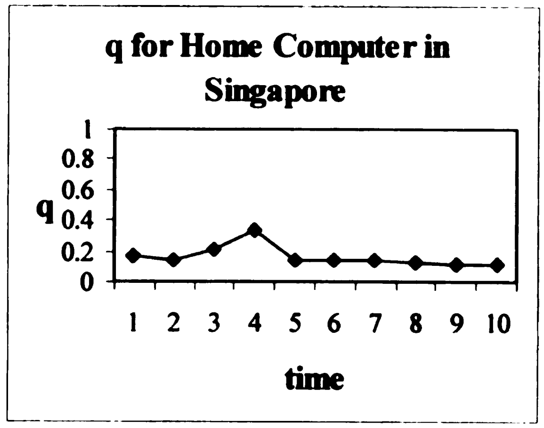
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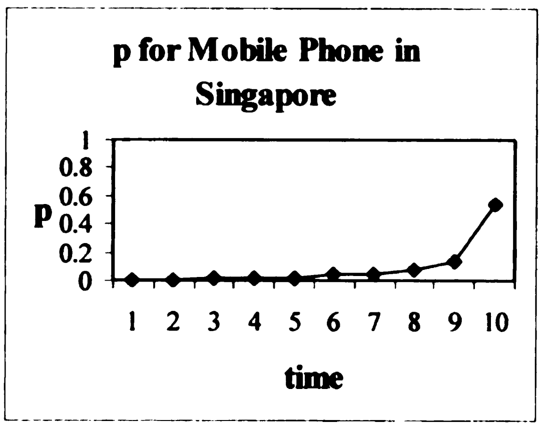
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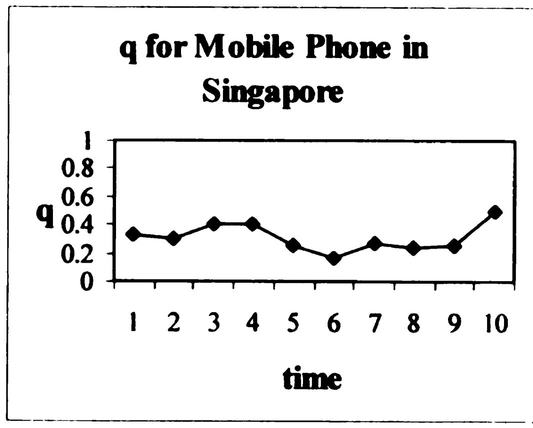
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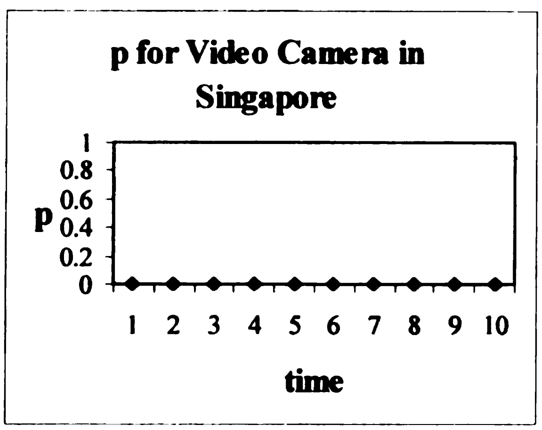
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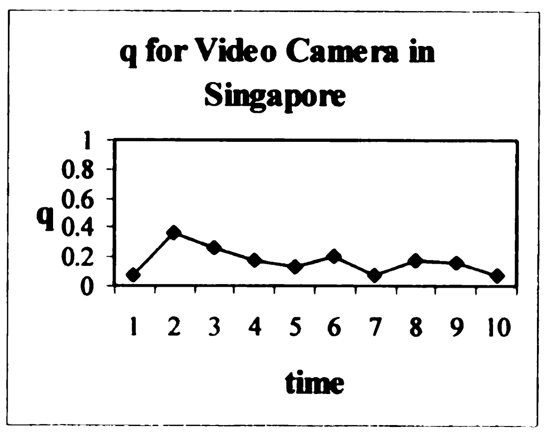
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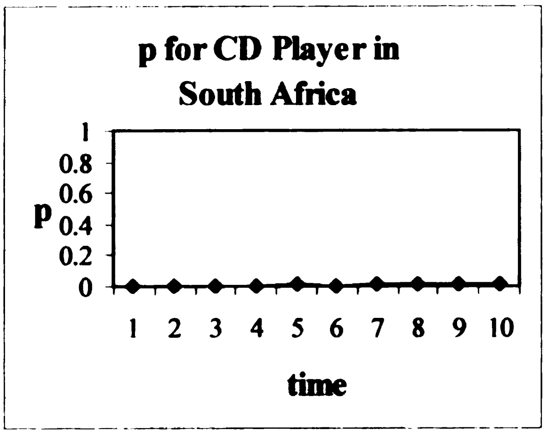
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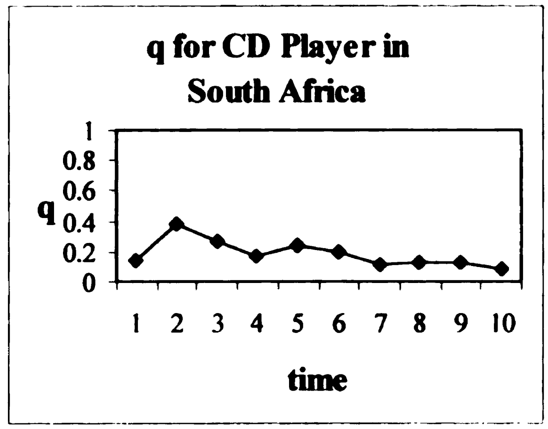
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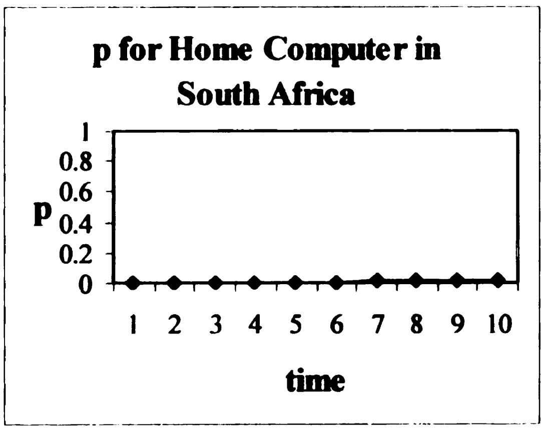
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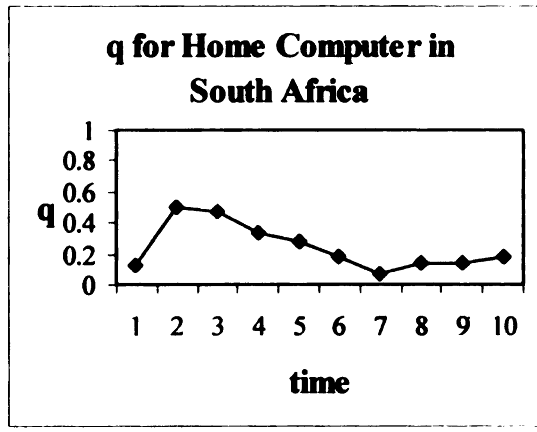
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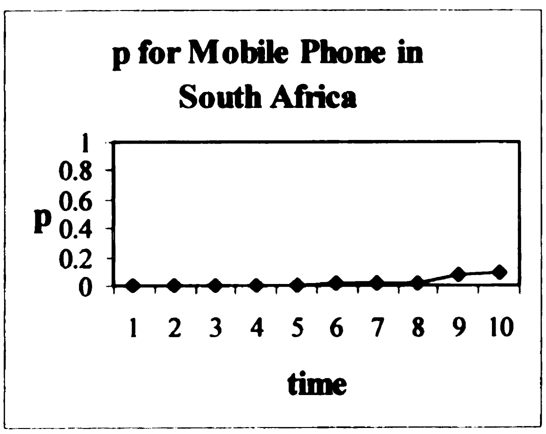
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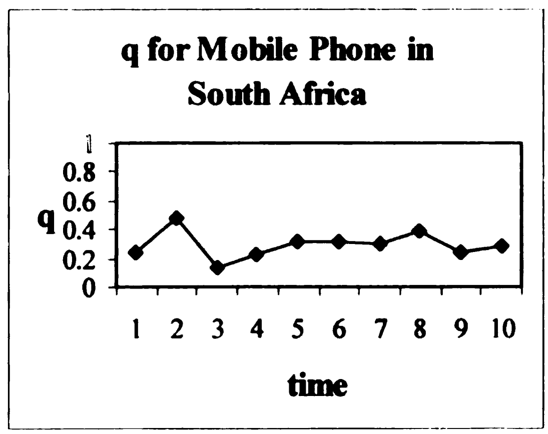
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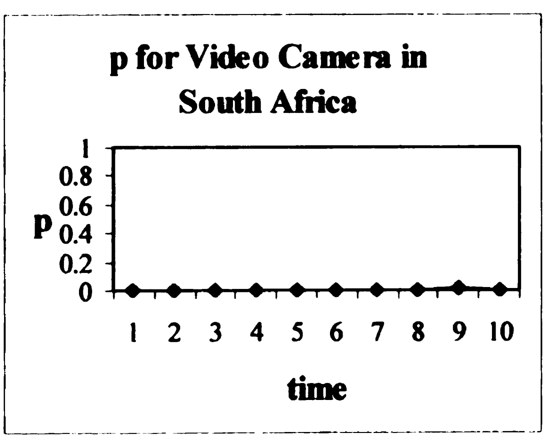
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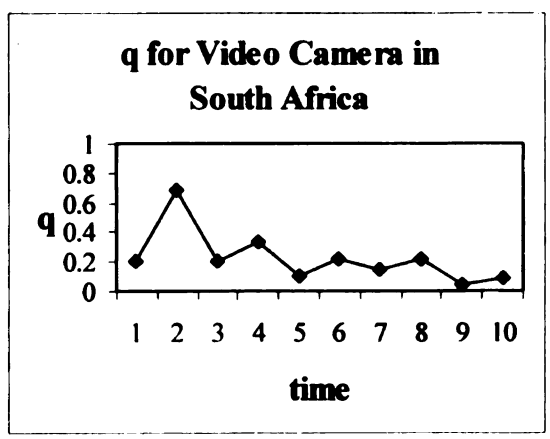
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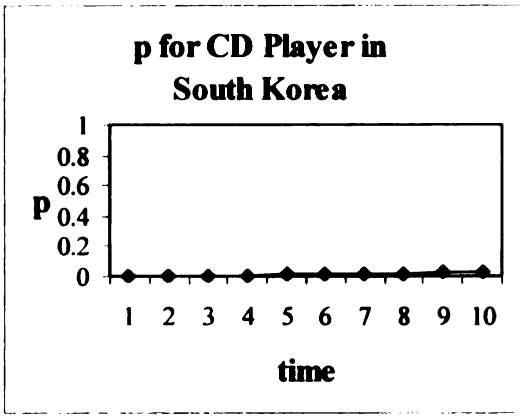
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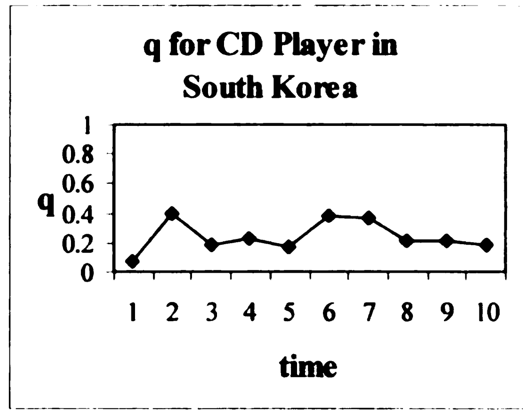
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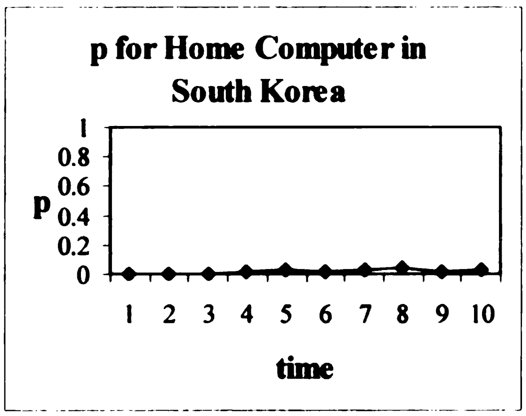
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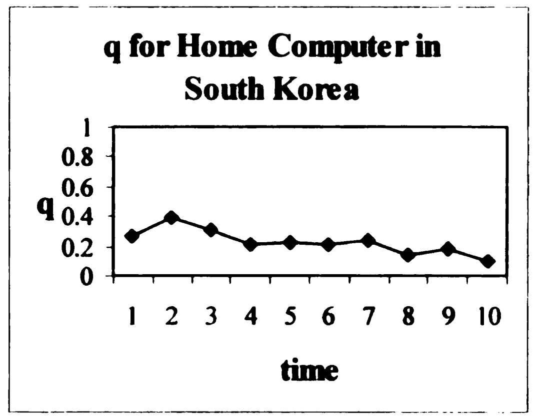
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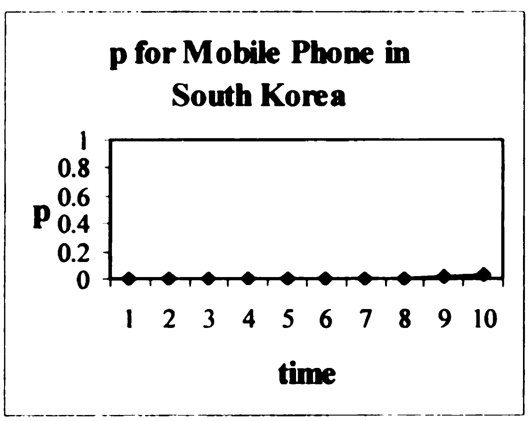
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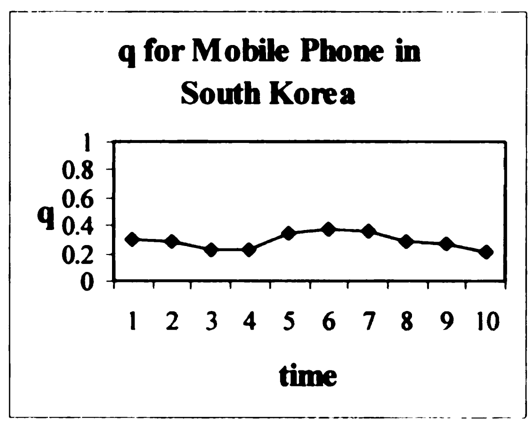
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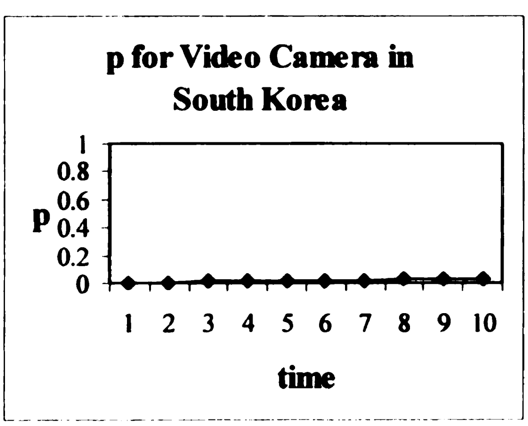
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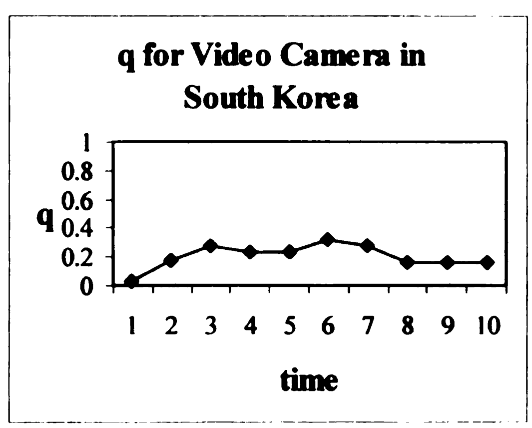
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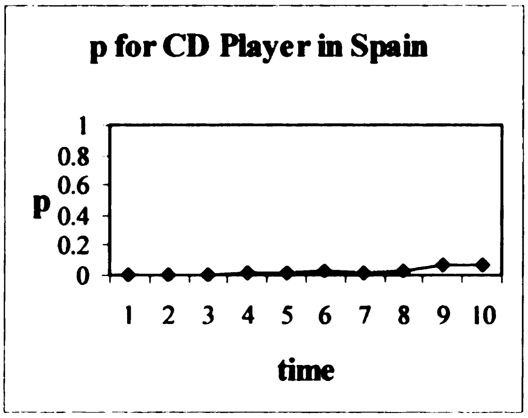
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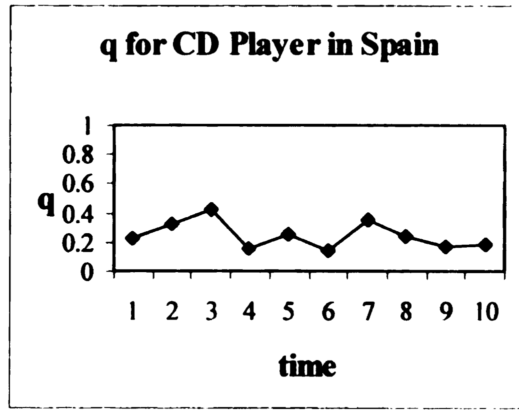
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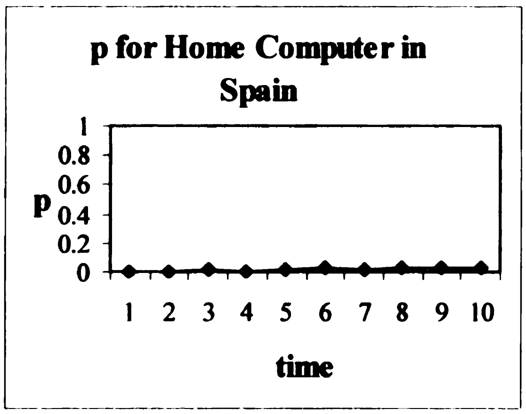
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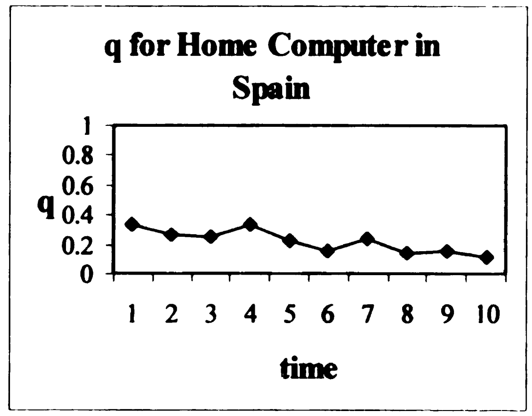
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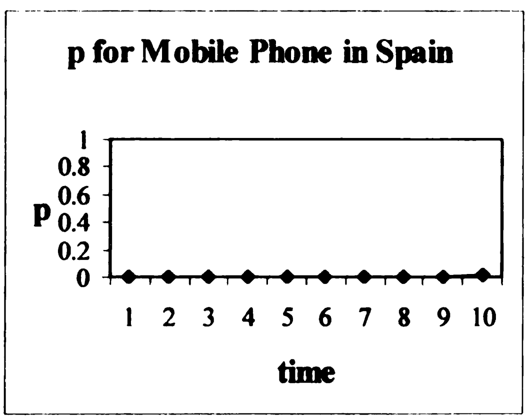
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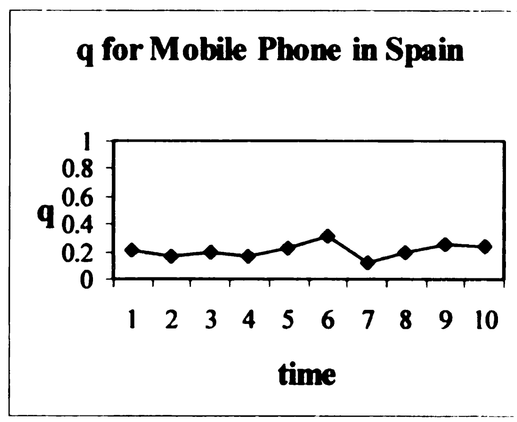
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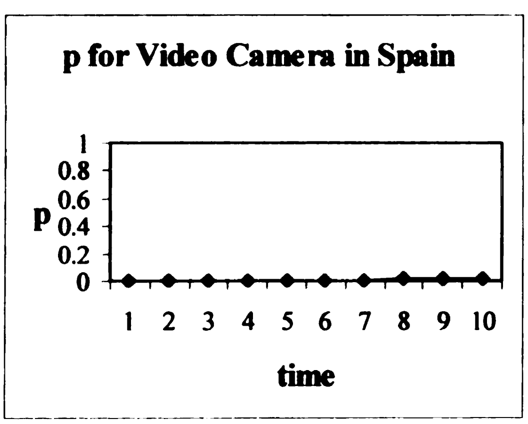
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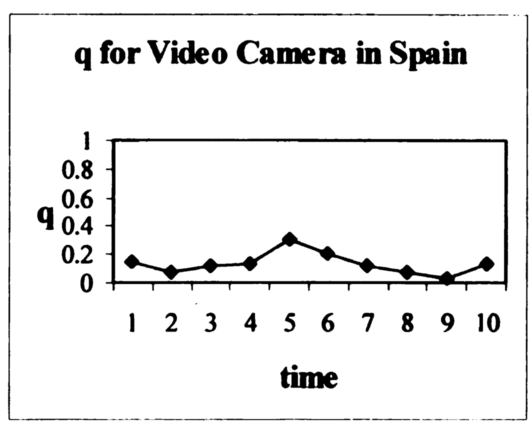
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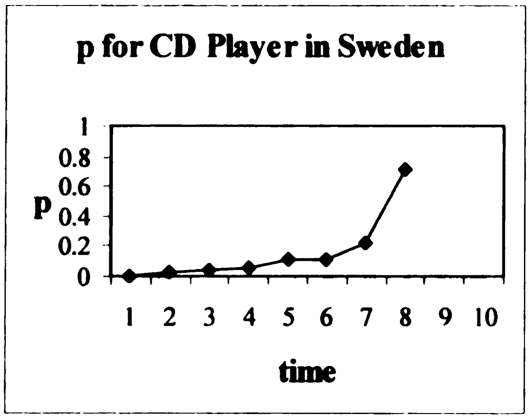
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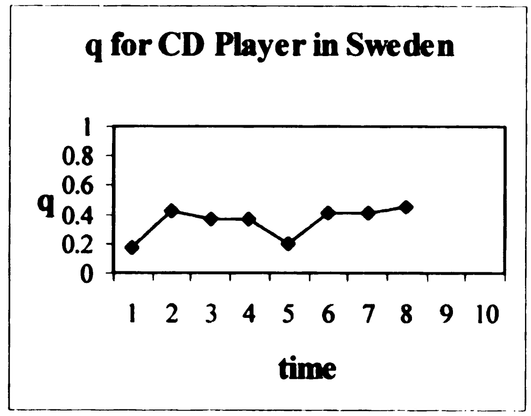
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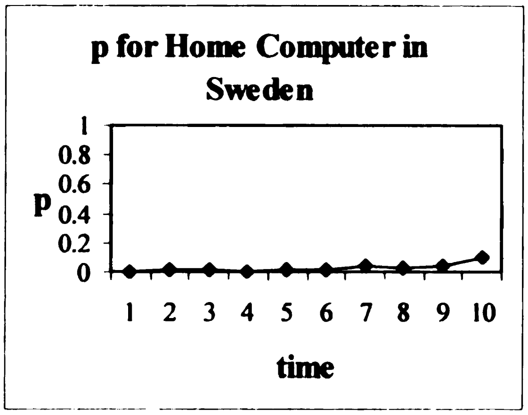
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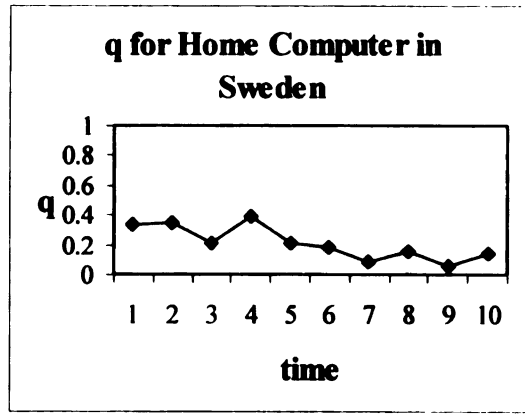
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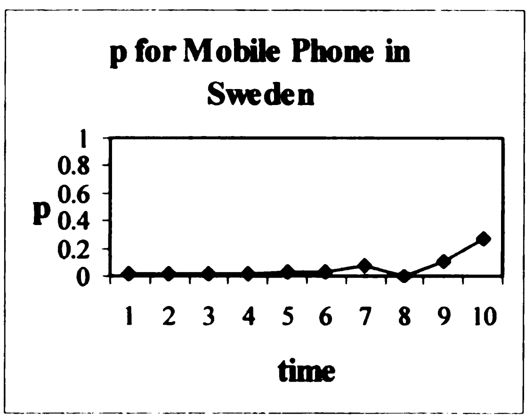
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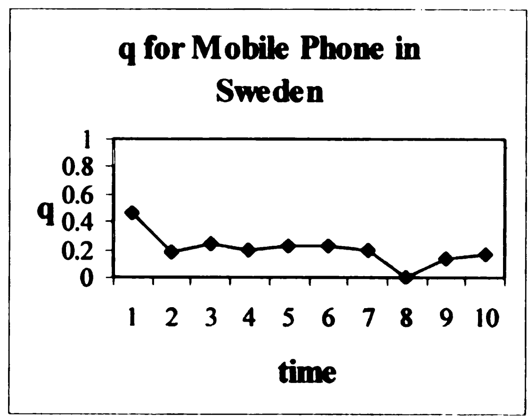
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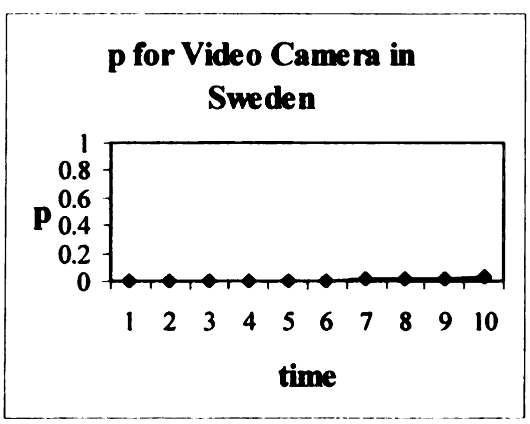
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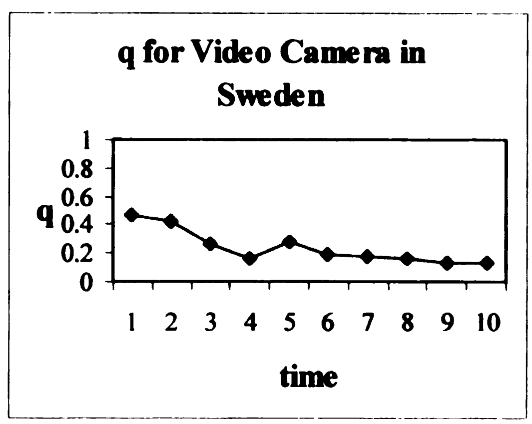
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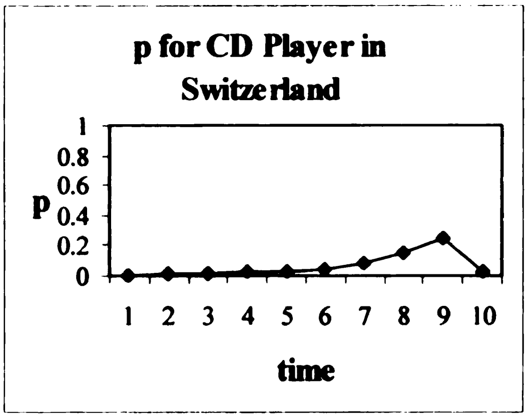
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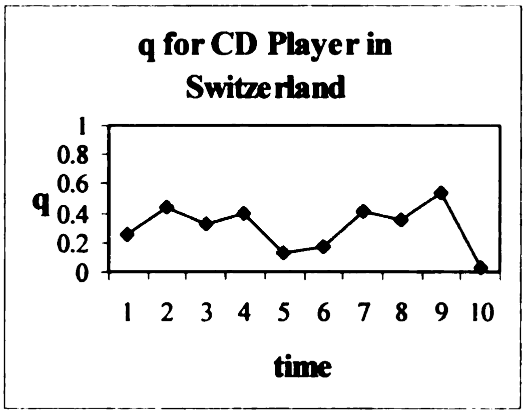
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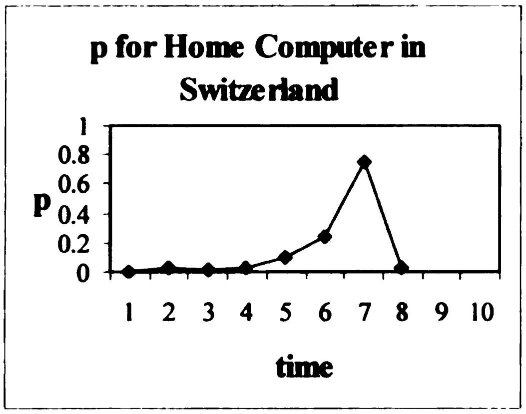
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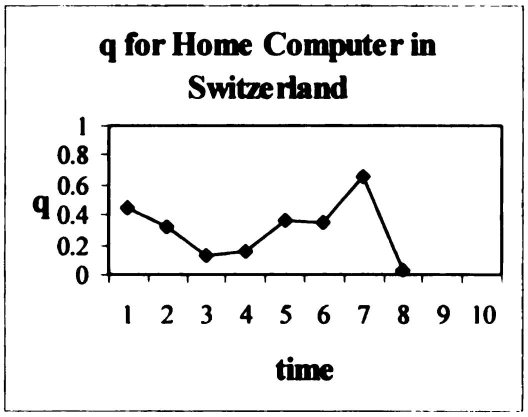
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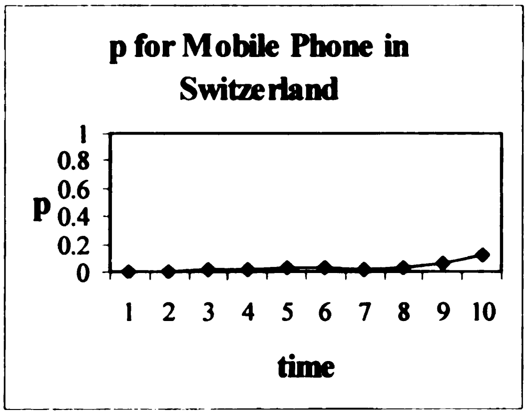
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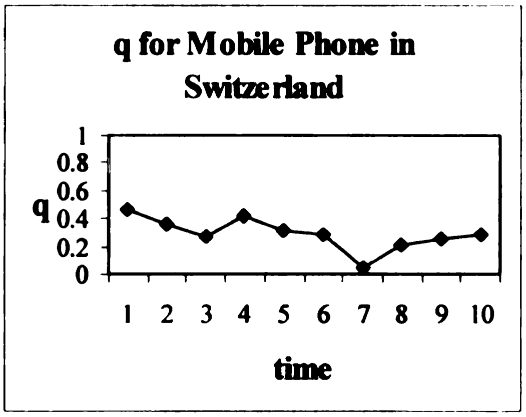
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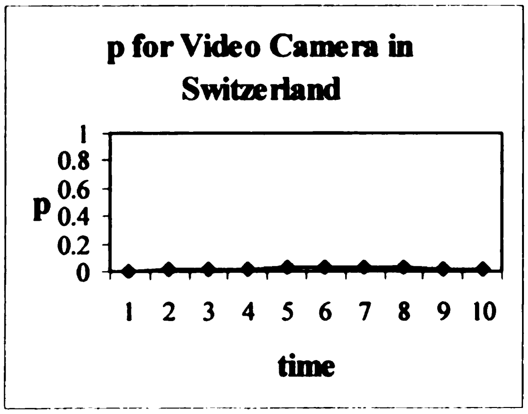
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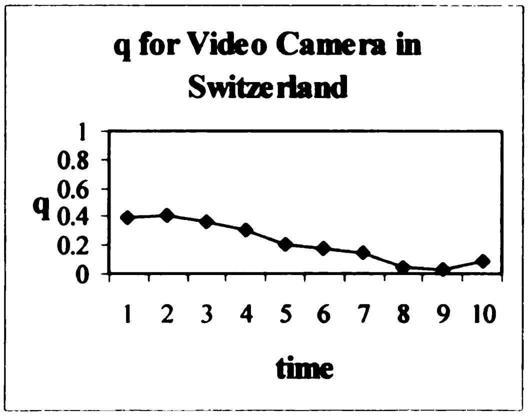
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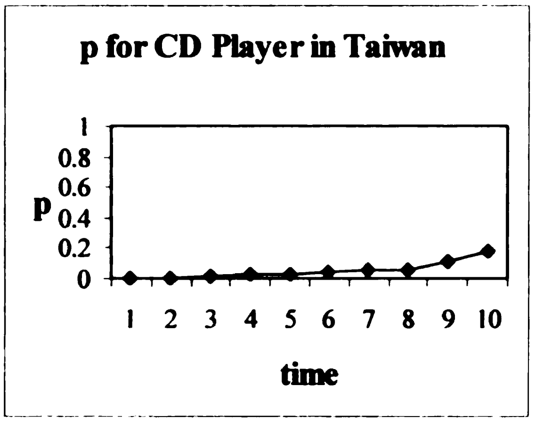
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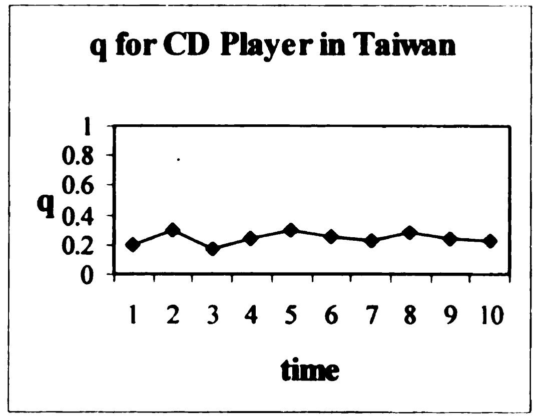
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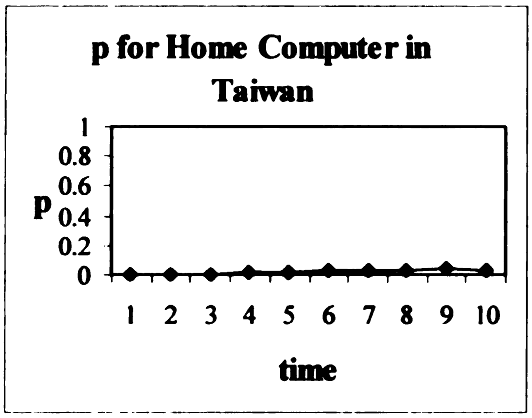
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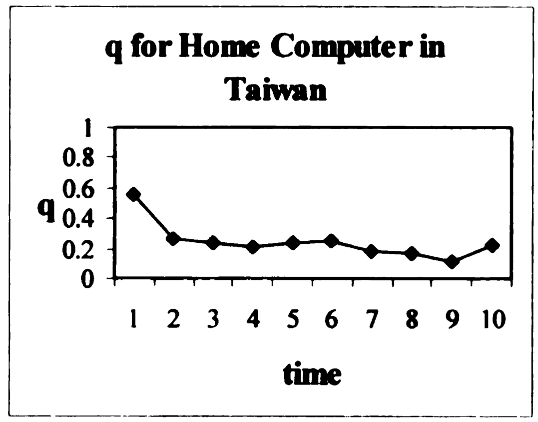
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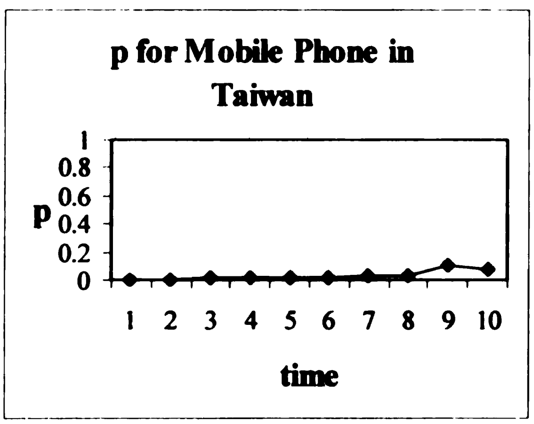
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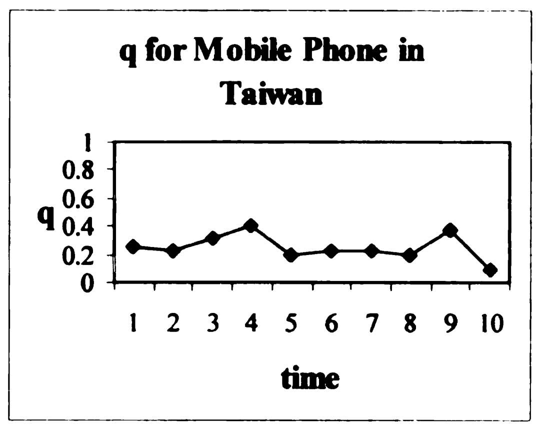
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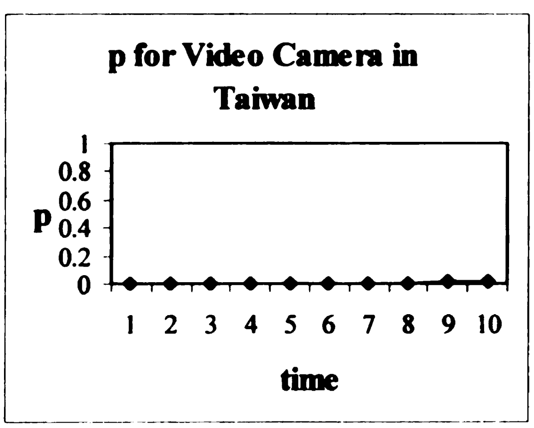
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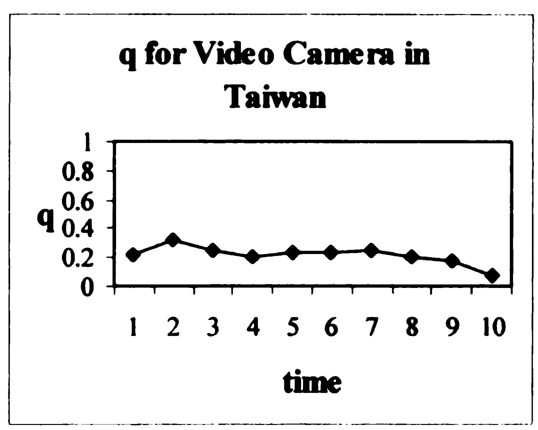
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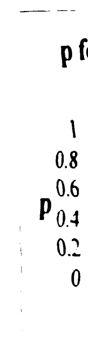
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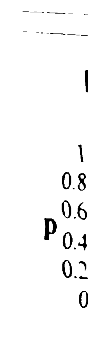
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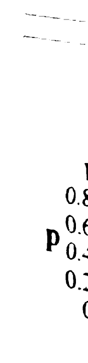
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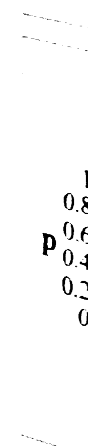
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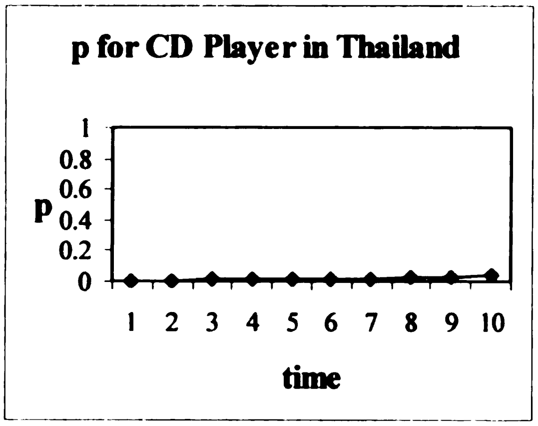
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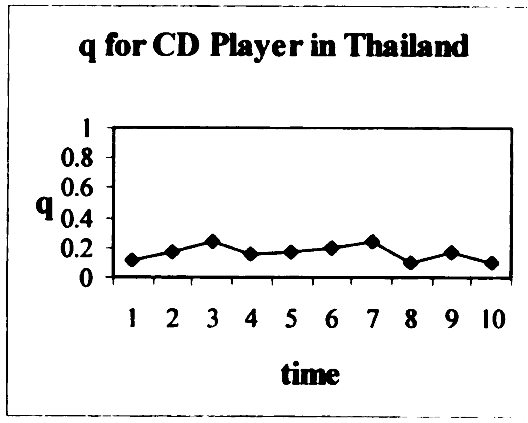
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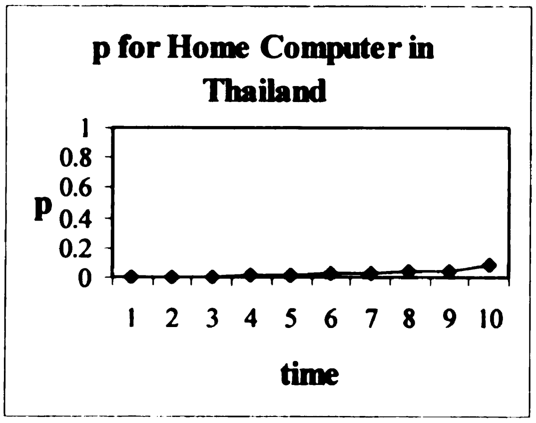
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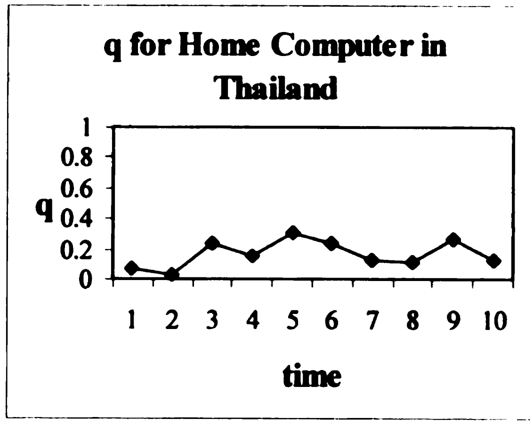
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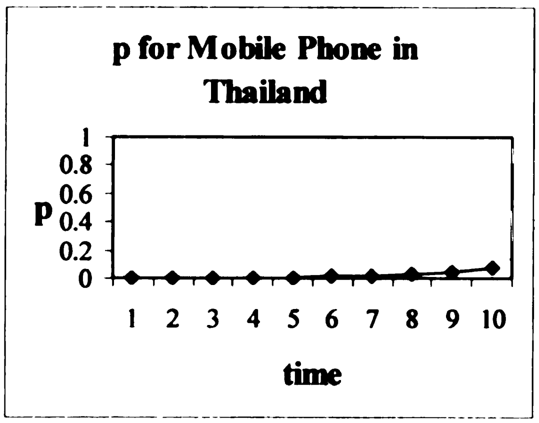
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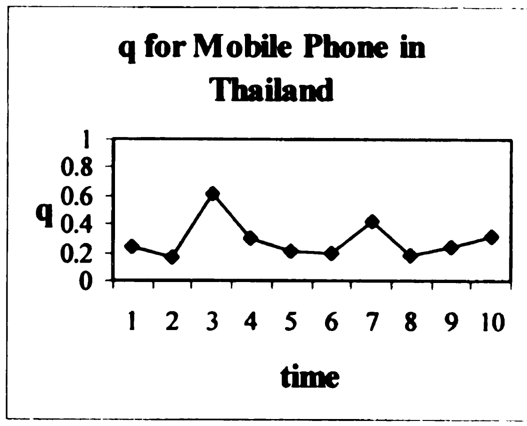
time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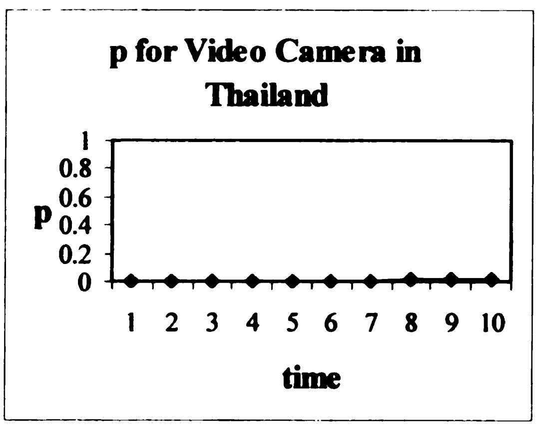
time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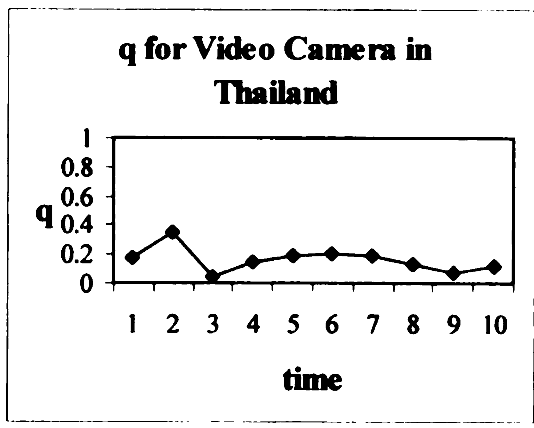
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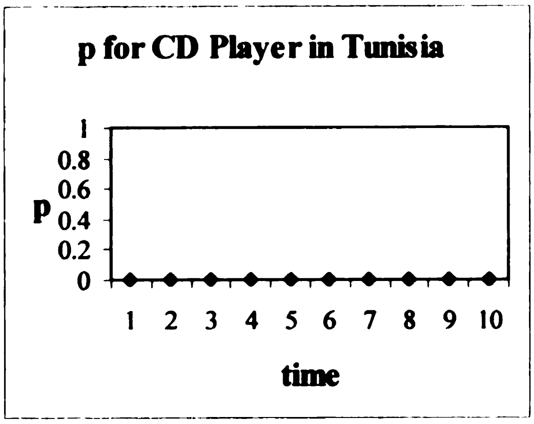
time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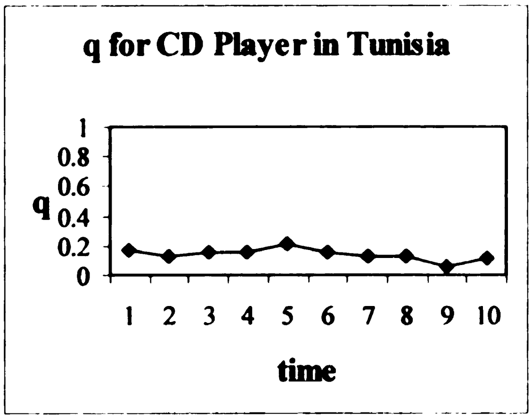
time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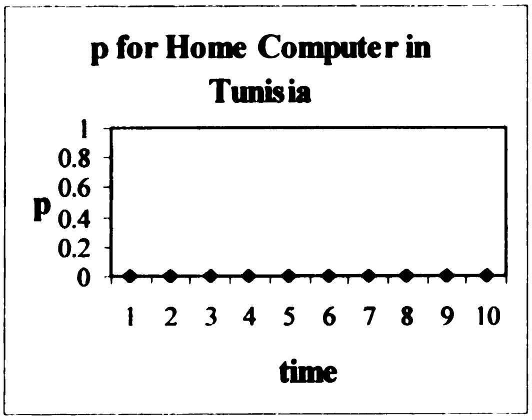
time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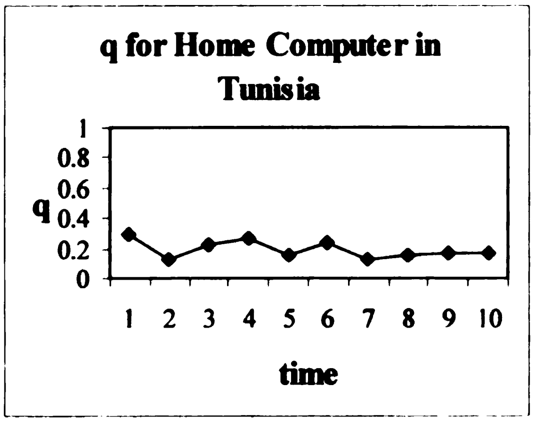
0.6
p 0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time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q 0.4
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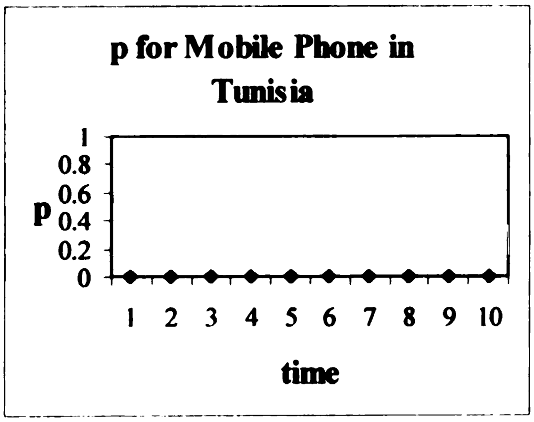
time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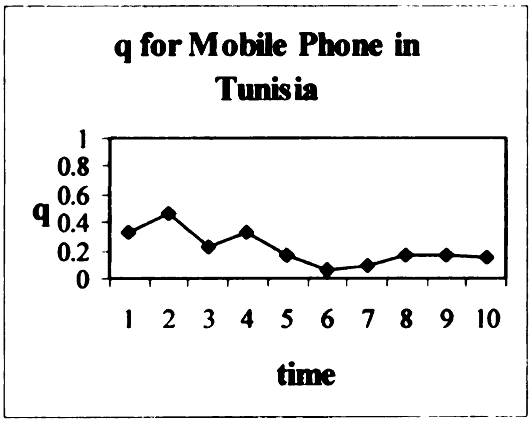
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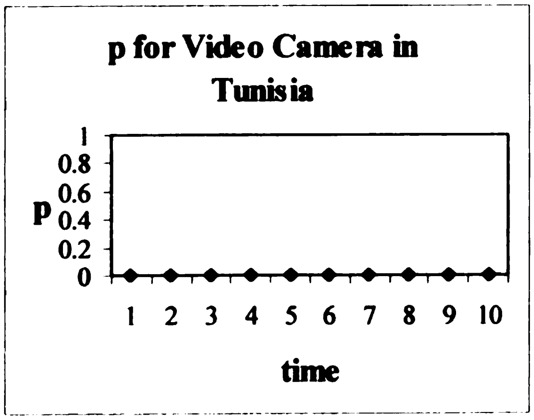
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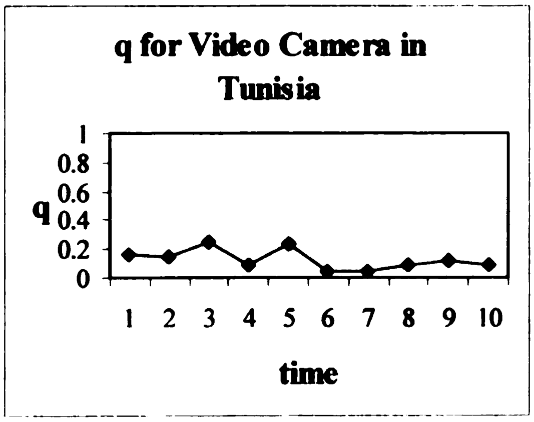
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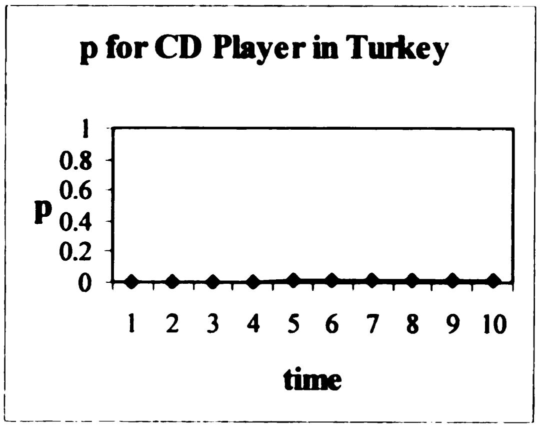

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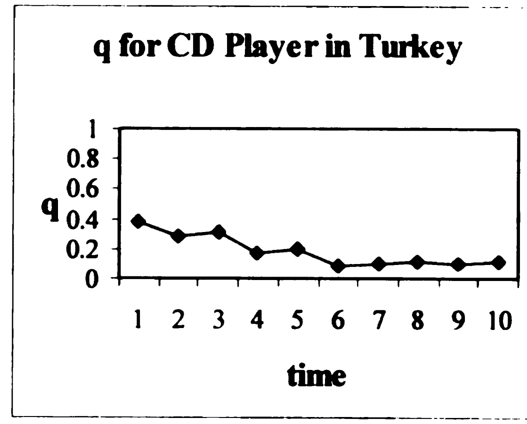

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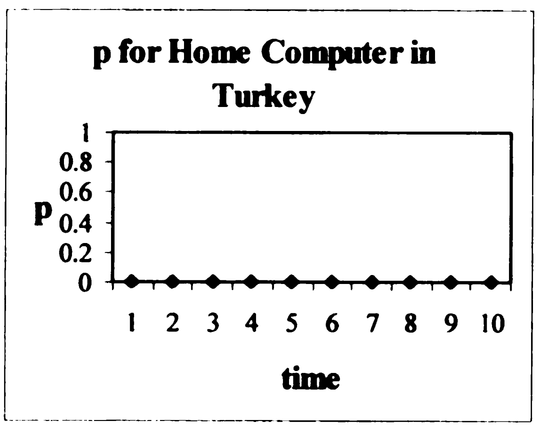

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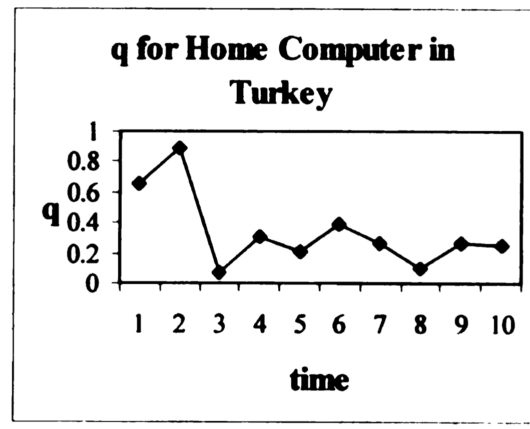

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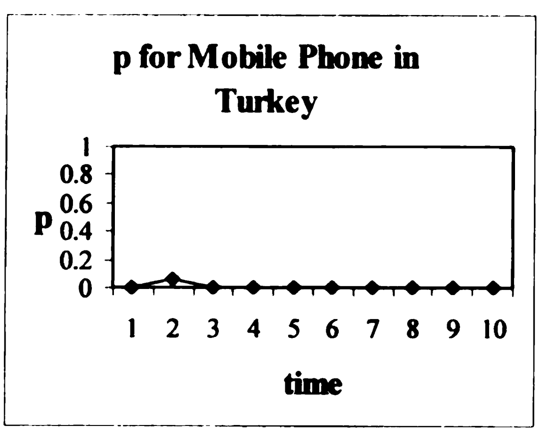

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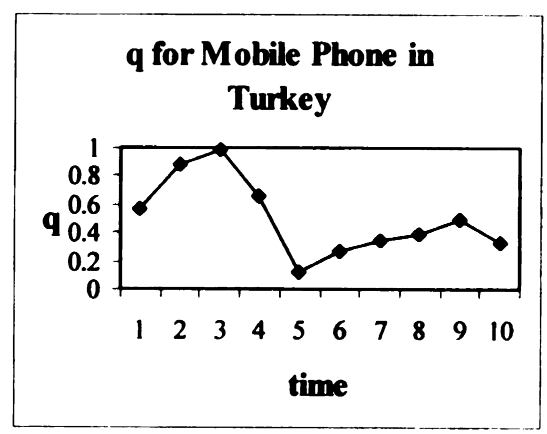

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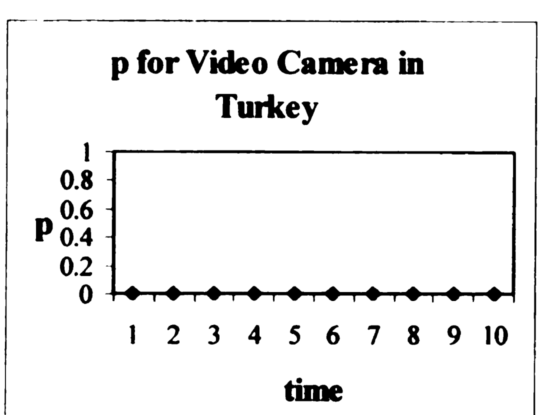

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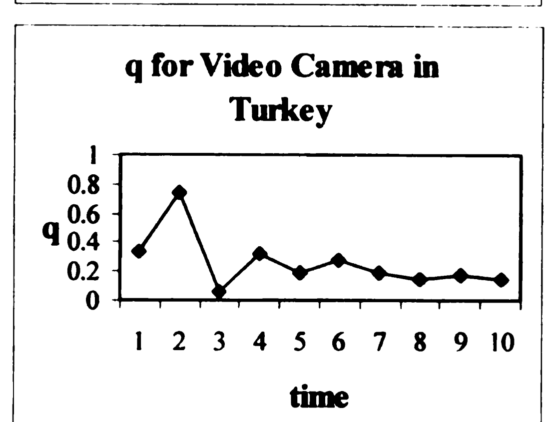

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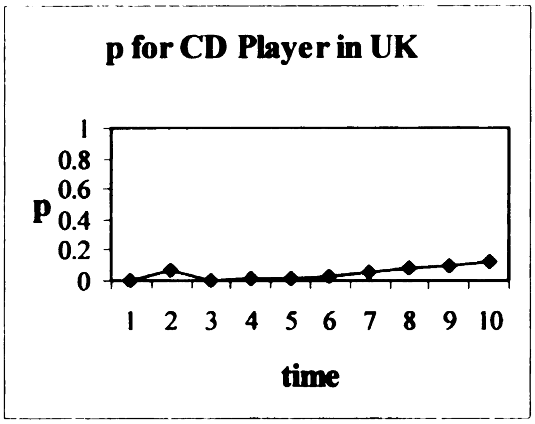
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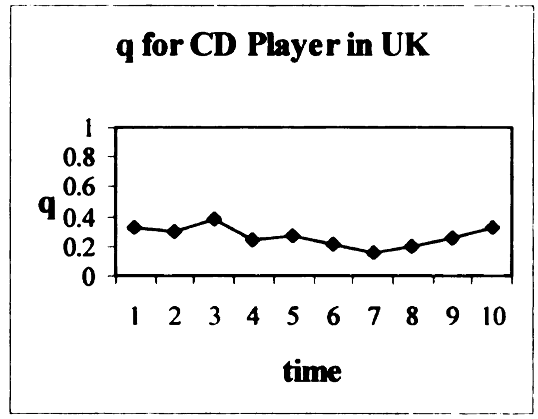
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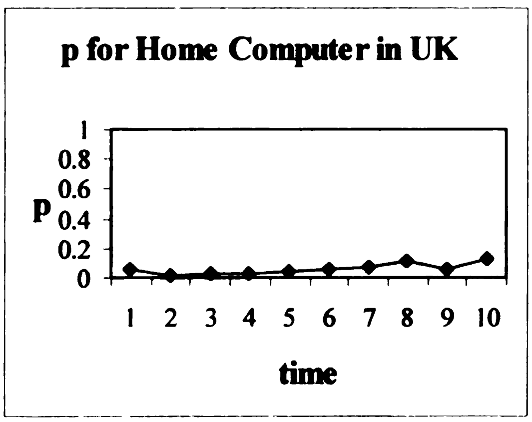
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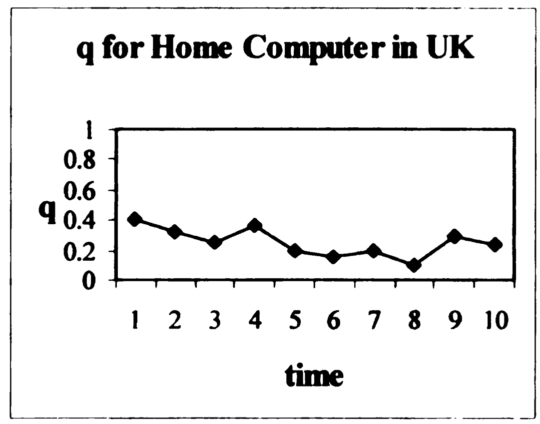
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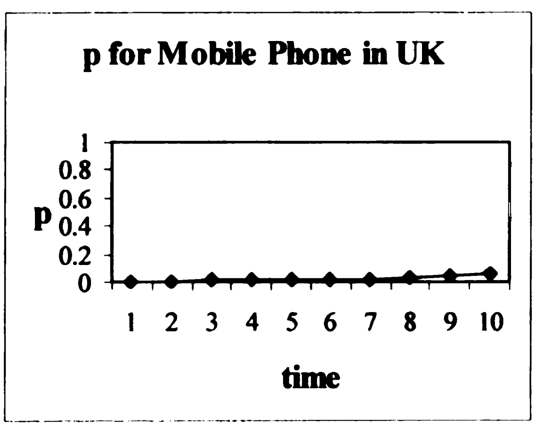
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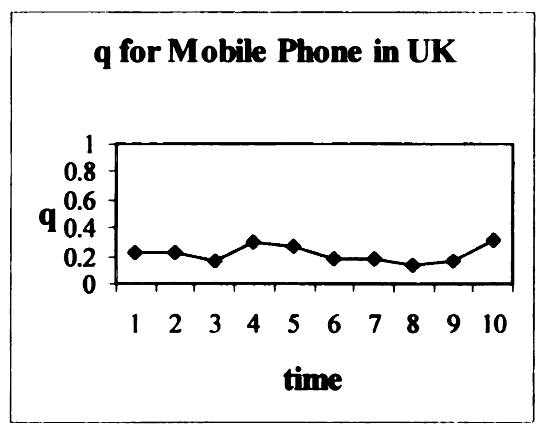
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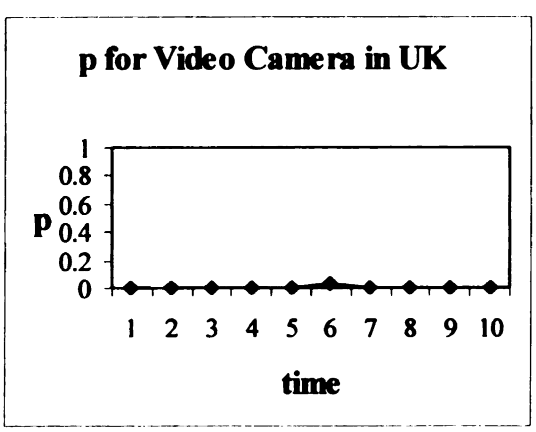
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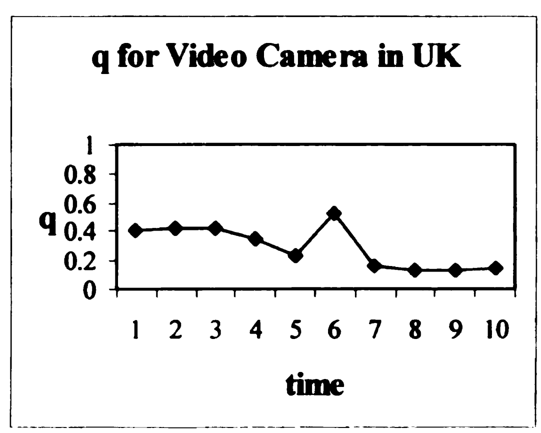
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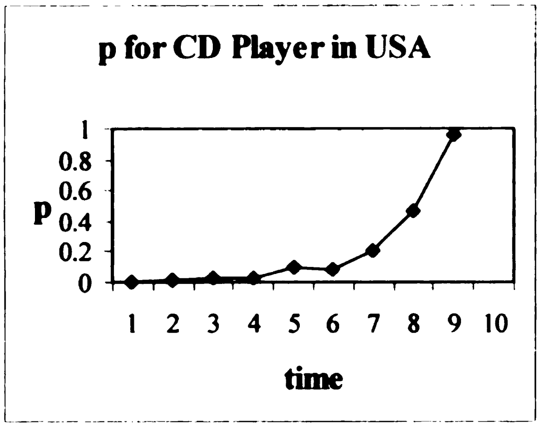
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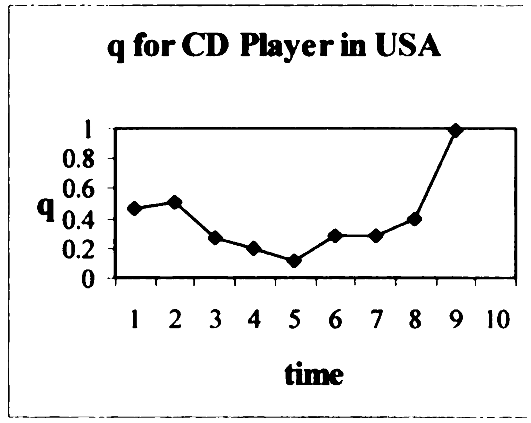
time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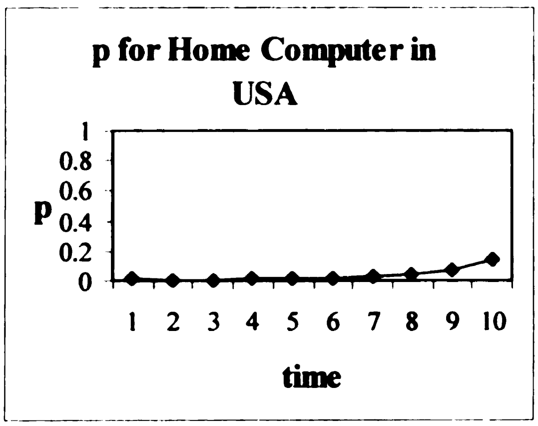
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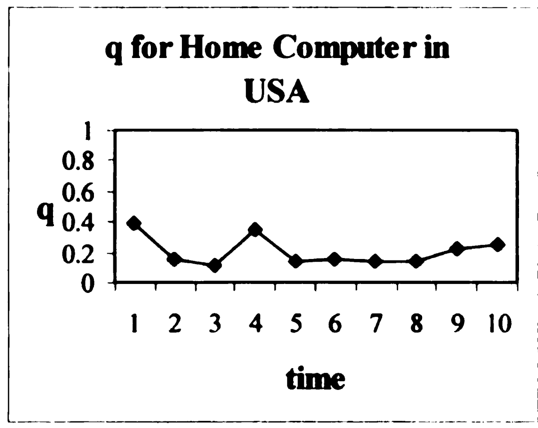
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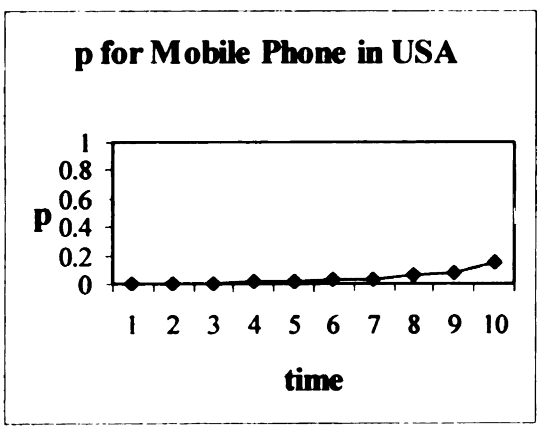
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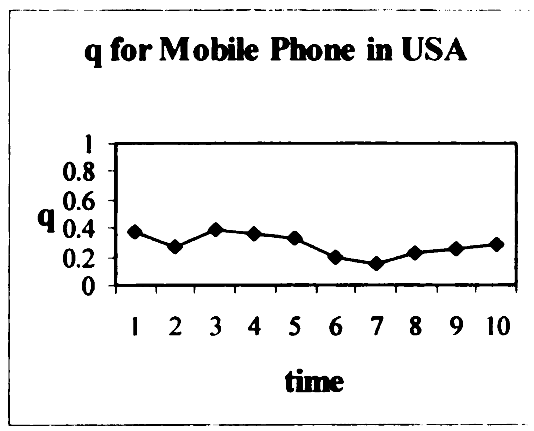
time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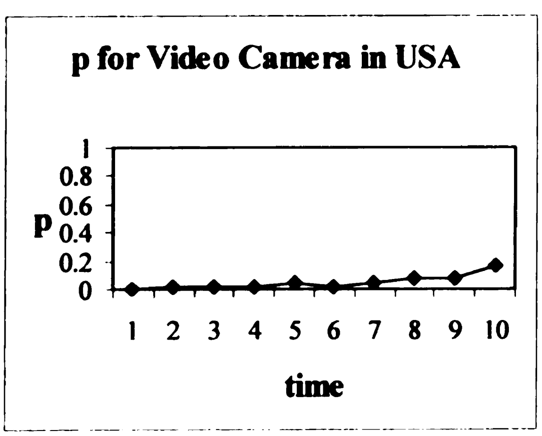
time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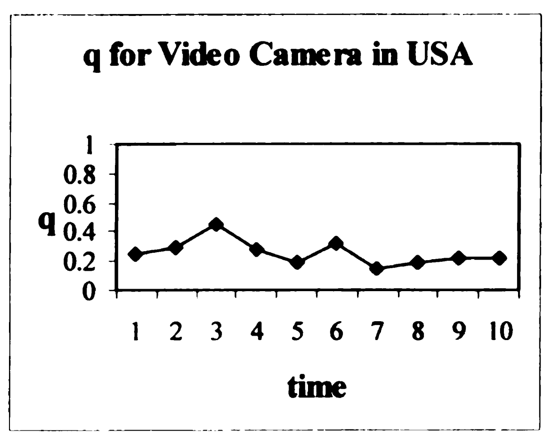
time


q for Video Camera in USA
q
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0
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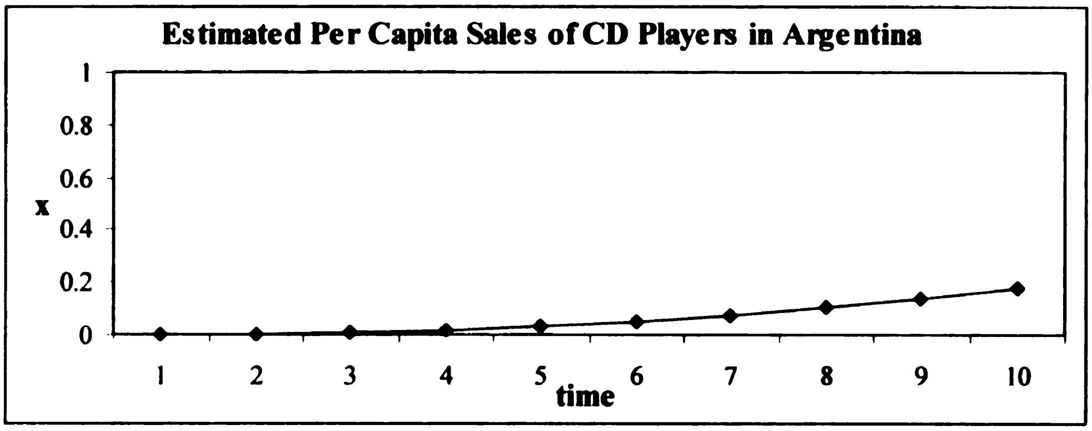
time

APPENDIX C

Diffusion Patterns Over Time for Each Country and Each Product


Estimated Per Capita Sales of CD Players in Argentina
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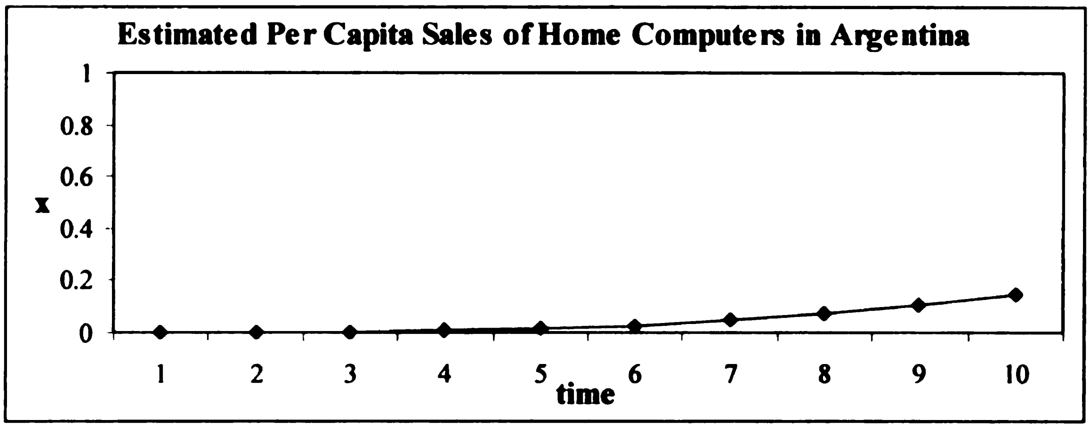
0.6
x
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time


Estimated Per Capita Sales of Home Computers in Argentina
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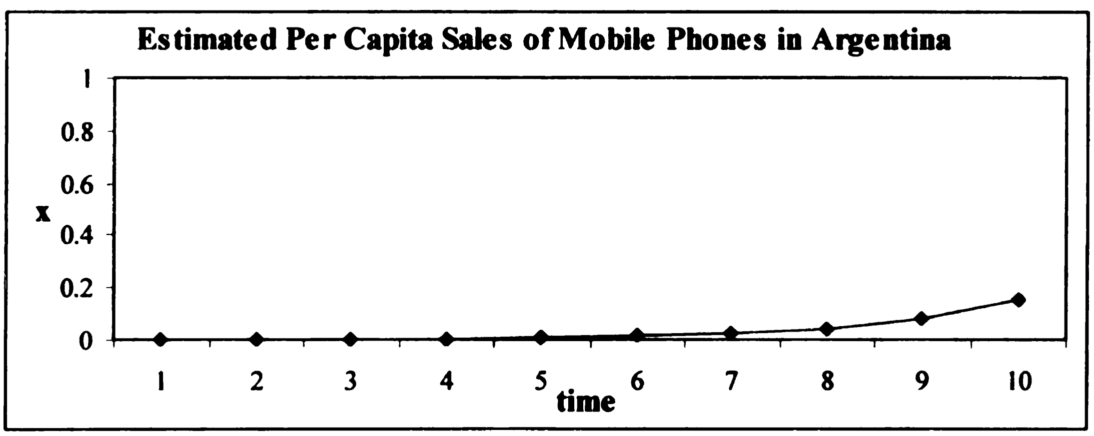
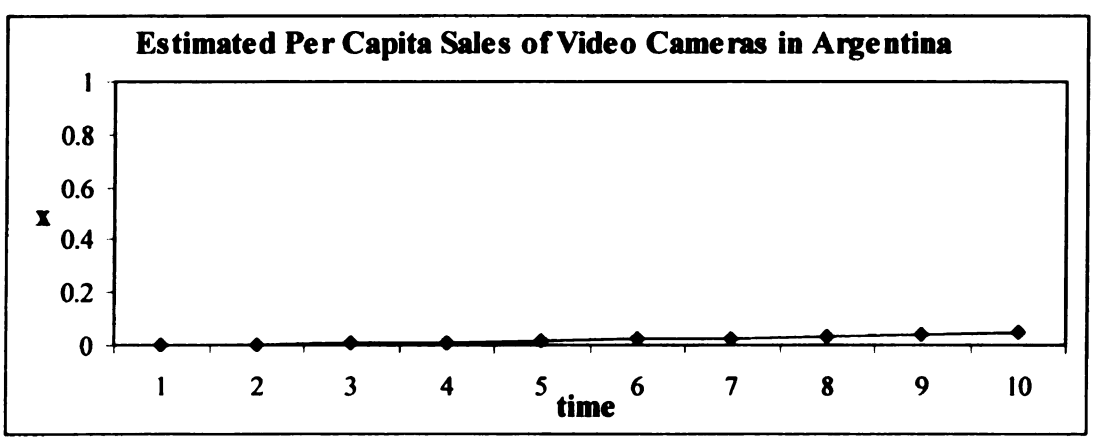
0.6
x
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time


Estimated Per Capita Sales of Mobile Phones in Argentina
1
0.8
0.6
x
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time


Estimated Per Capita Sales of Video Cameras in Argentina
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0.8
0.6
x
0.4
0.2
0
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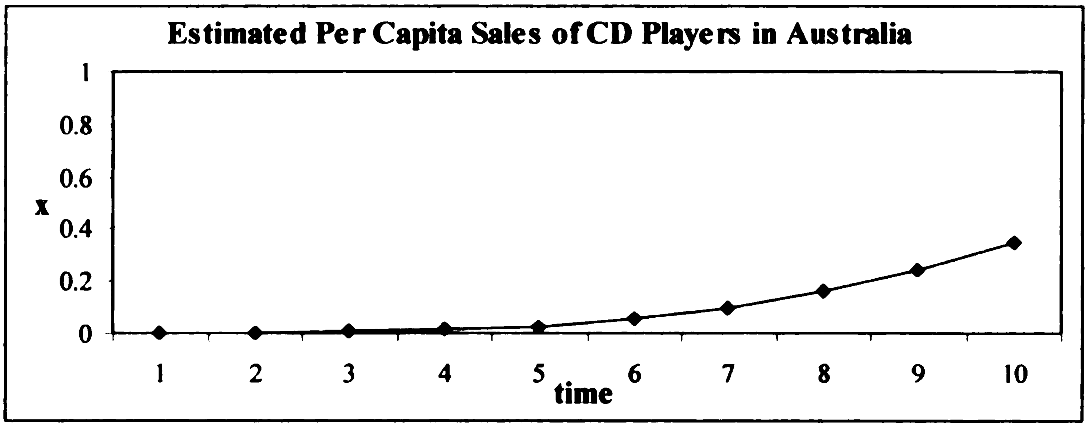
time


Estimated Per Capita Sales of CD Players in Australia
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0.8
0.6
x
0.4
0.2
0
1
2
3
4
5
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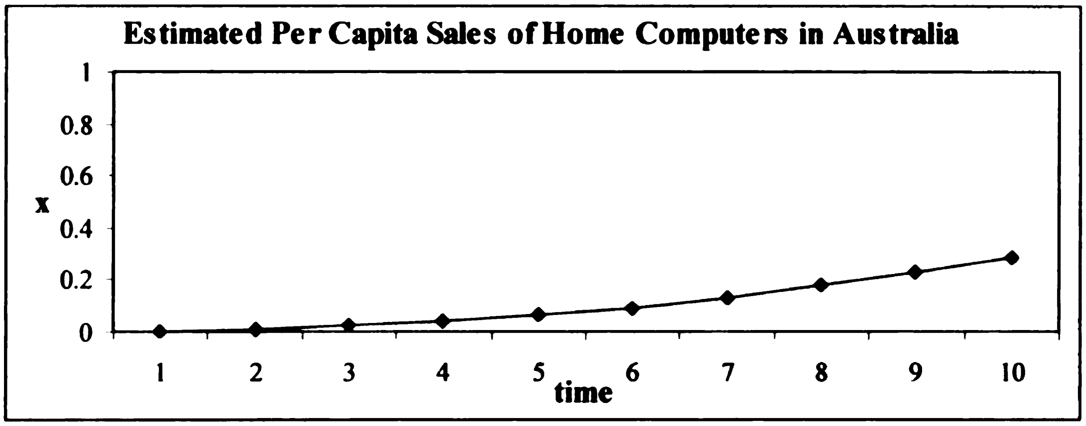
7
8
9
10
time


Estimated Per Capita Sales of Home Computers in Australia
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0.6
x
0.4
0.2
0
1
2
3
4
5
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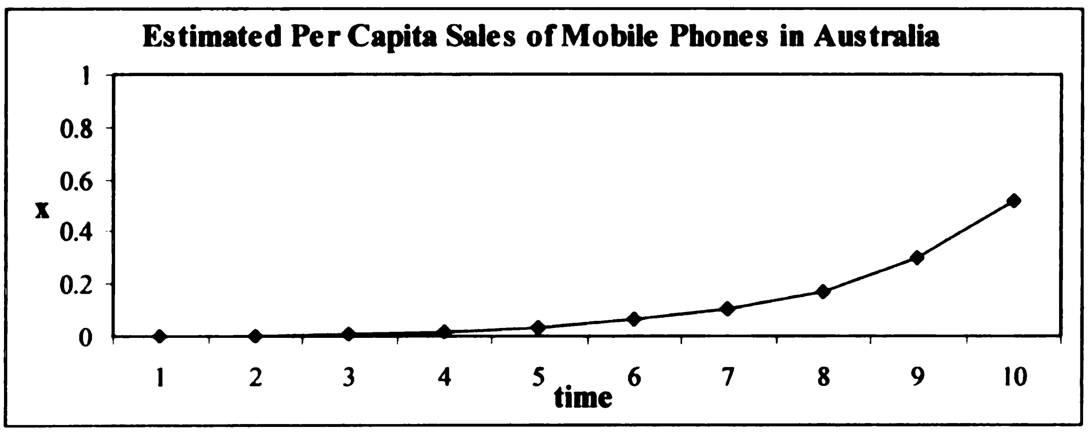
7
8
9
10
time


Estimated Per Capita Sales of Mobile Phones in Australia
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0.8
0.6
x
0.4
0.2
0
1
2
3
4
5
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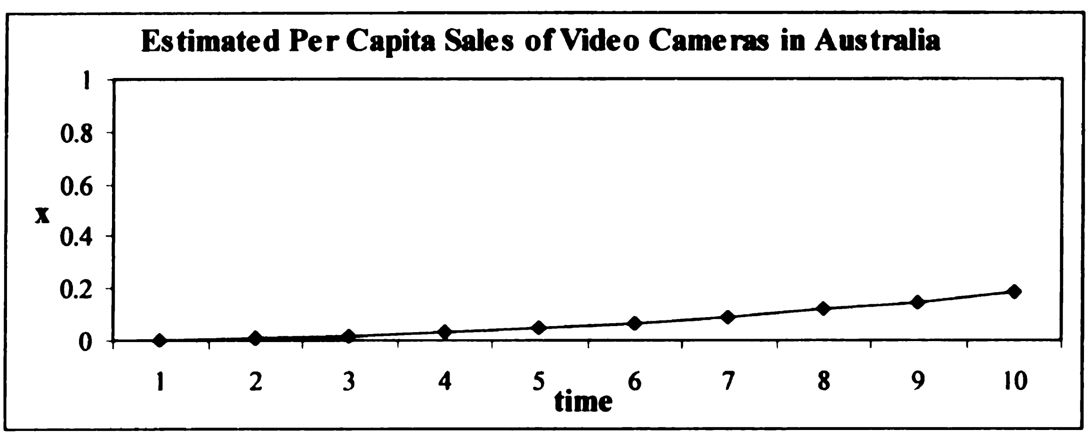
7
8
9
10
time


Estimated Per Capita Sales of Video Cameras in Australia
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0.8
0.6
x
0.4
0.2
0
1
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5
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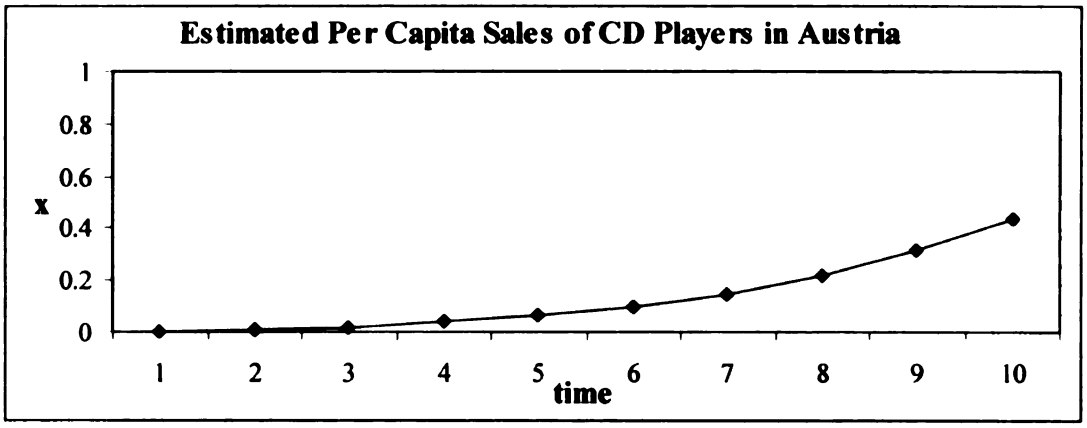
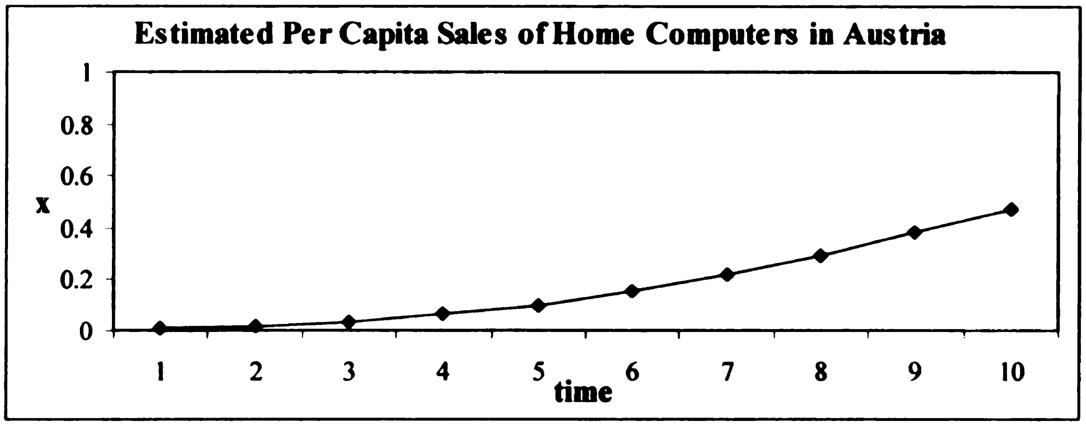
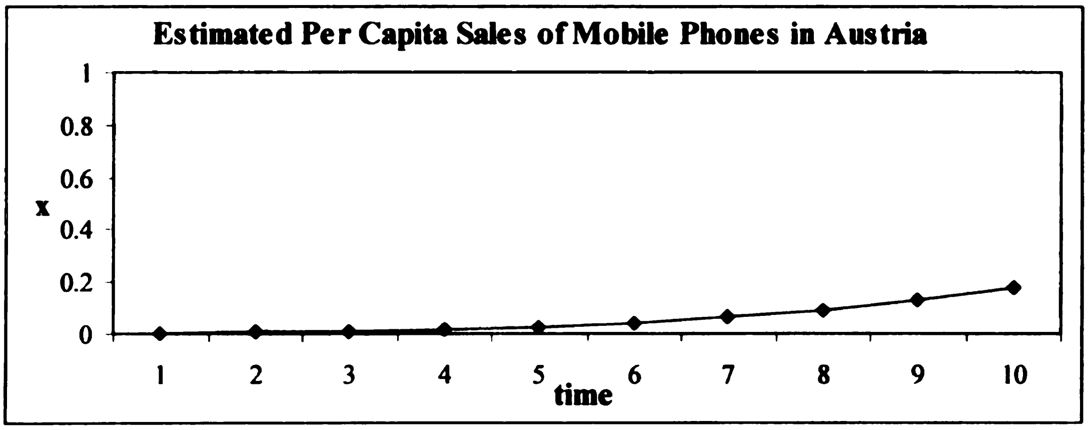
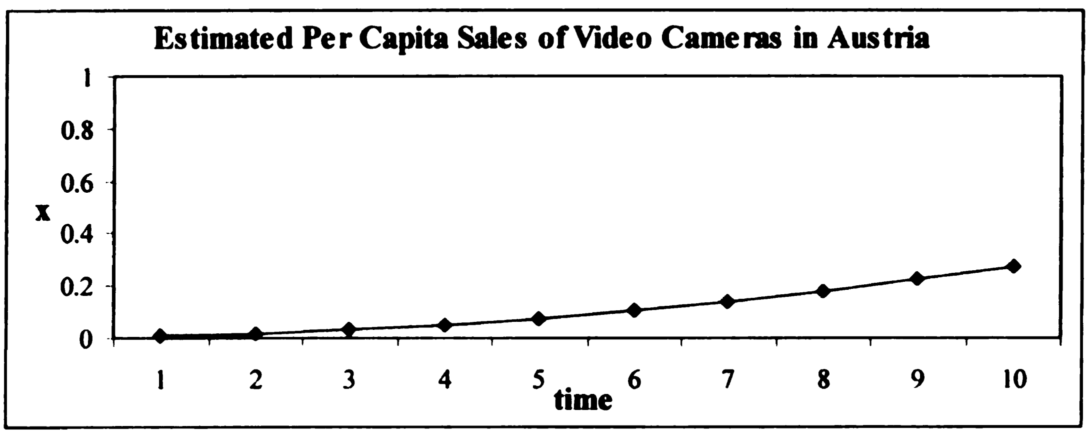
7
8
9
10
time


Estimated Per Capita Sales of CD Players in Austria
x
time


Estimated Per Capita Sales of Home Computers in Austria
x
time


Estimated Per Capita Sales of Mobile Phones in Austria
x
time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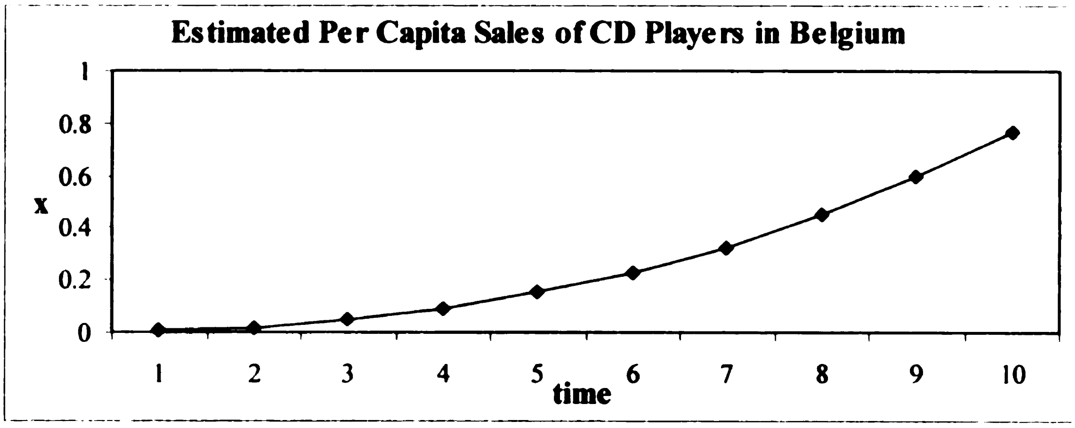
x
time


Estimated Per Capita Sales of CD Players in Belgium
x
0
0.2
0.4
0.6
0.8
1
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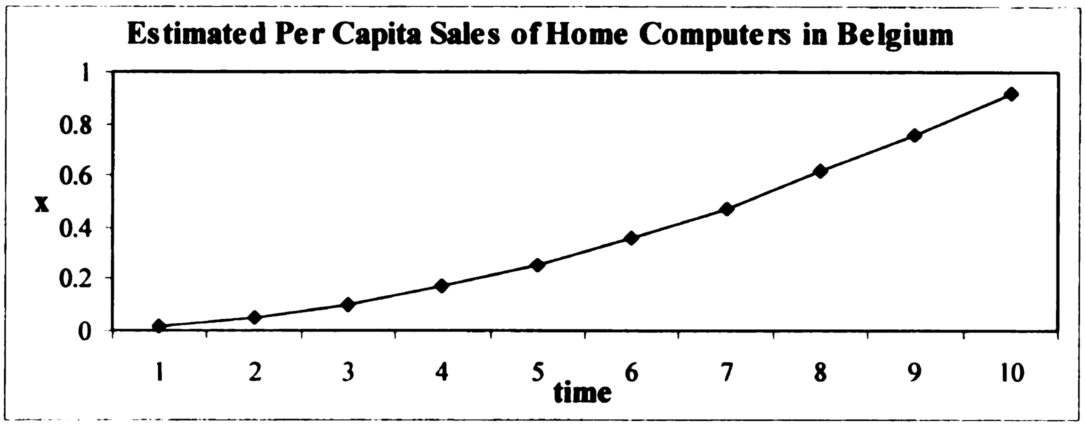
time


Estimated Per Capita Sales of Home Computers in Belgium
x
0
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0.6
0.8
1
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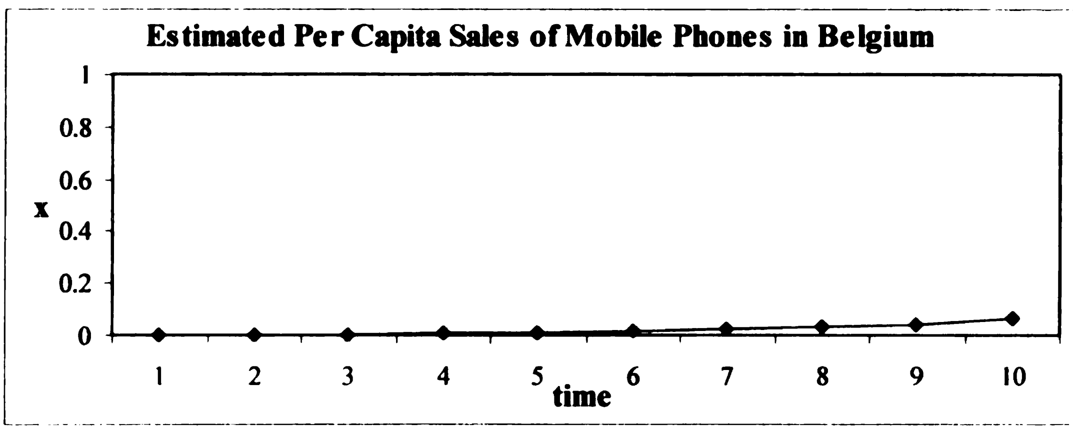
time


Estimated Per Capita Sales of Mobile Phones in Belgium
x
0
0.2
0.4
0.6
0.8
1
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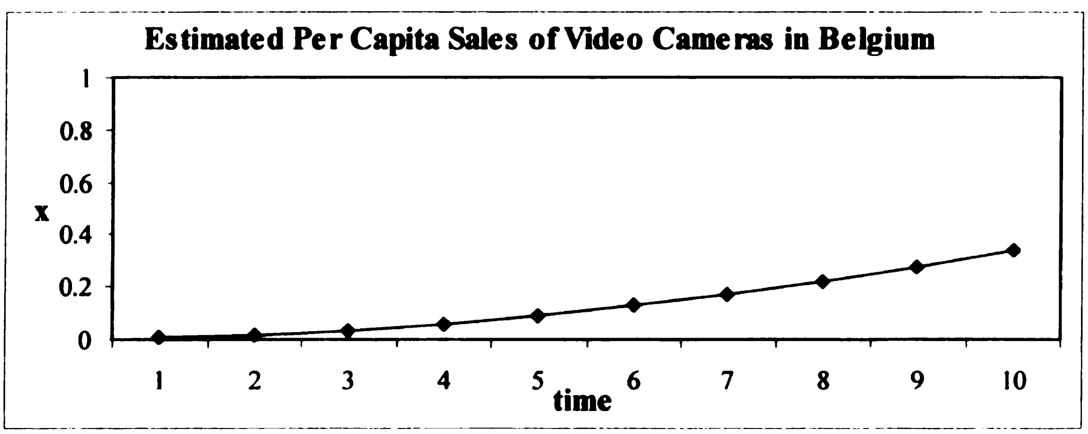
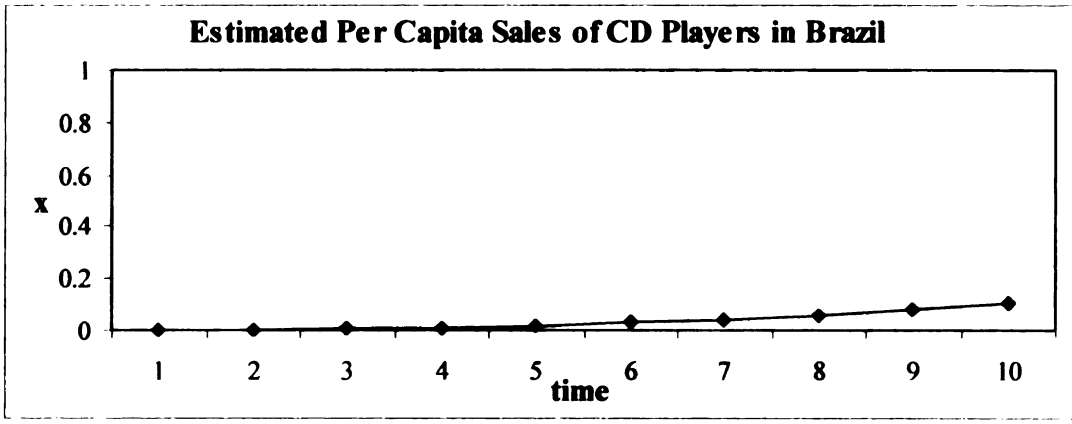
time


Estimated Per Capita Sales of Video Cameras in Belgium
x
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10
time


Estimated Per Capita Sales of CD Players in Brazil
1
0.8
0.6
x
0.4
0.2
0
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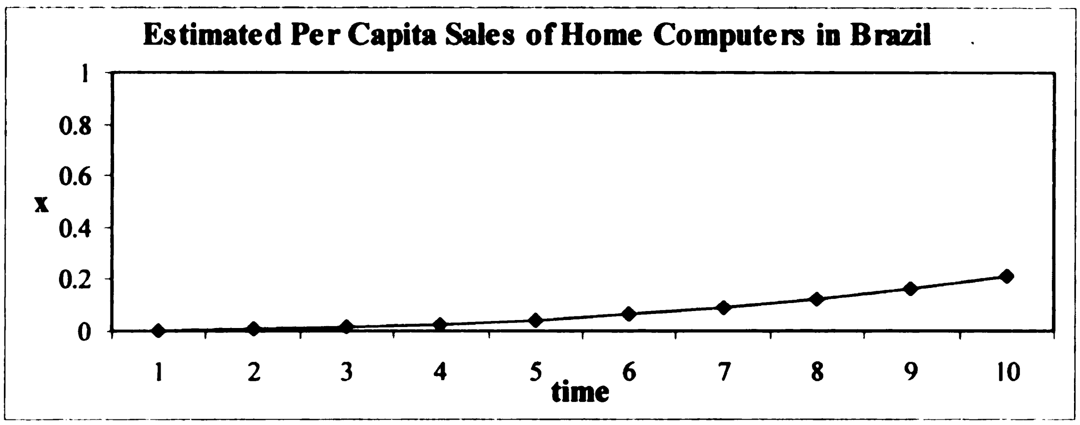
time


Estimated Per Capita Sales of Home Computers in Brazil
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0.8
0.6
x
0.4
0.2
0
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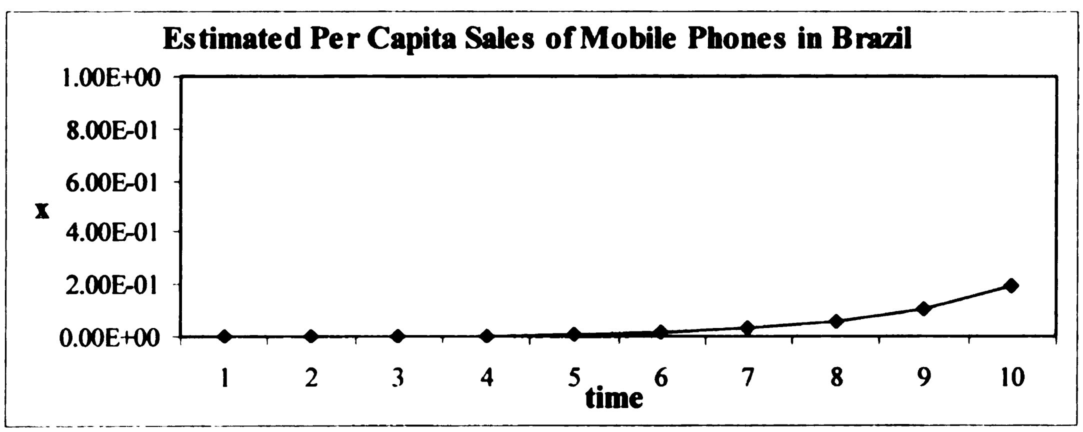
time


Estimated Per Capita Sales of Mobile Phones in Brazil
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8.00E-01
6.00E-01
x
4.00E-01
2.00E-01
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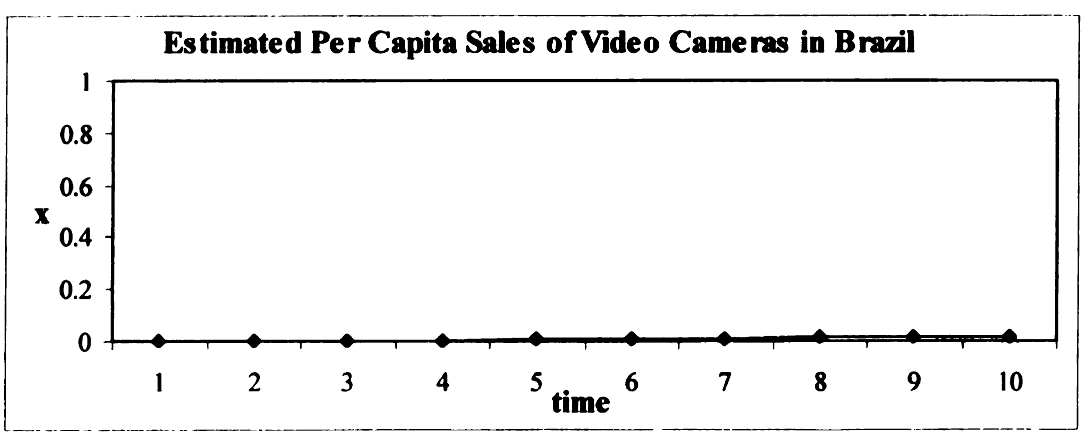
1 2 3 4 5 6 7 8 9 10
time


Estimated Per Capita Sales of Video Cameras in Brazil
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0.8
0.6
x
0.4
0.2
0
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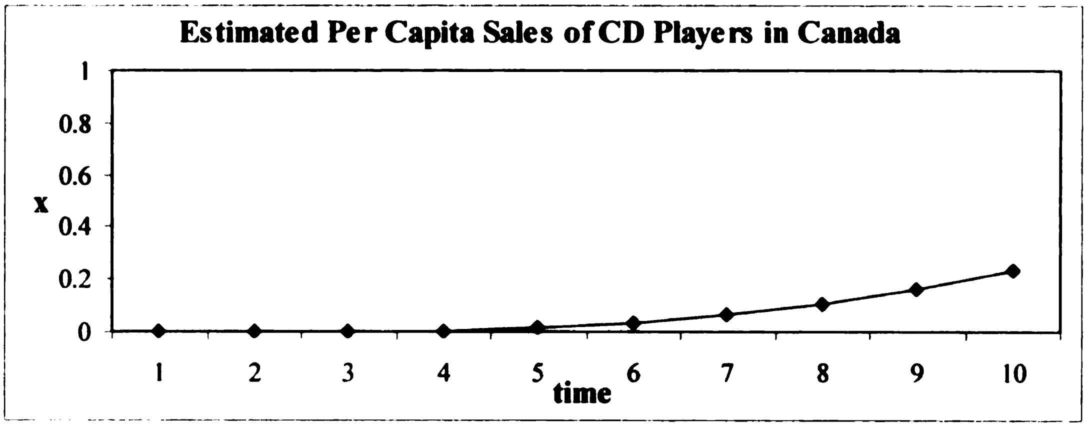
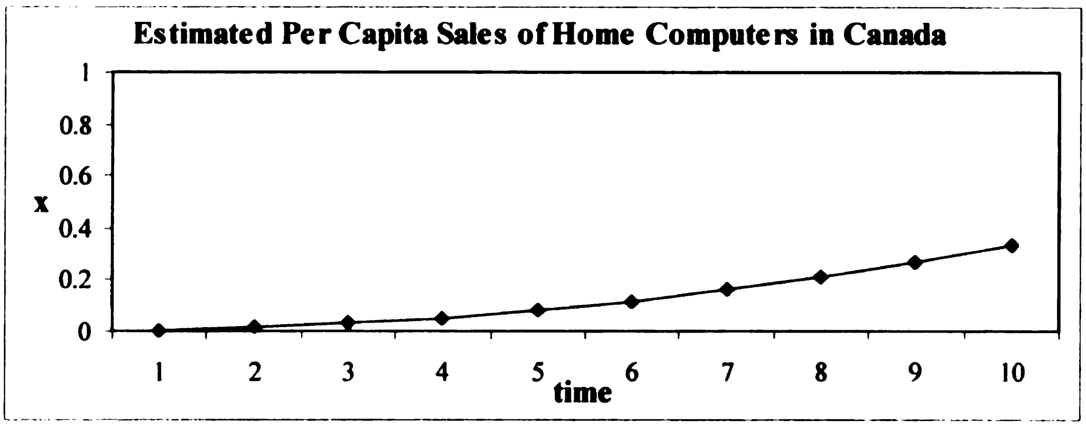
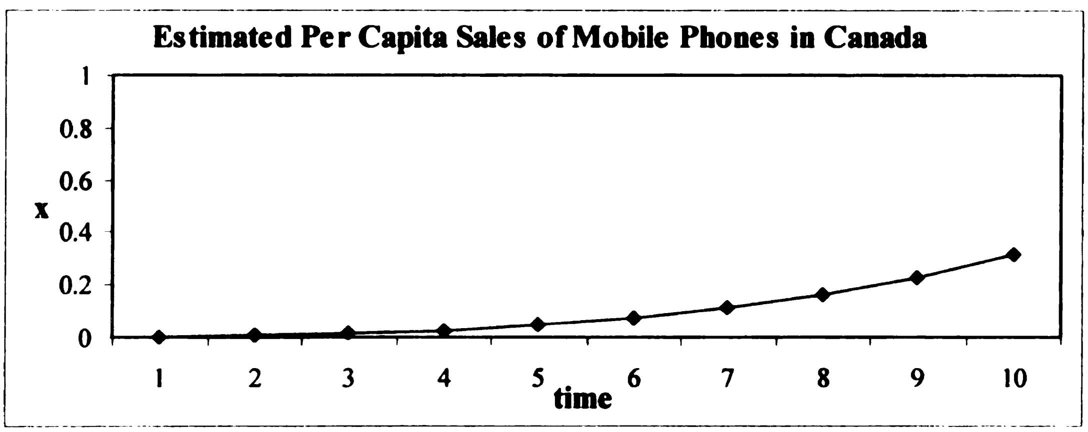
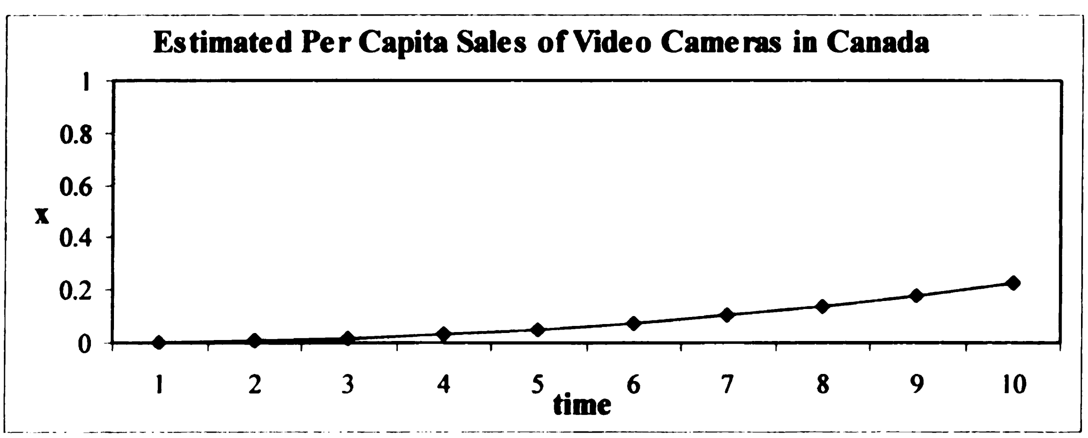
time


Estimated Per Capita Sales of CD Players in Canada
x
time


Estimated Per Capita Sales of Home Computers in Canada
x
time


Estimated Per Capita Sales of Mobile Phones in Canada
x
time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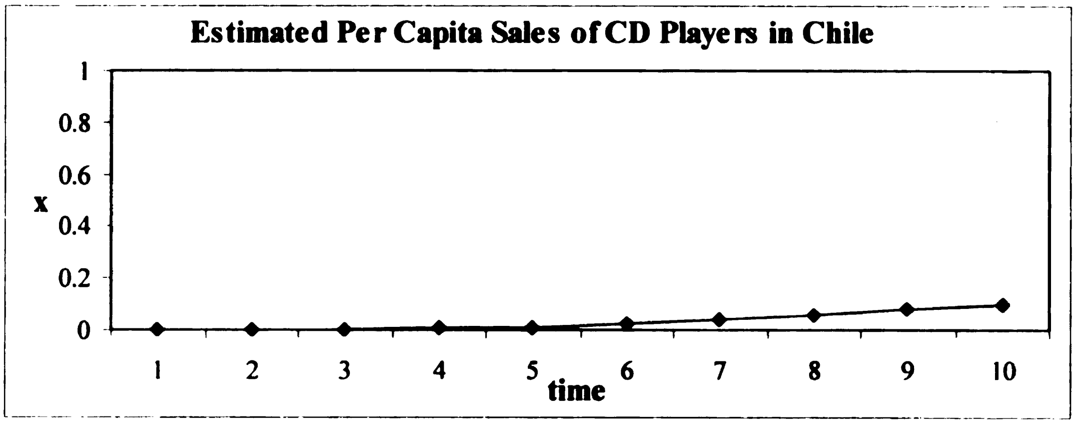
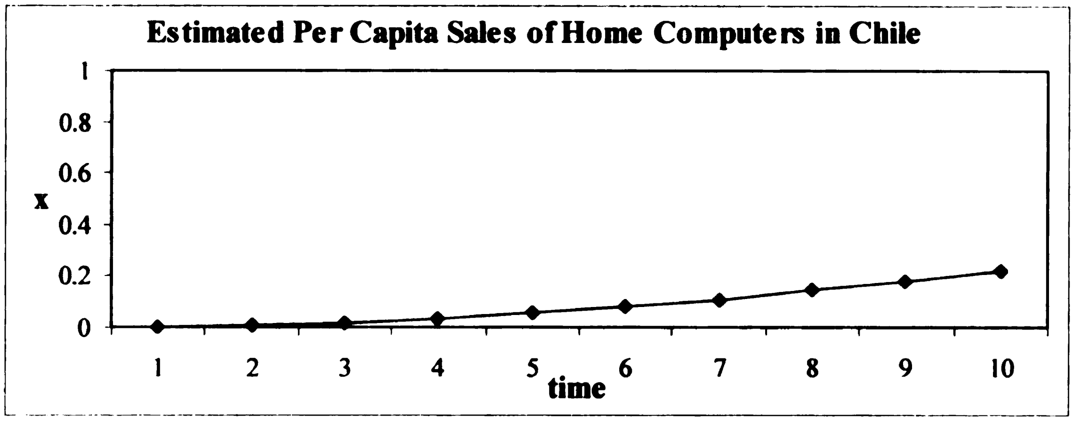
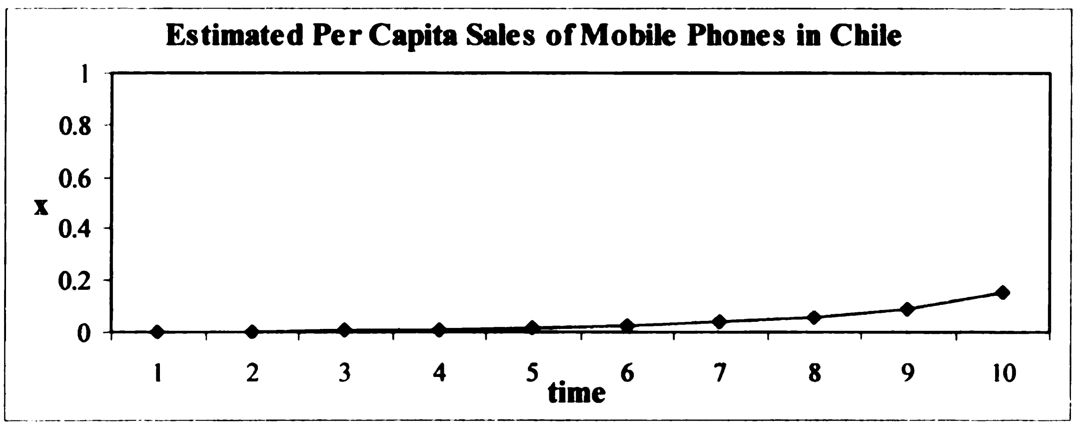
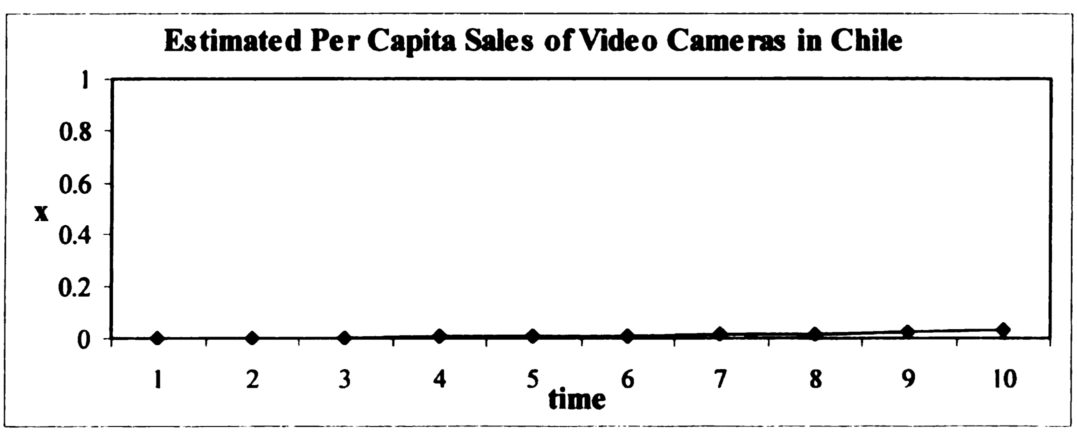
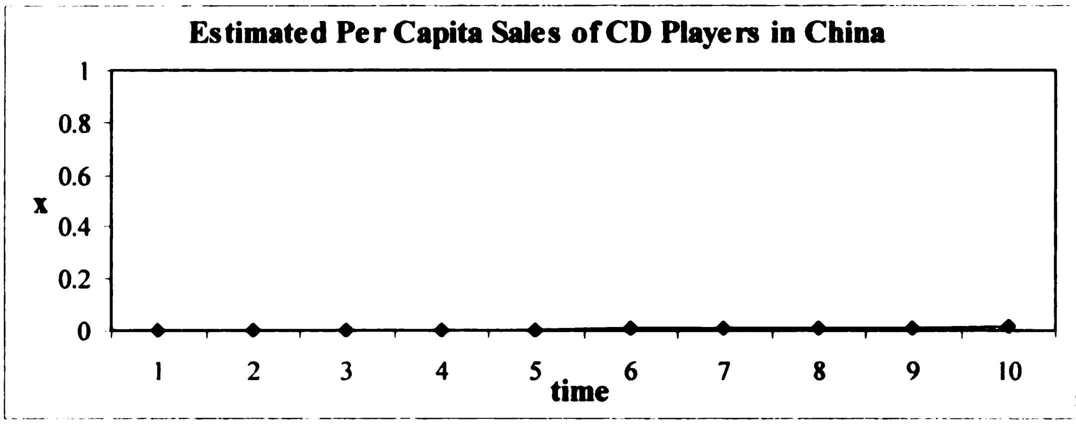
x
time

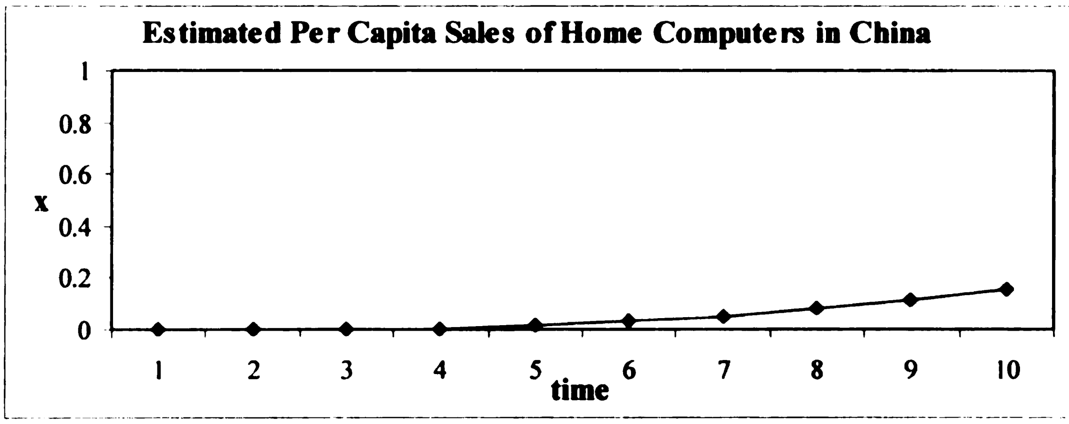

Estimated Per Capita Sales of CD Players in Chile
x
time

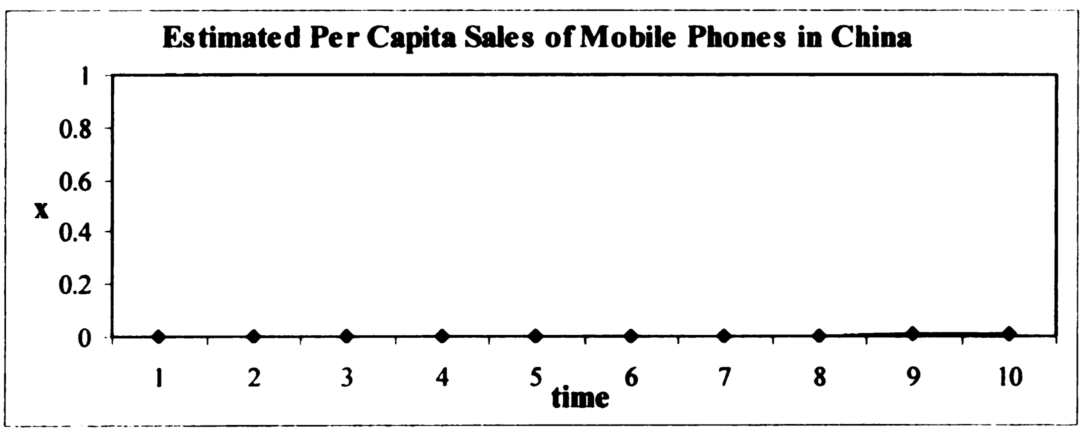

Estimated Per Capita Sales of Home Computers in Chile
x
time

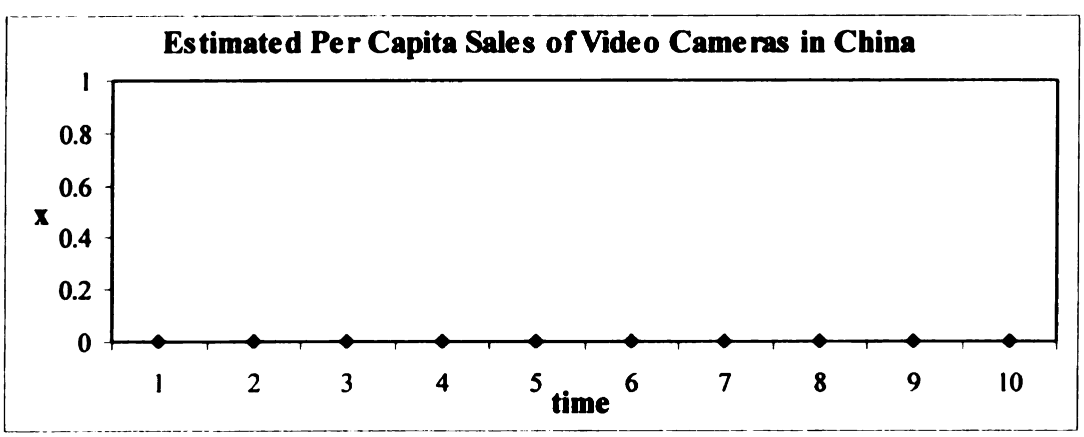

Estimated Per Capita Sales of Mobile Phones in Chile
x
time

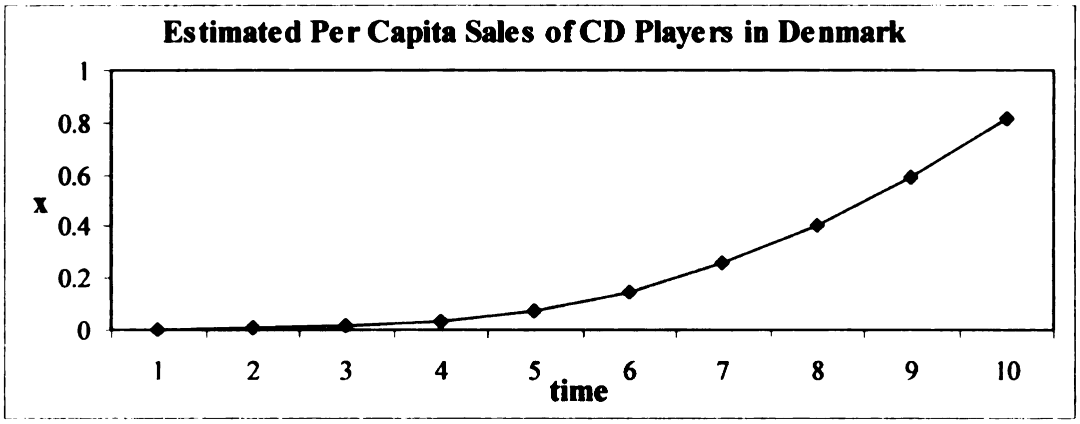

Estimated Per Capita Sales of Video Cameras in Chile
x
time


Estimated Per Capita Sales of CD Players in China
x
time


Estimated Per Capita Sales of Home Computers in China
x
time


Estimated Per Capita Sales of Mobile Phones in China
x
time


Estimated Per Capita Sales of Video Cameras in China
x
time


Estimated Per Capita Sales of CD Players in Denmark
x
time
0
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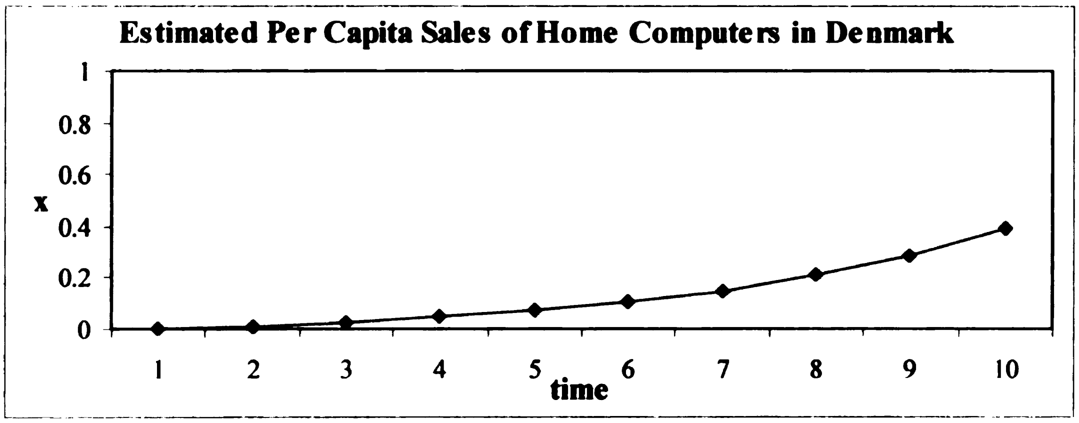
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10


Estimated Per Capita Sales of Home Computers in Denmark
x
time
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0.6
0.8
1
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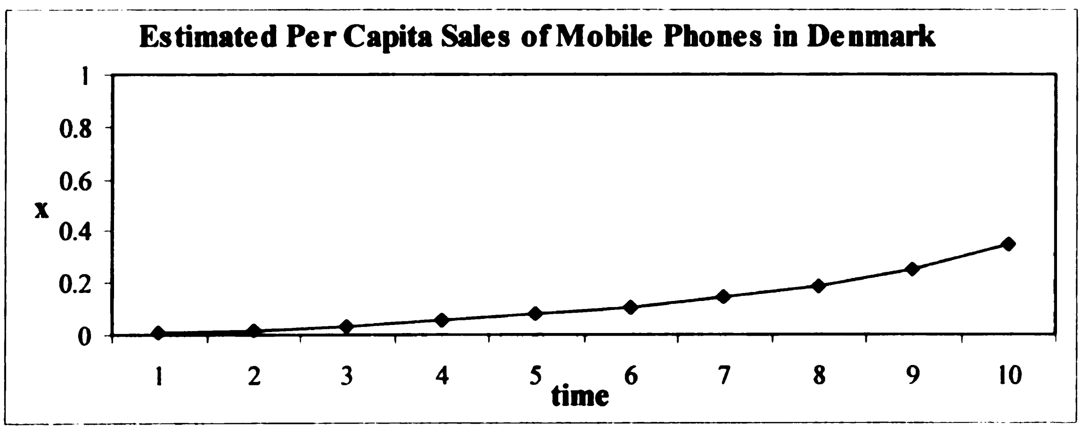
Estimated Per Capita Sales of Mobile Phones in Denmark
x
time
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0.6
0.8
1
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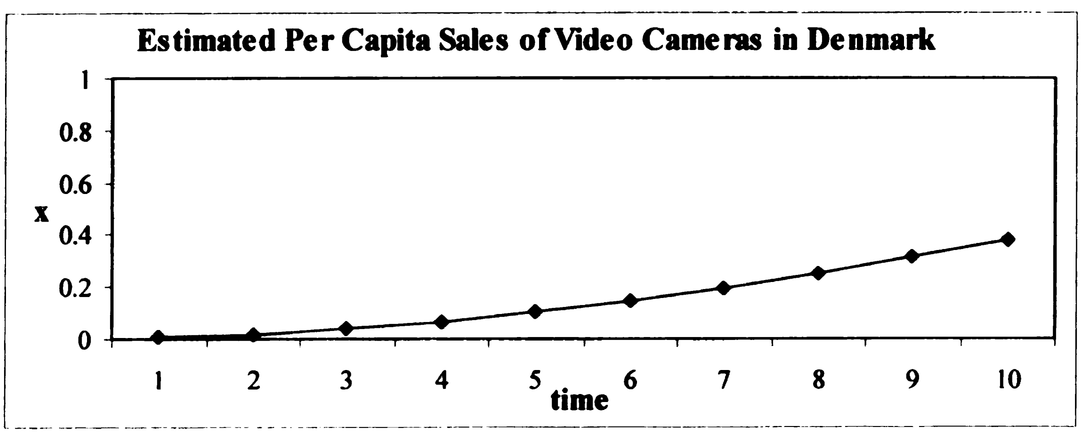
Estimated Per Capita Sales of Video Cameras in Denmark
x
time
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0.6
0.8
1
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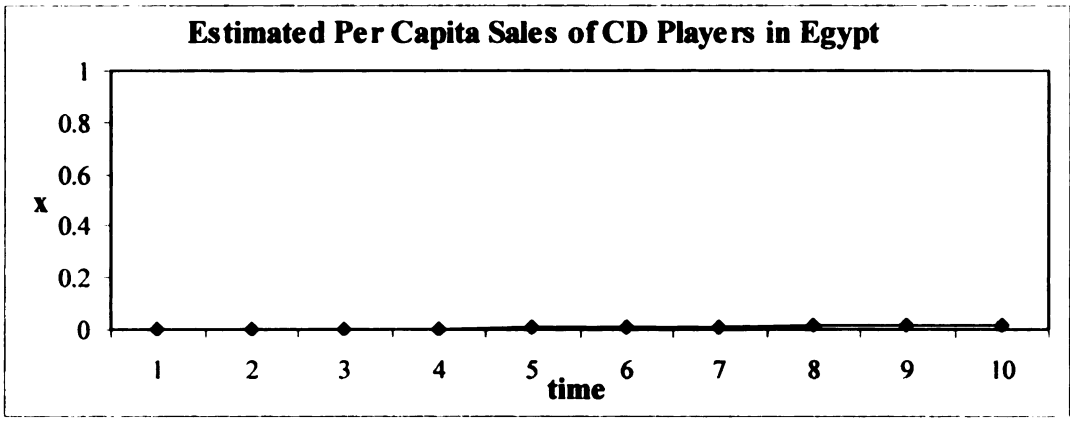
Estimated Per Capita Sales of CD Players in Egypt
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0.6
0.8
1
1
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4
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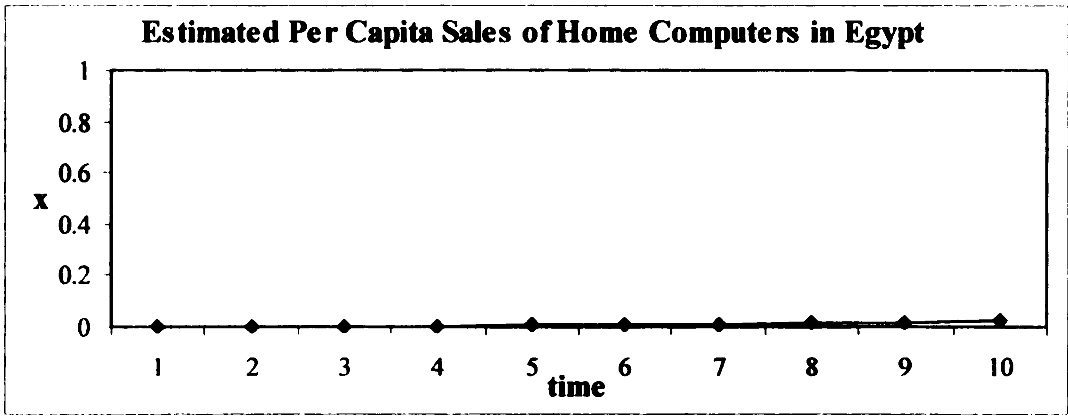
8
9
10
time


Estimated Per Capita Sales of Home Computers in Egypt
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0.6
0.8
1
1
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8
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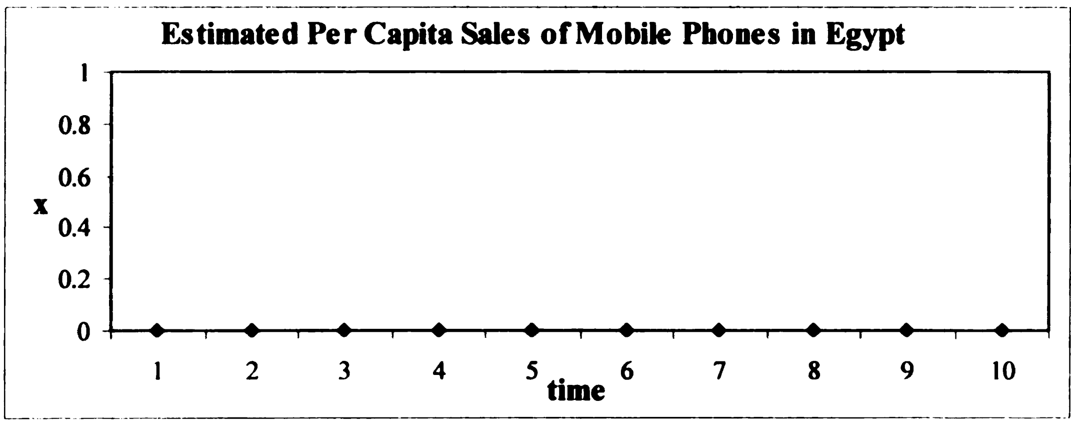
10
time


Estimated Per Capita Sales of Mobile Phones in Egypt
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0.6
0.8
1
1
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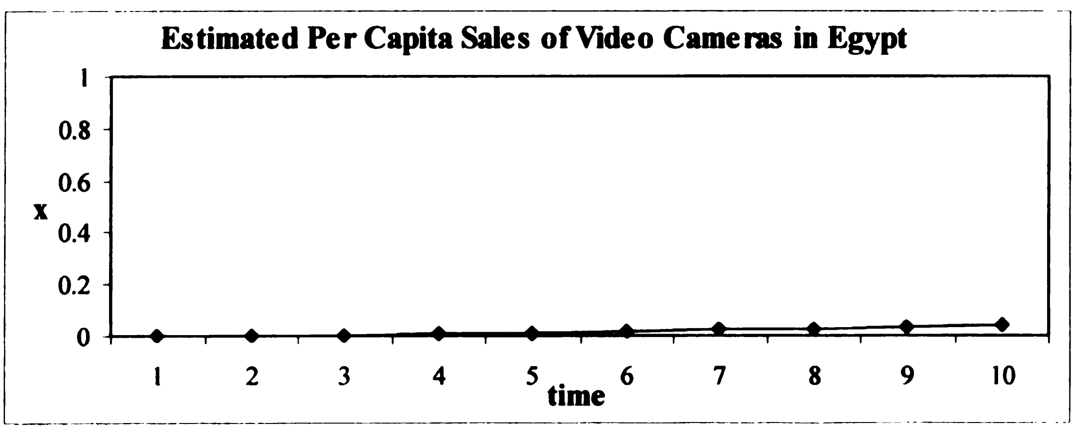
10
time


Estimated Per Capita Sales of Video Cameras in Egypt
x
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0.8
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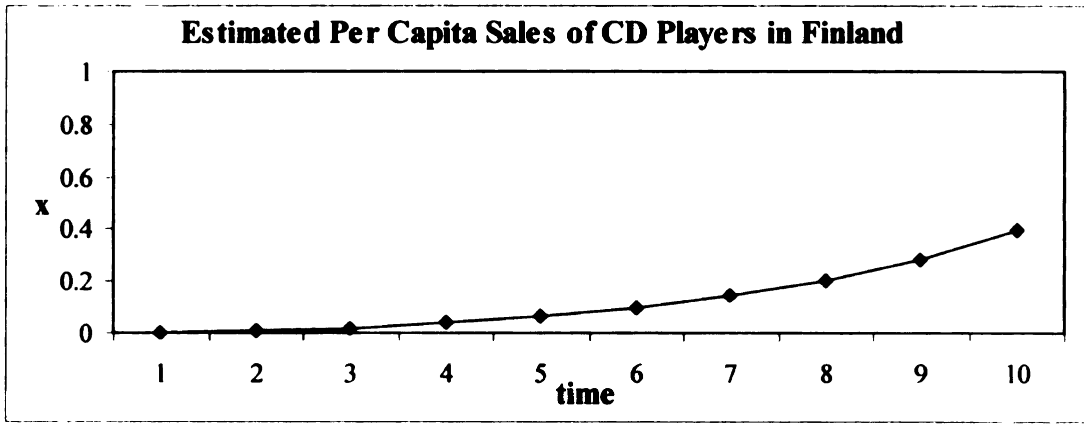
10
time


Estimated Per Capita Sales of CD Players in Finland
x
time
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0.6
0.8
1
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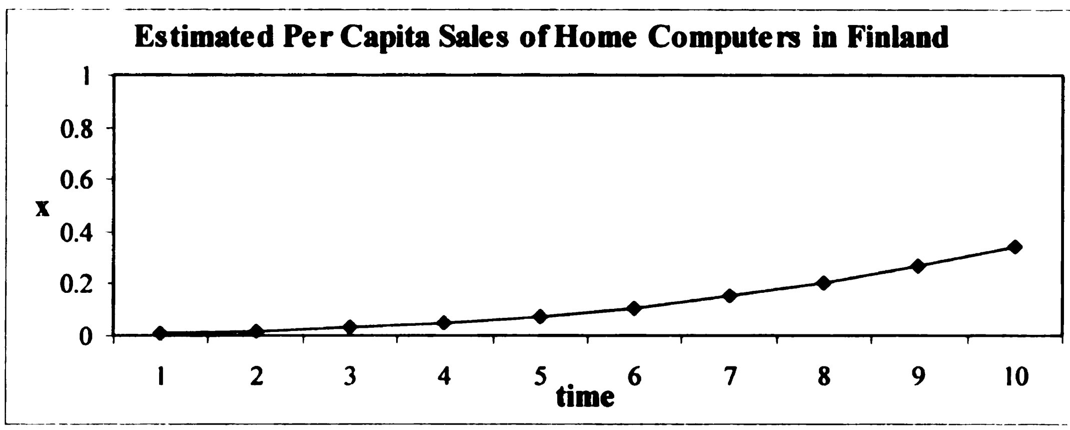
Estimated Per Capita Sales of Home Computers in Finland
x
time
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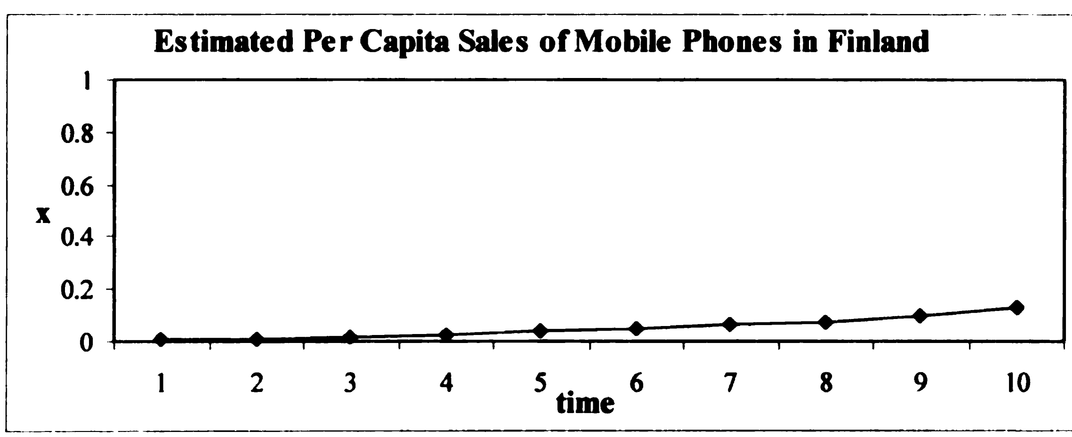
Estimated Per Capita Sales of Mobile Phones in Finland
x
time
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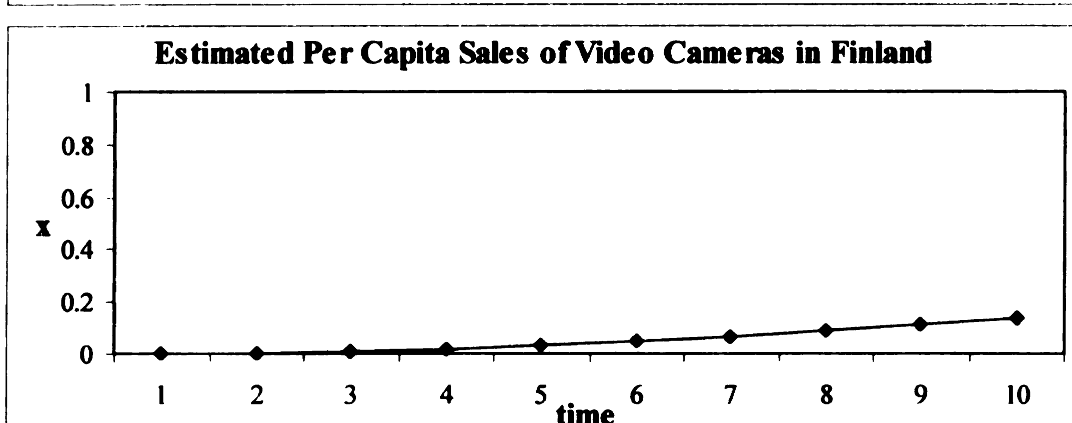
Estimated Per Capita Sales of Video Cameras in Finland
x
time
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0.6
0.8
1
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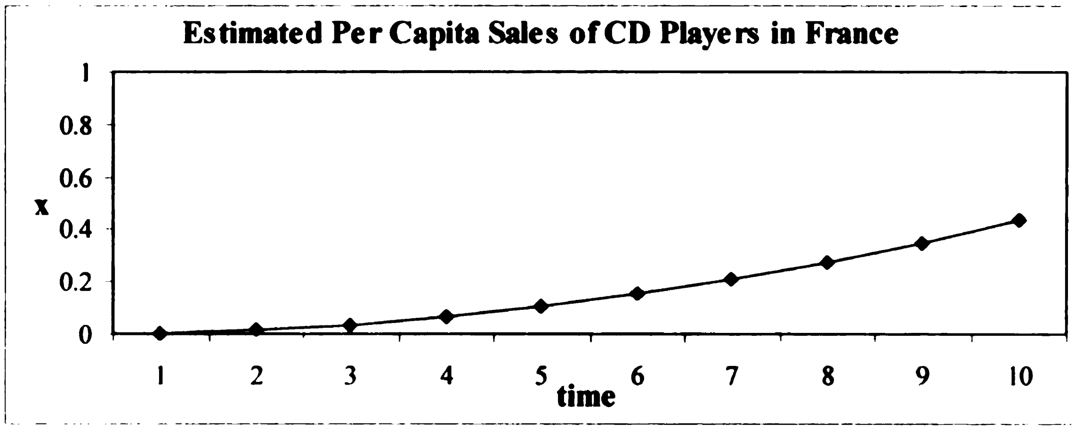
Estimated Per Capita Sales of CD Players in France
x
time
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0.6
0.8
1
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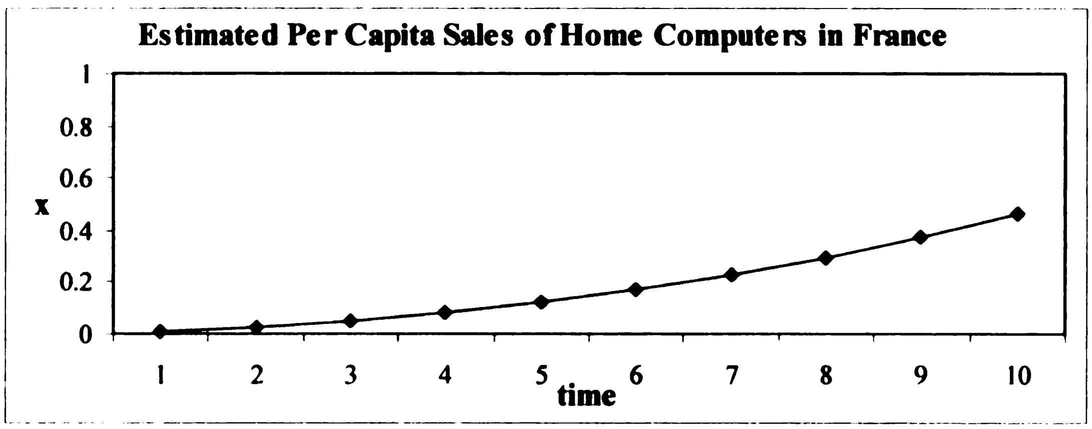
Estimated Per Capita Sales of Home Computers in France
x
time
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0.8
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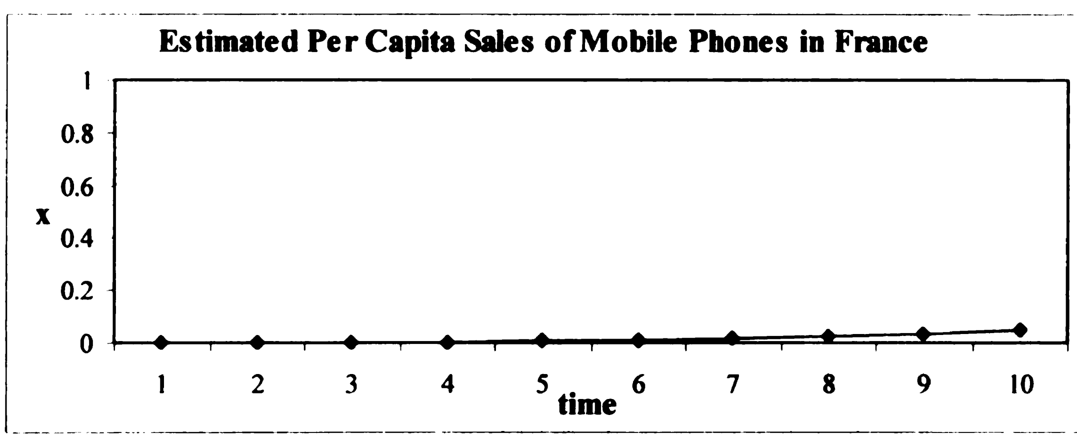
Estimated Per Capita Sales of Mobile Phones in France
x
time
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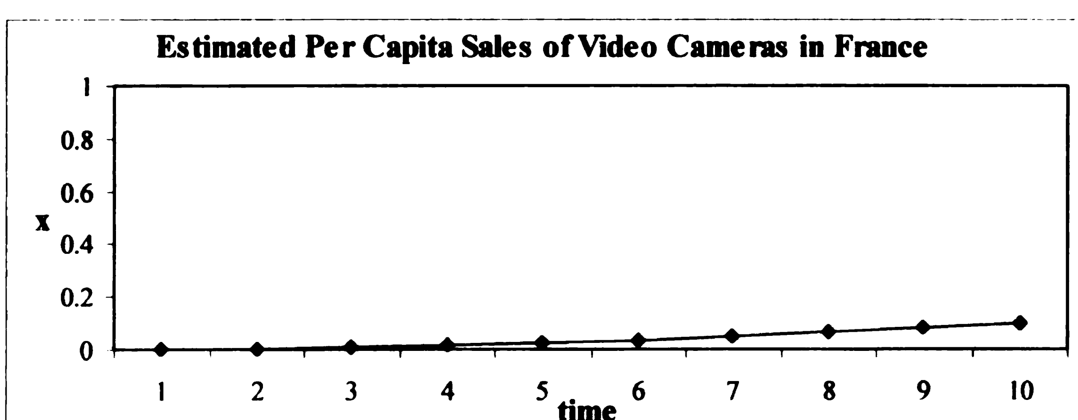
Estimated Per Capita Sales of Video Cameras in France
x
time
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0.6
0.8
1
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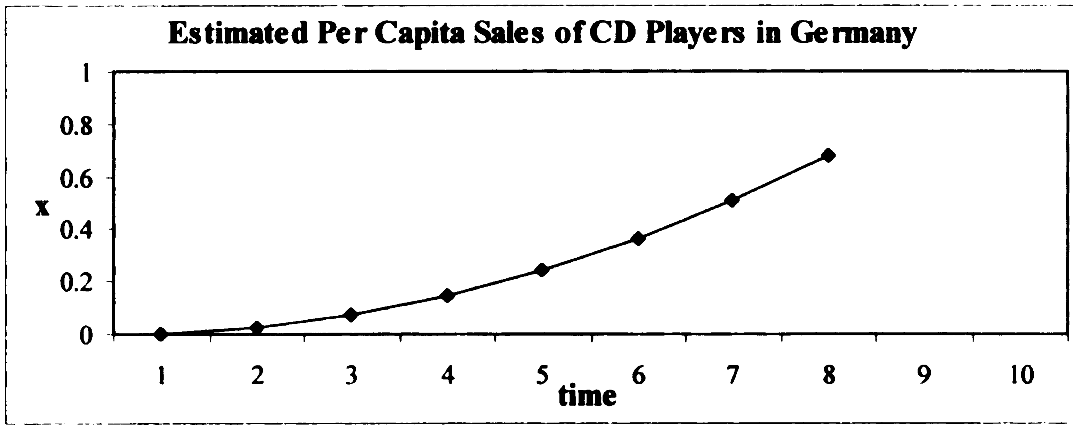
Estimated Per Capita Sales of CD Players in Germany
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0.8
0.6
x
0.4
0.2
0
1
2
3
4
5
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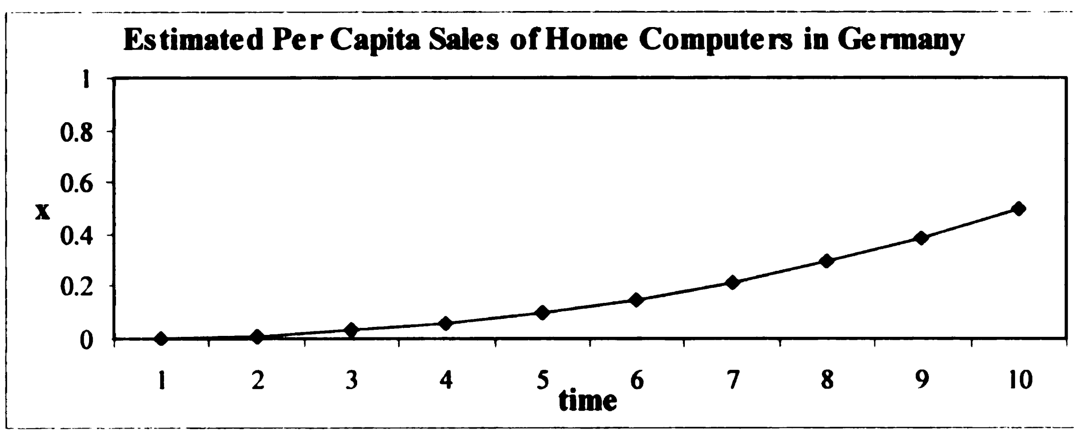
7
8
9
10
time


Estimated Per Capita Sales of Home Computers in Germany
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0.6
x
0.4
0.2
0
1
2
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4
5
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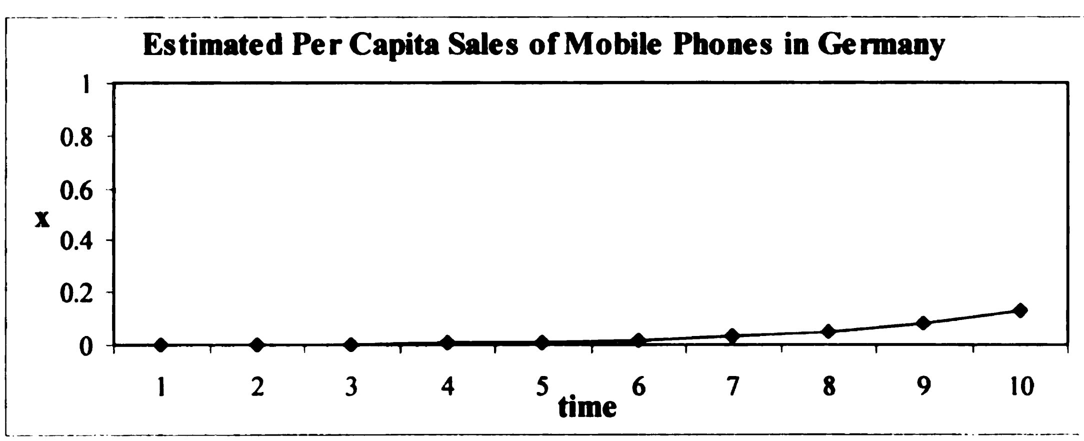
7
8
9
10
time


Estimated Per Capita Sales of Mobile Phones in Germany
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x
0.4
0.2
0
1
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5
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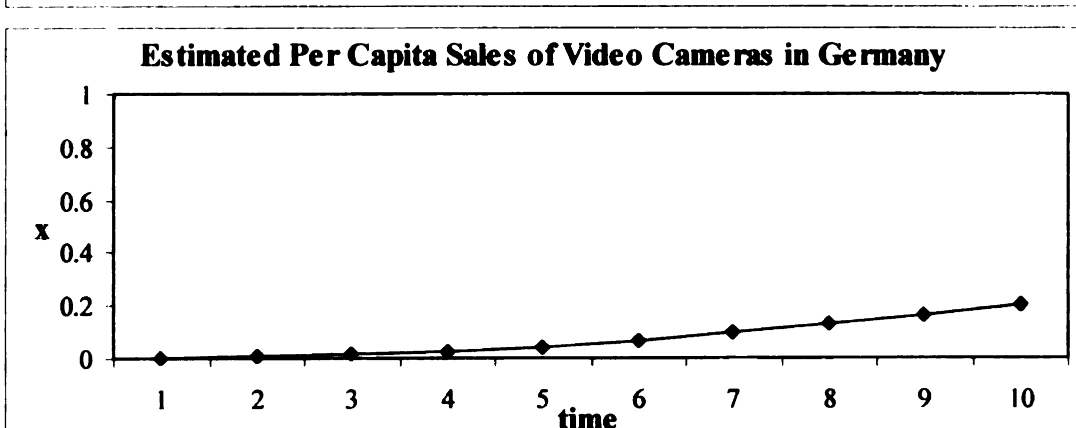
7
8
9
10
time


Estimated Per Capita Sales of Video Cameras in Germany
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x
0.4
0.2
0
1
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4
5
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8
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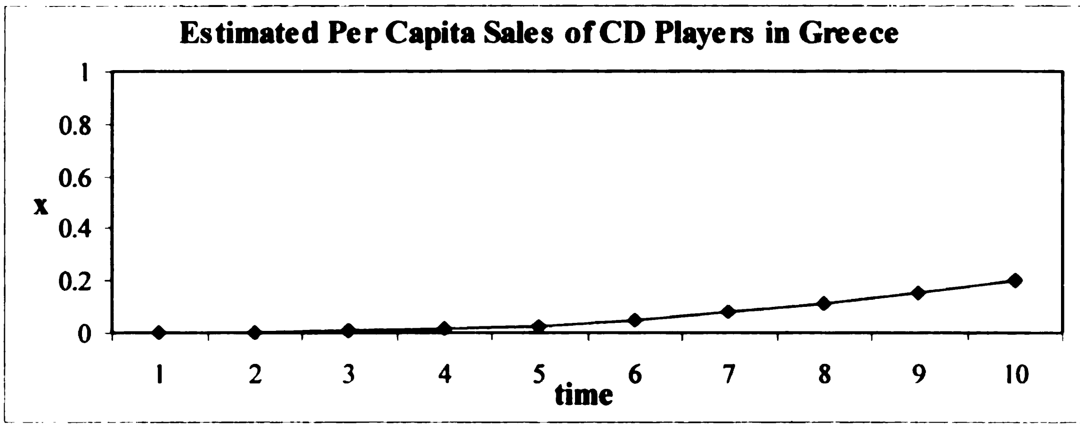
10
time


Estimated Per Capita Sales of CD Players in Greece
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0.6
x
0.4
0.2
0
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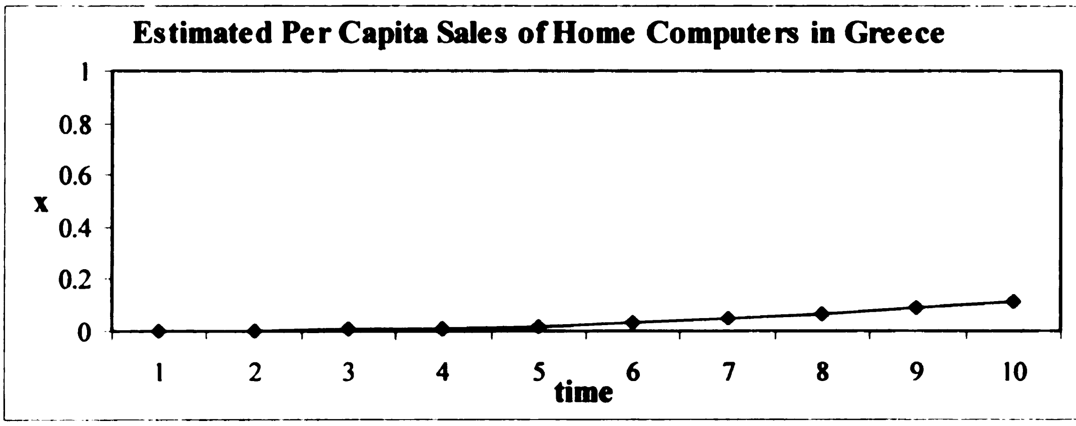
8
9
10
time


Estimated Per Capita Sales of Home Computers in Greece
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0.6
x
0.4
0.2
0
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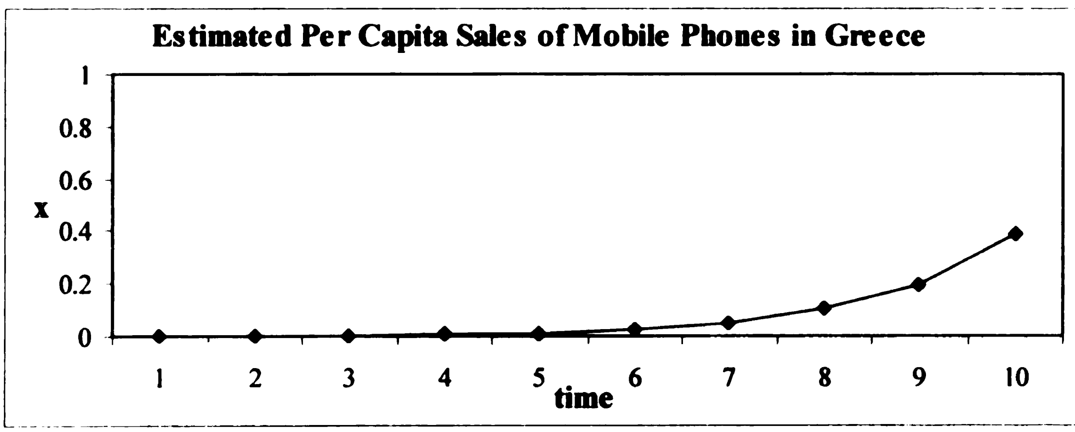
10
time


Estimated Per Capita Sales of Mobile Phones in Greece
1
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0.6
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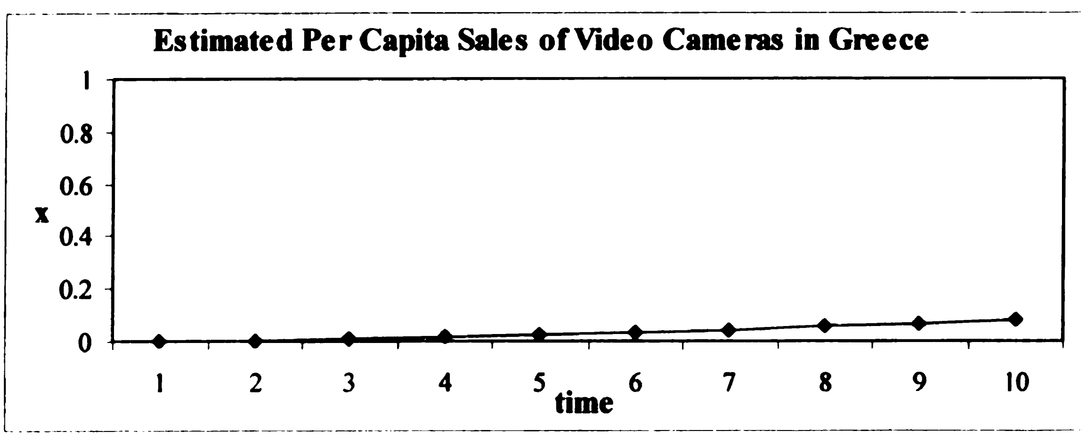
time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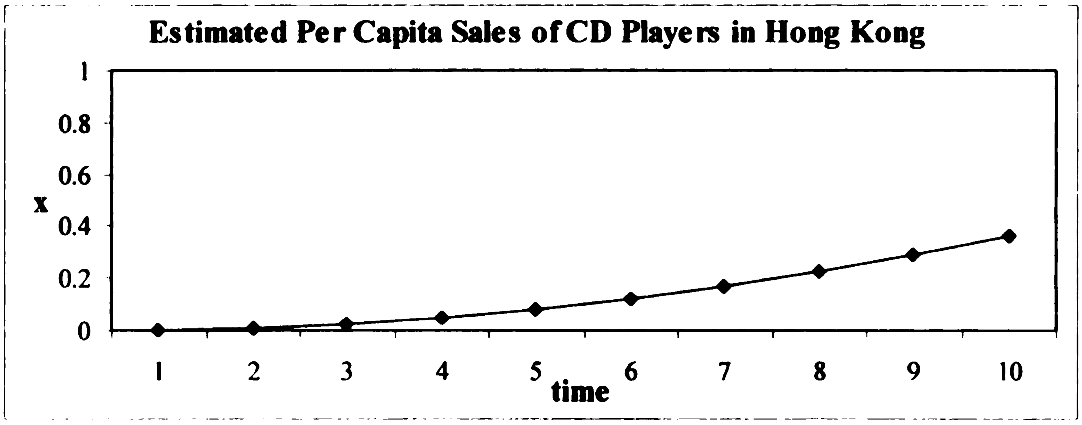
time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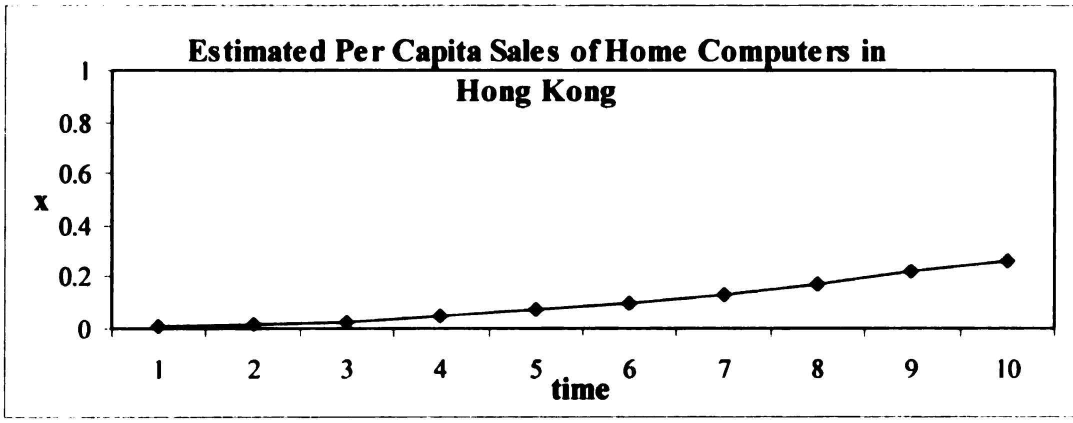
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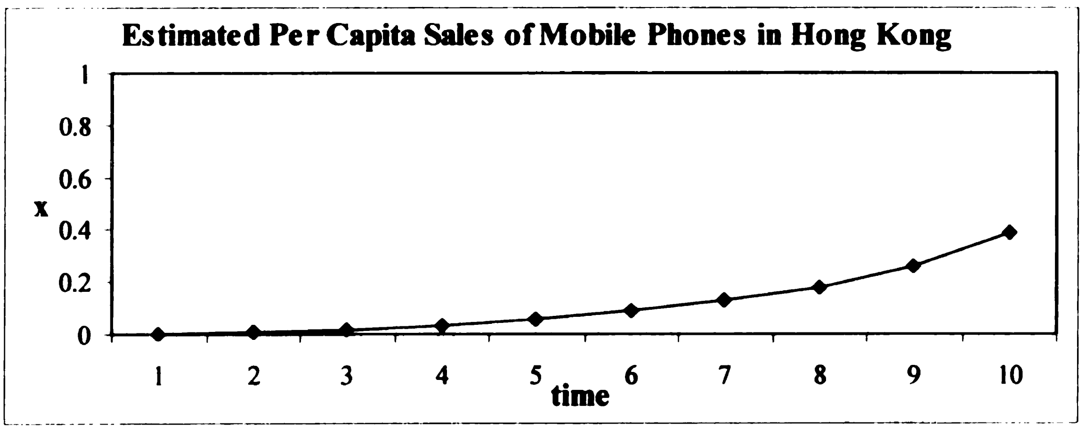
Estimated Per Capita Sales of Mobile Phones in Hong Kong
x
time
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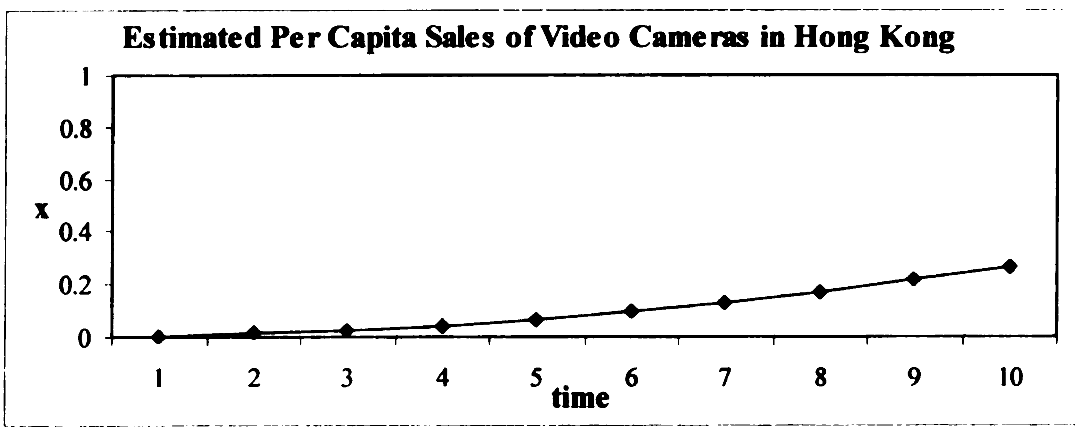
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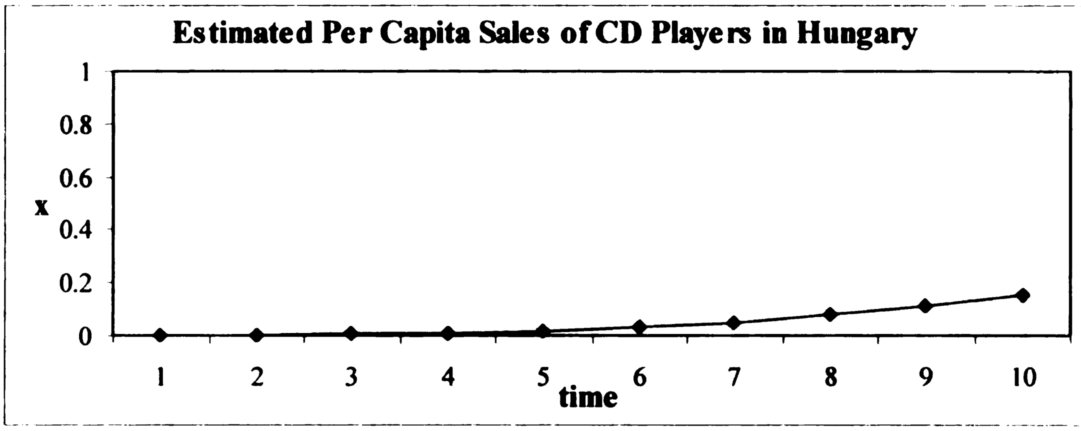
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time
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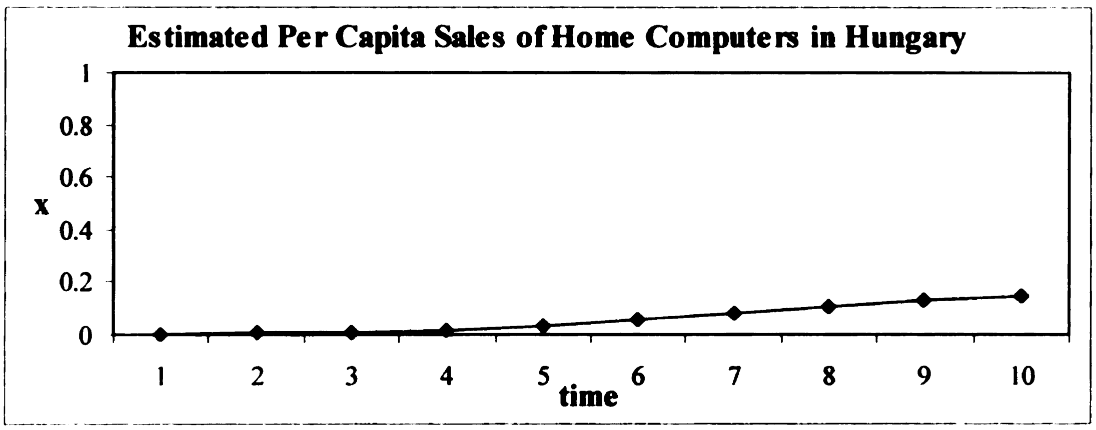
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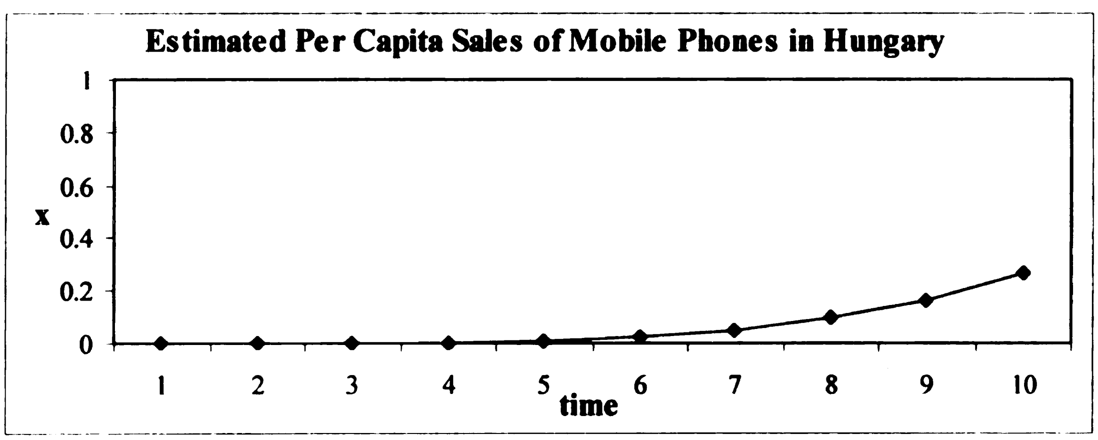
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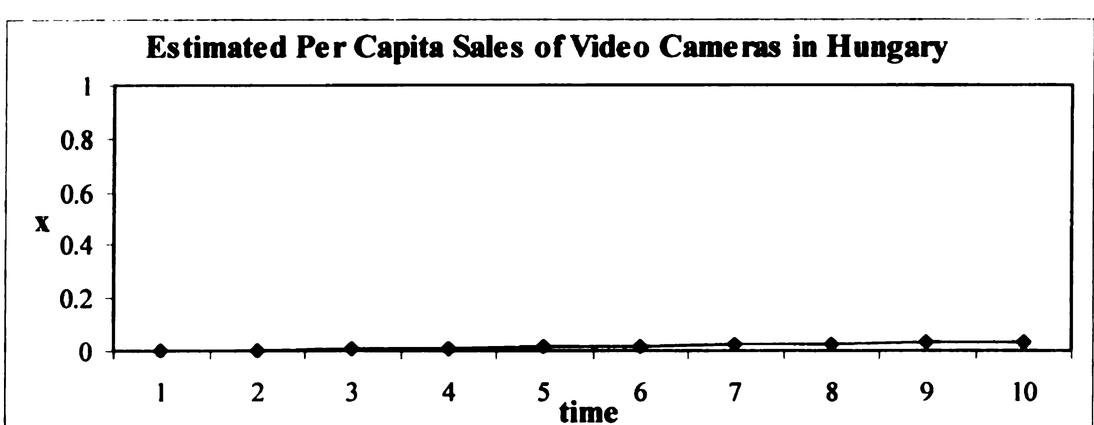
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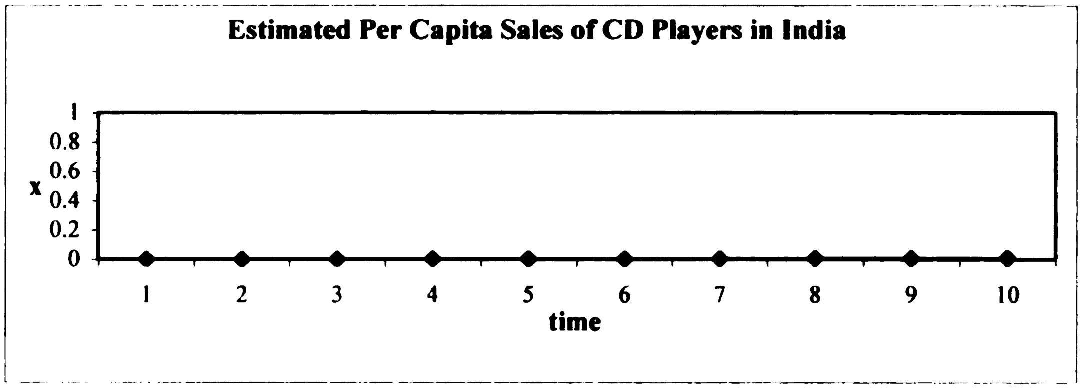
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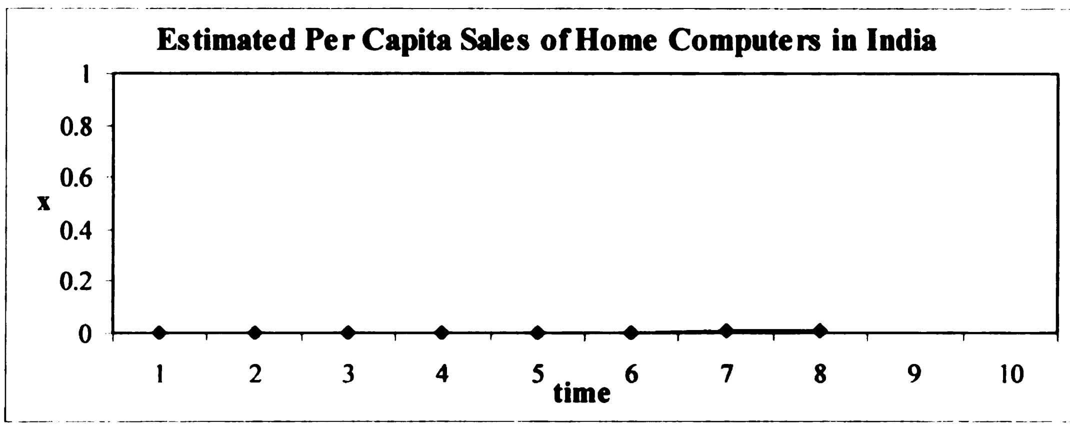
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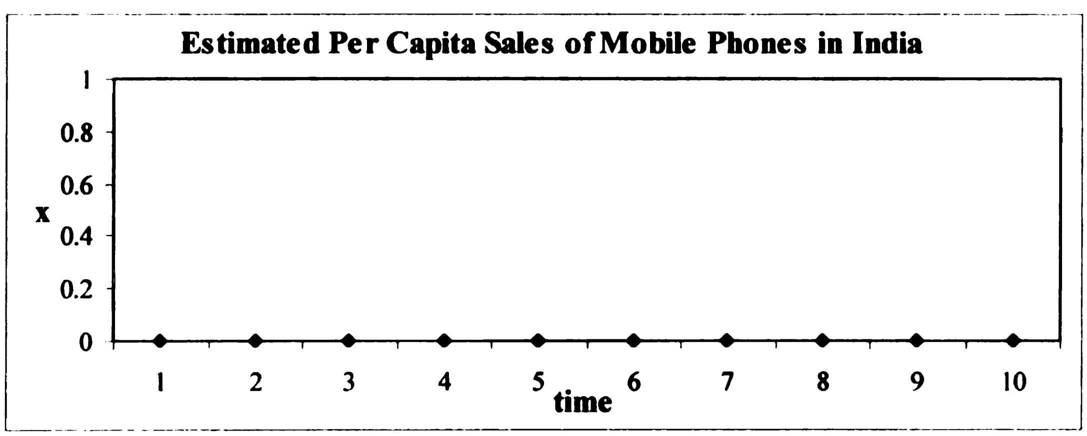
time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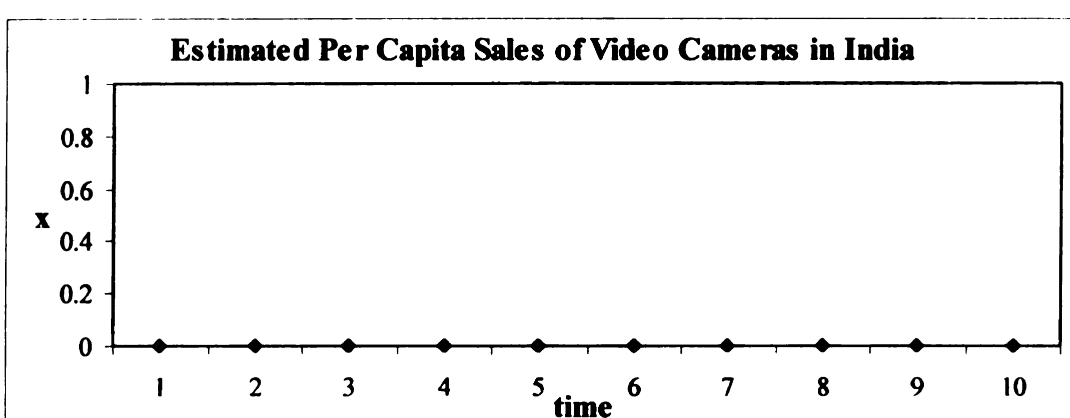
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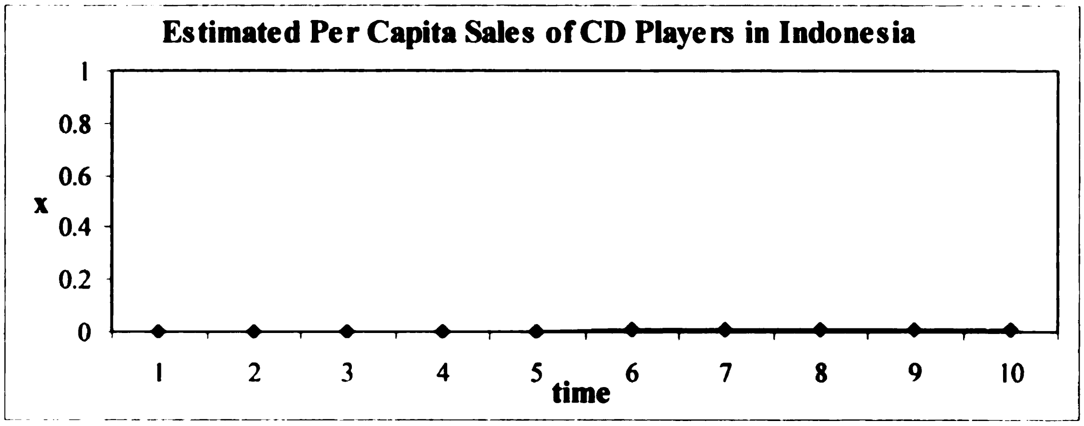
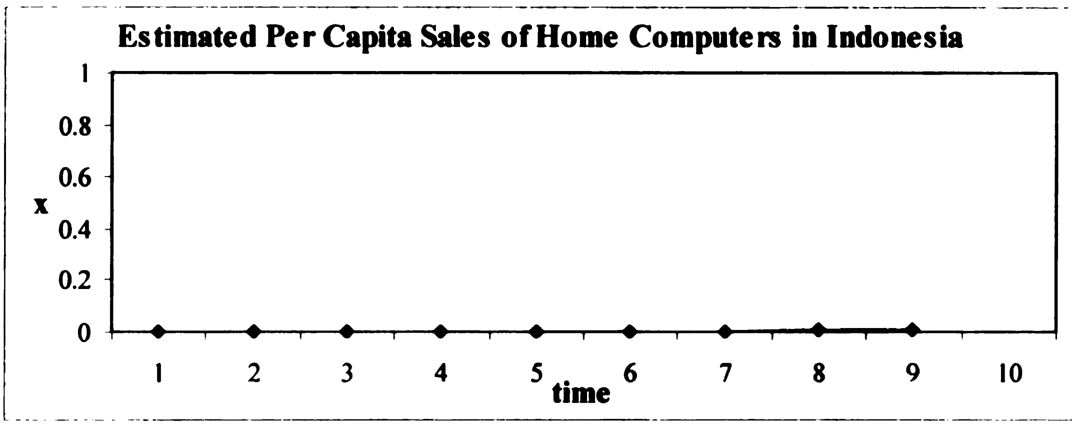
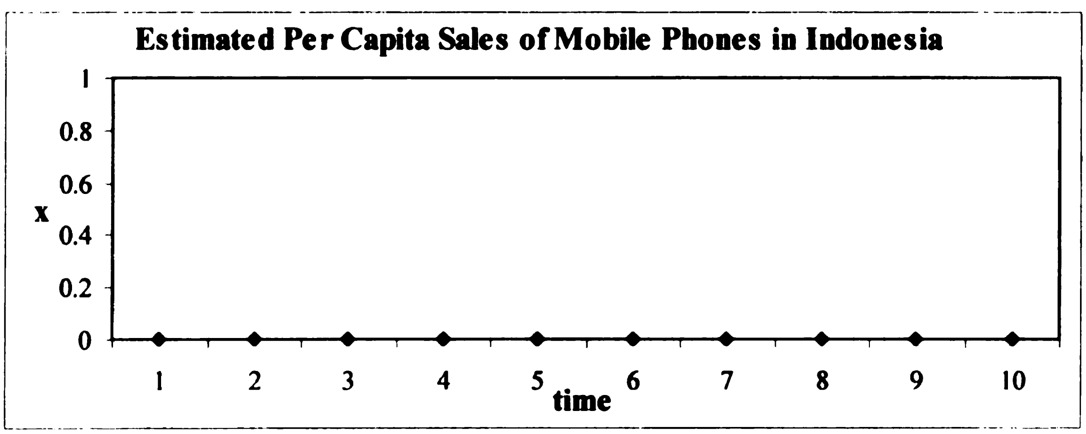

Estimated Per Capita Sales of CD Players in Indonesia
x
time


Estimated Per Capita Sales of Home Computers in Indonesia
x
time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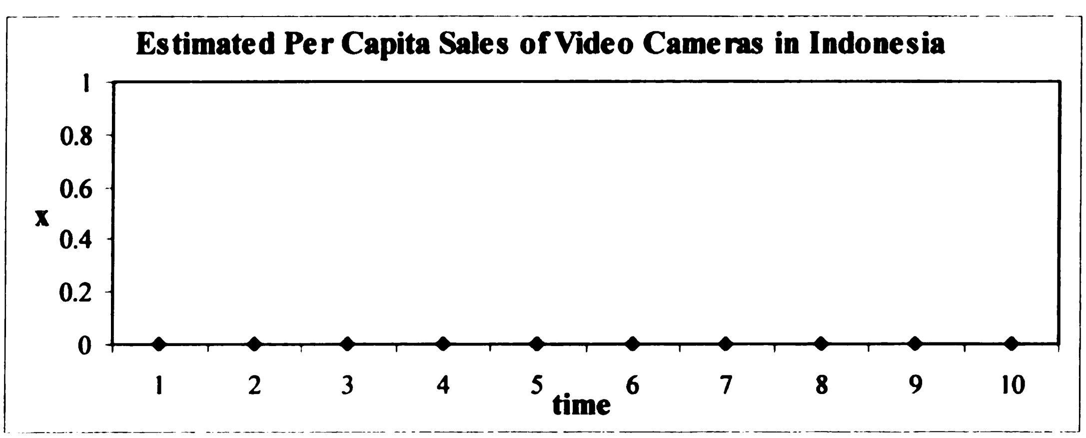
x
time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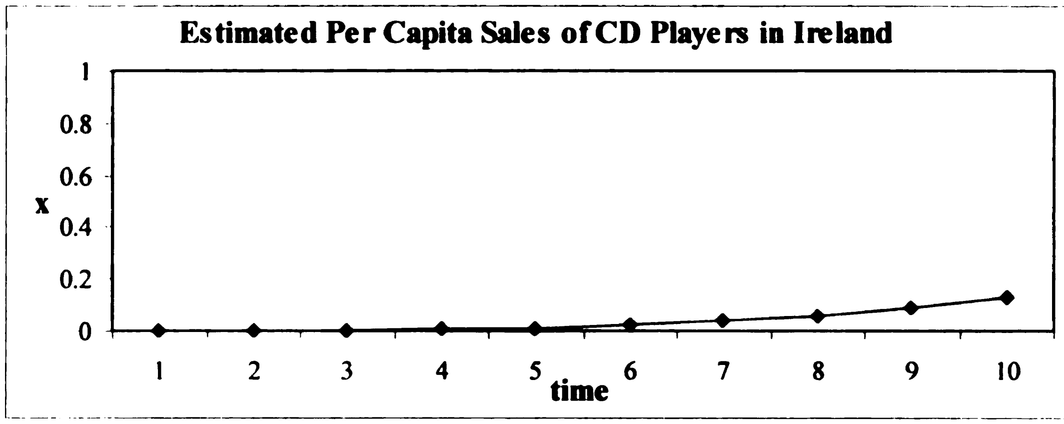
x
time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x
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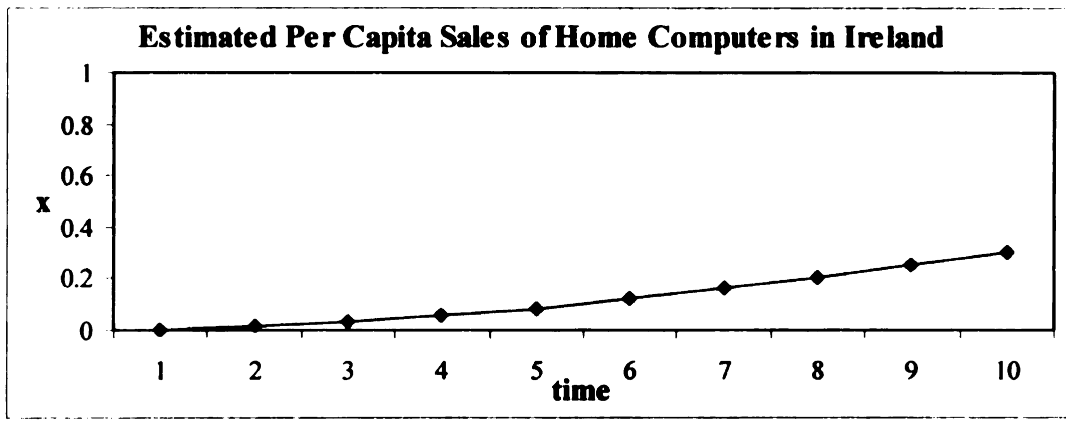
time


Estimated Per Capita Sales of Home Computers in Ireland
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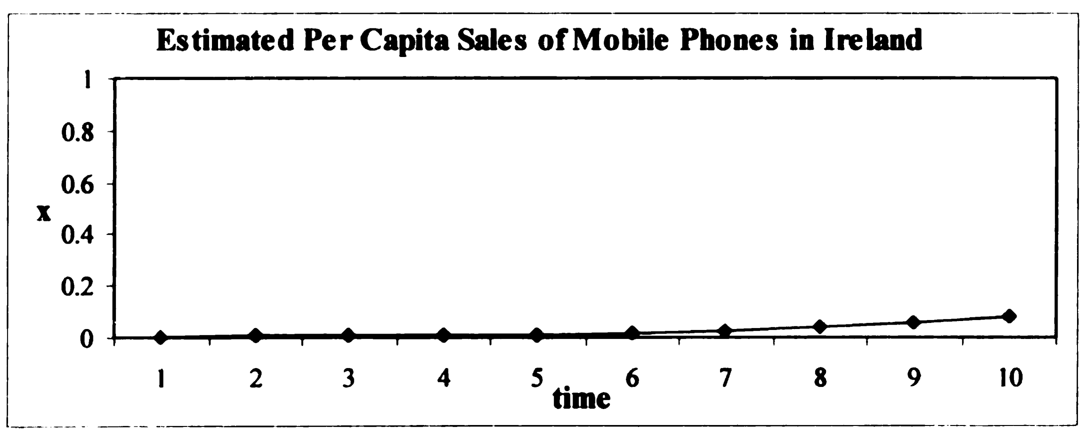
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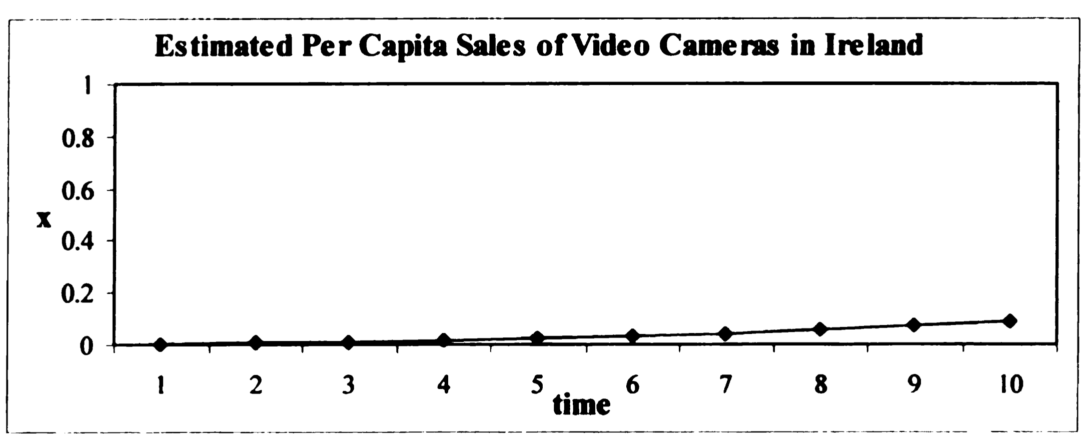
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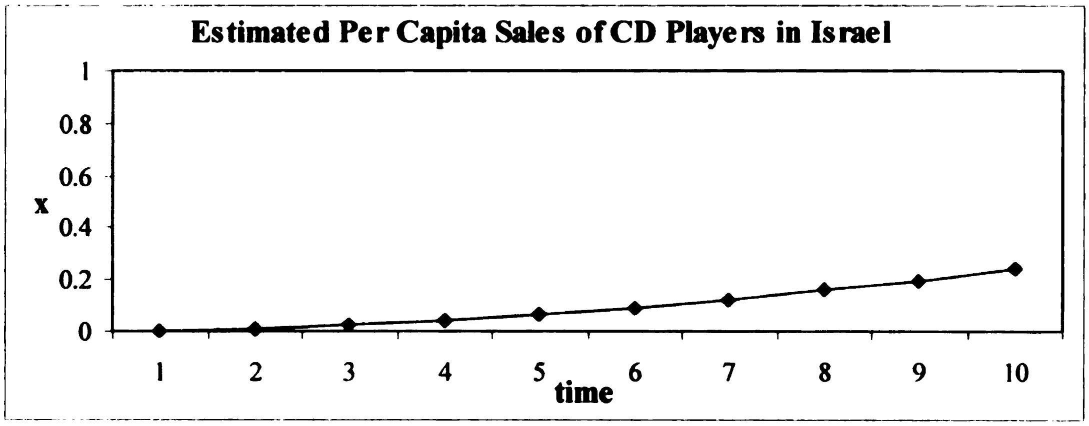
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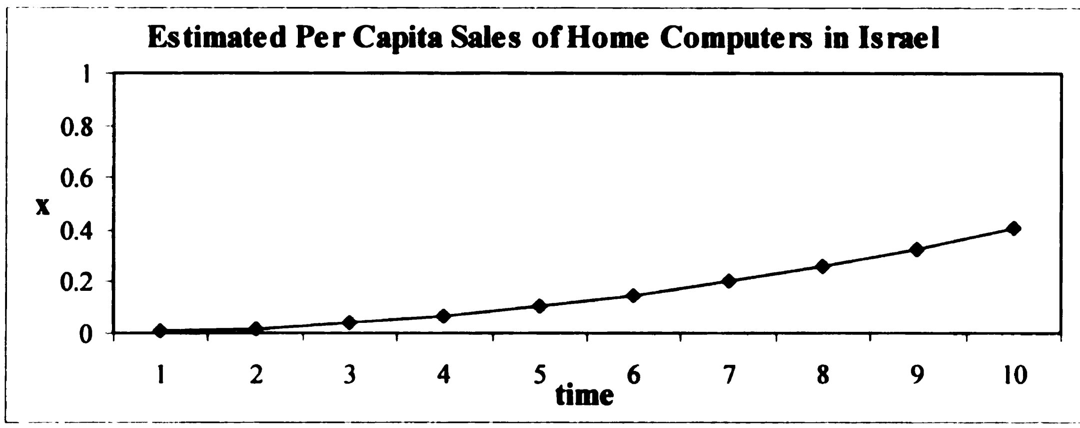
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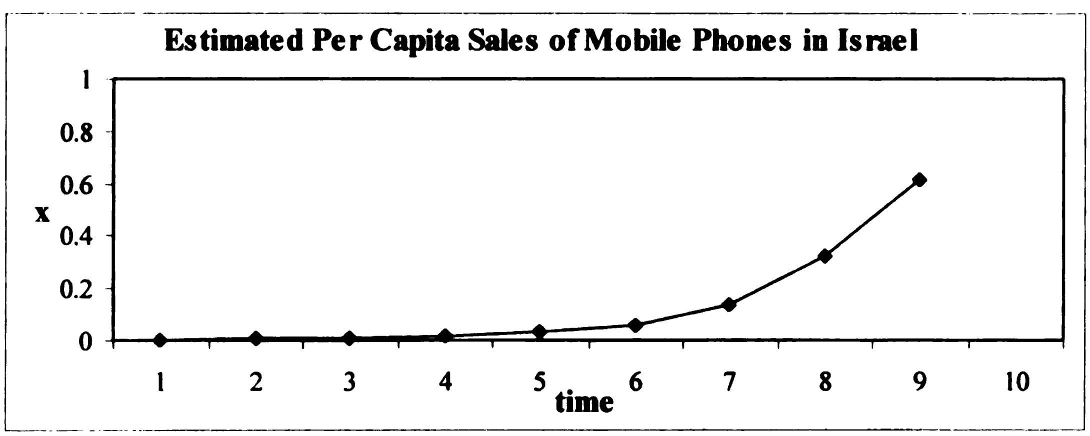
Estimated Per Capita Sales of Mobile Phones in Israel
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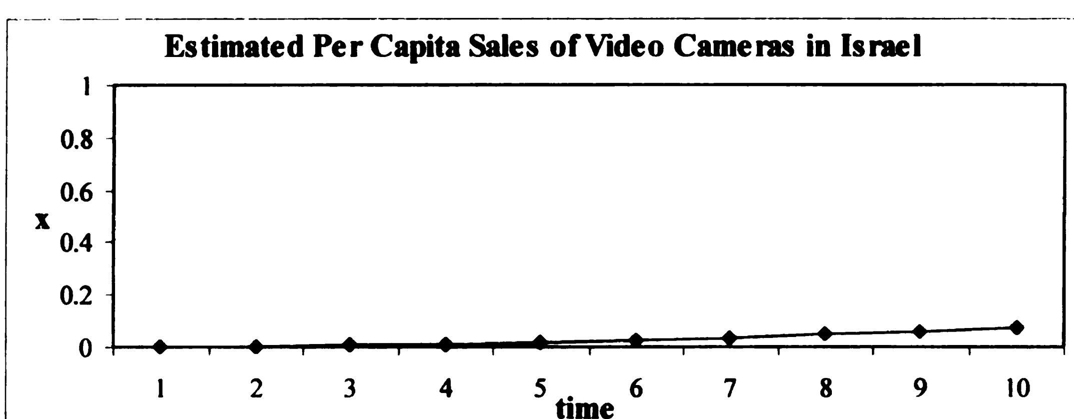
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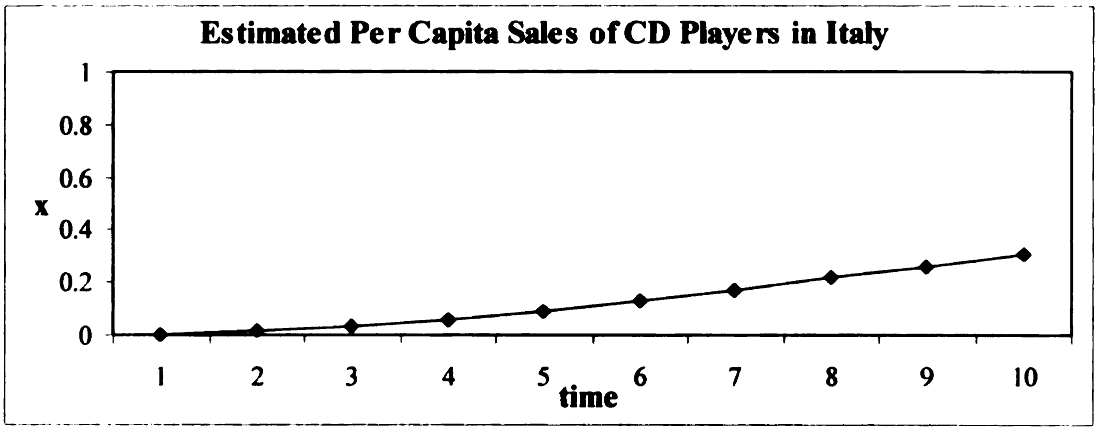
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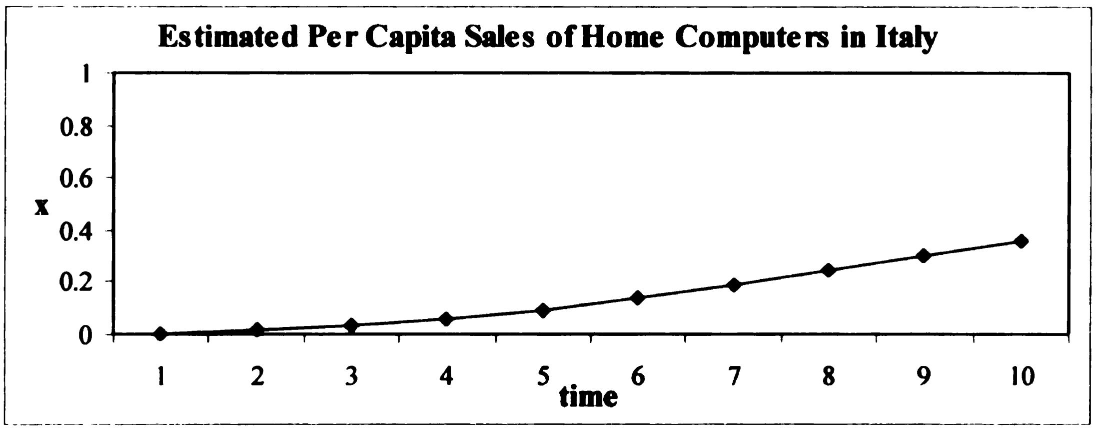
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time
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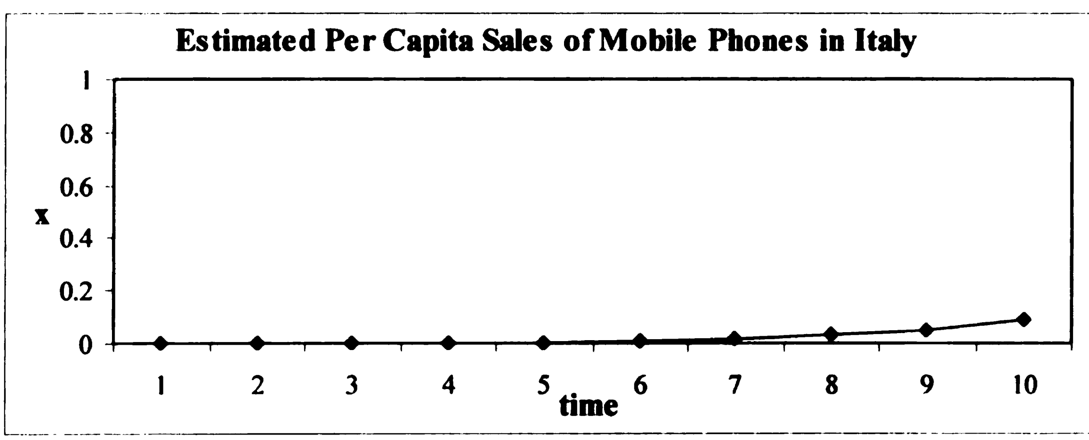
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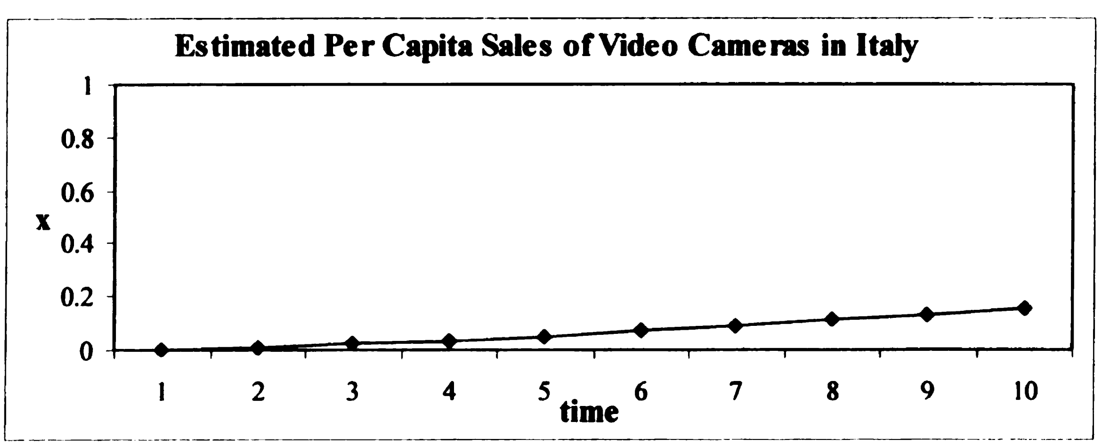
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time
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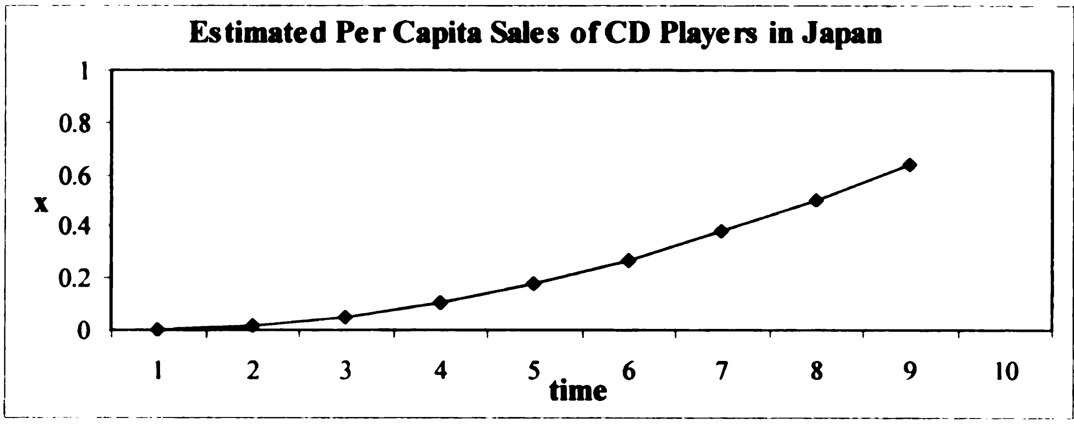
Estimated Per Capita Sales of CD Players in Japan
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time
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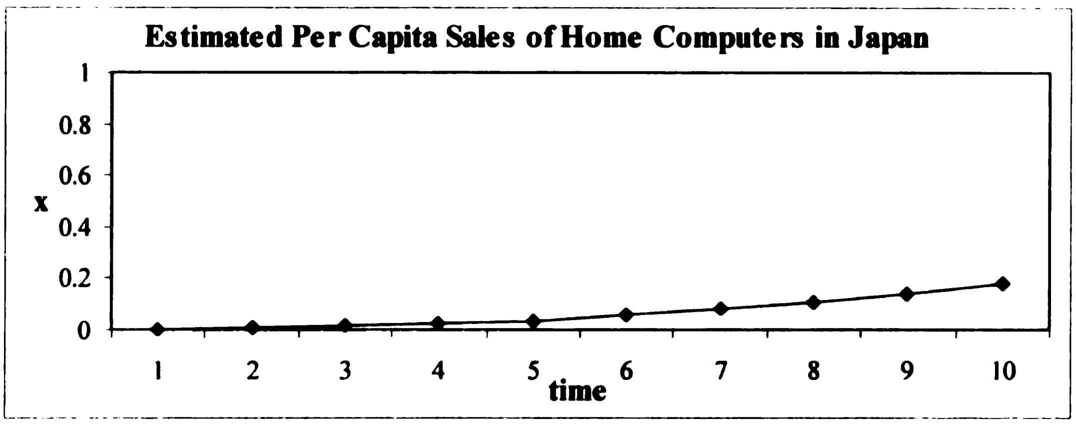
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time
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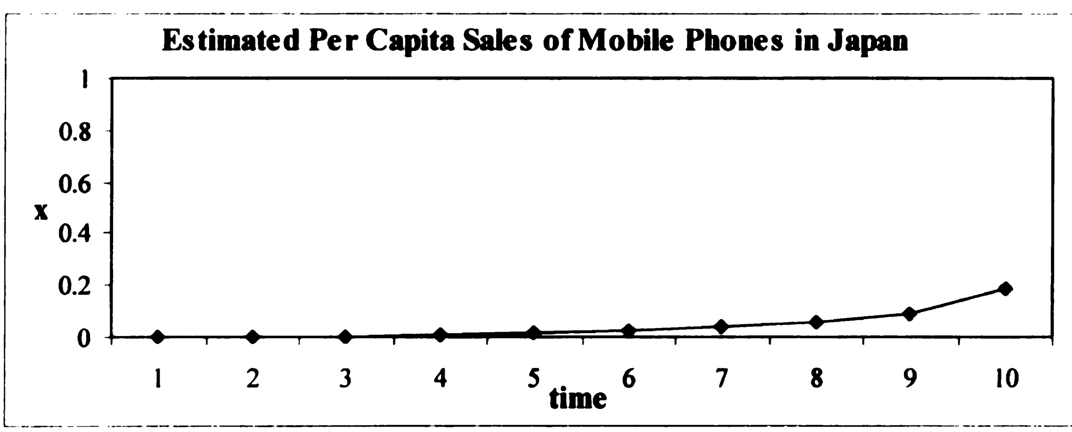
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time
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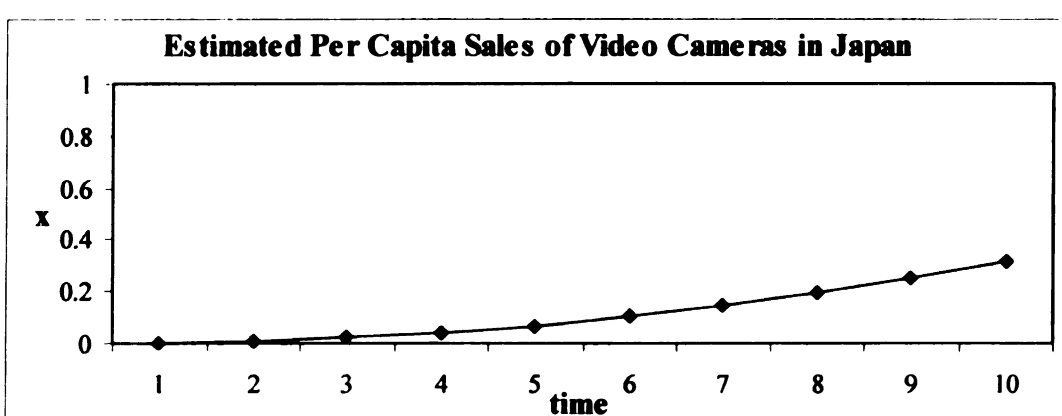
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time
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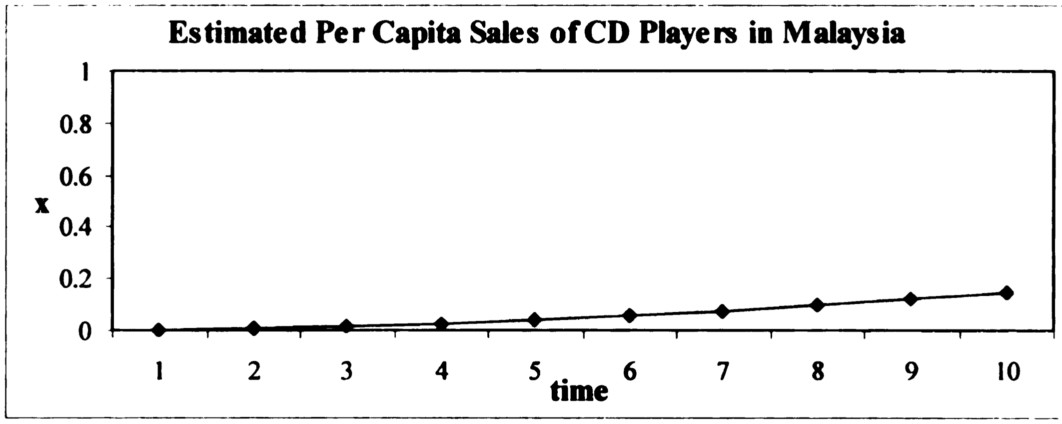
Estimated Per Capita Sales of CD Players in Malaysia
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time
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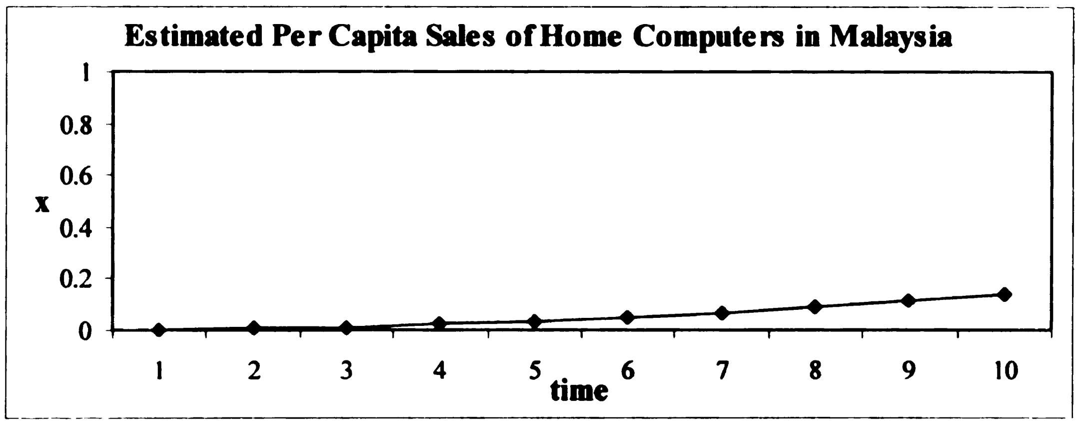
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time
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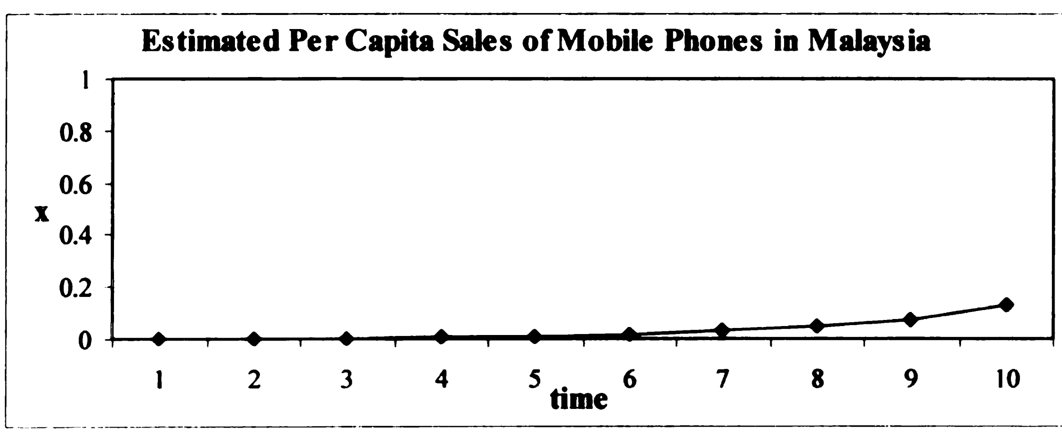
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time
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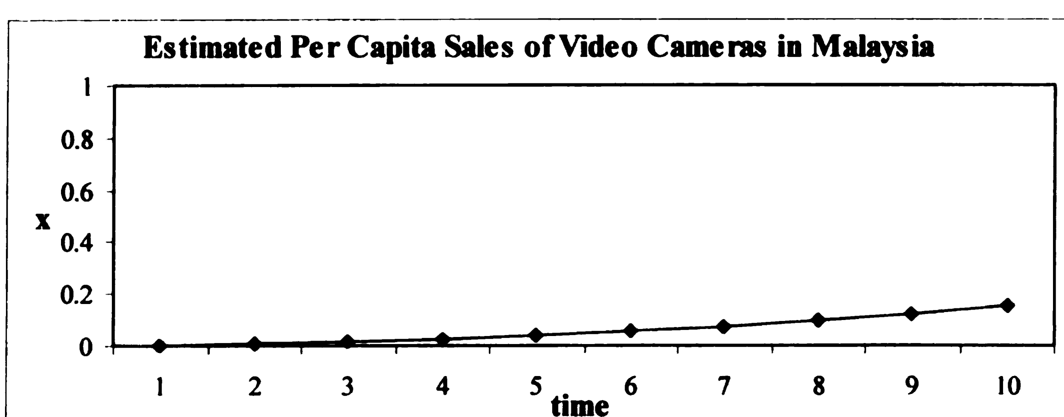
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time
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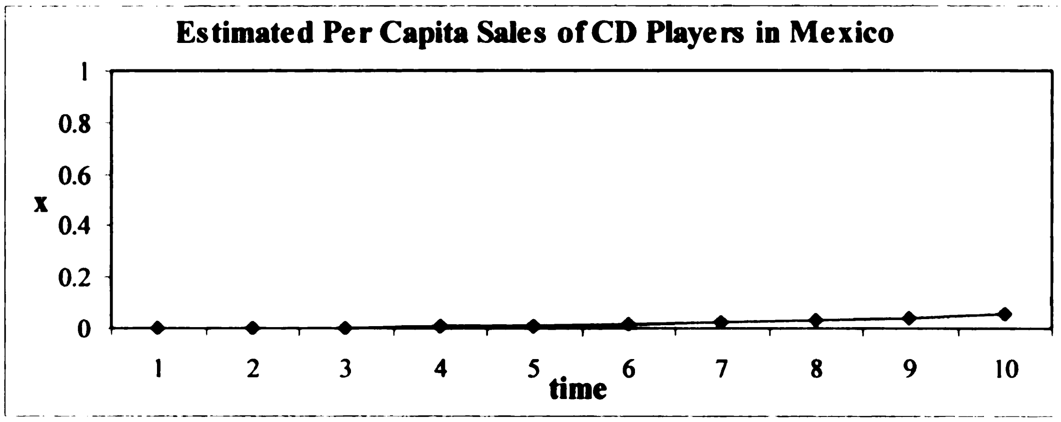
Estimated Per Capita Sales of CD Players in Mexico
x
time
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0.8
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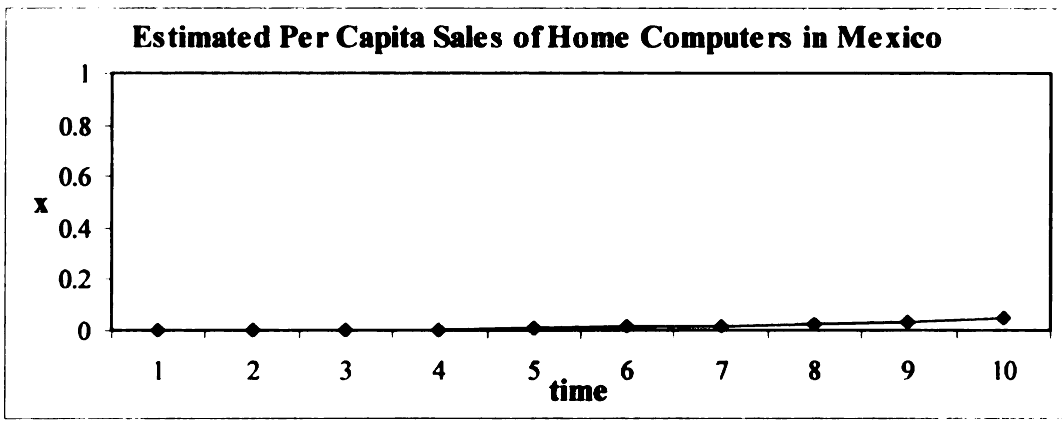
Estimated Per Capita Sales of Home Computers in Mexico
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time
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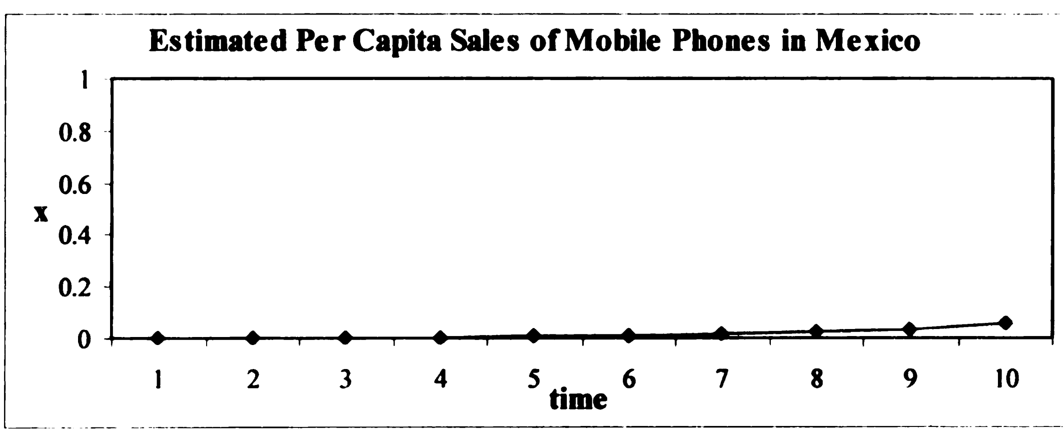
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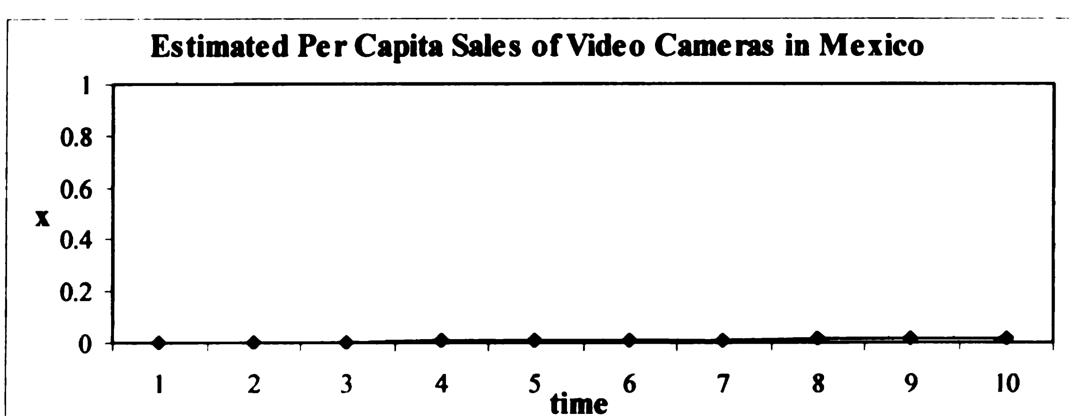
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time
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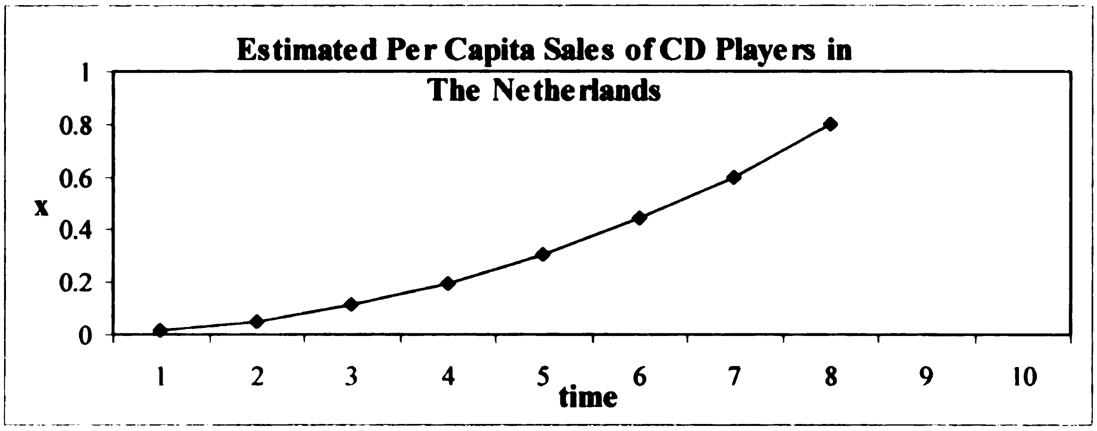
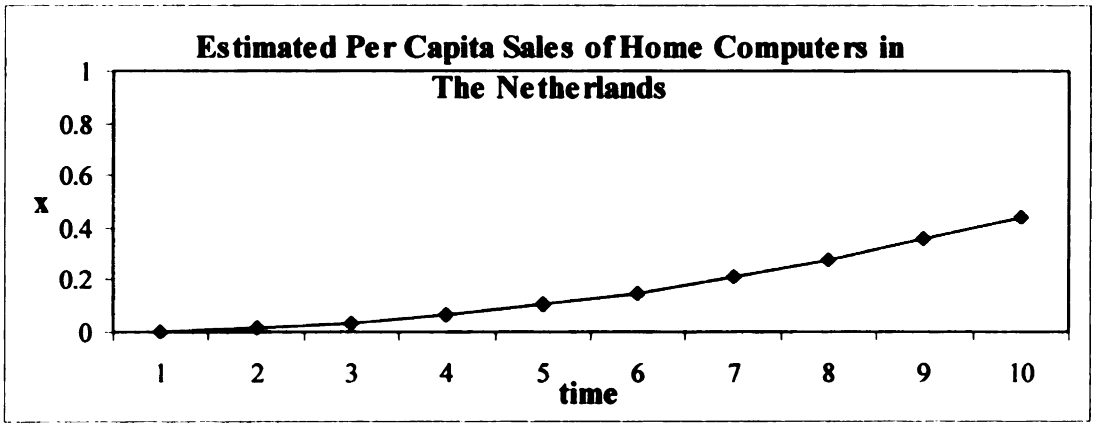
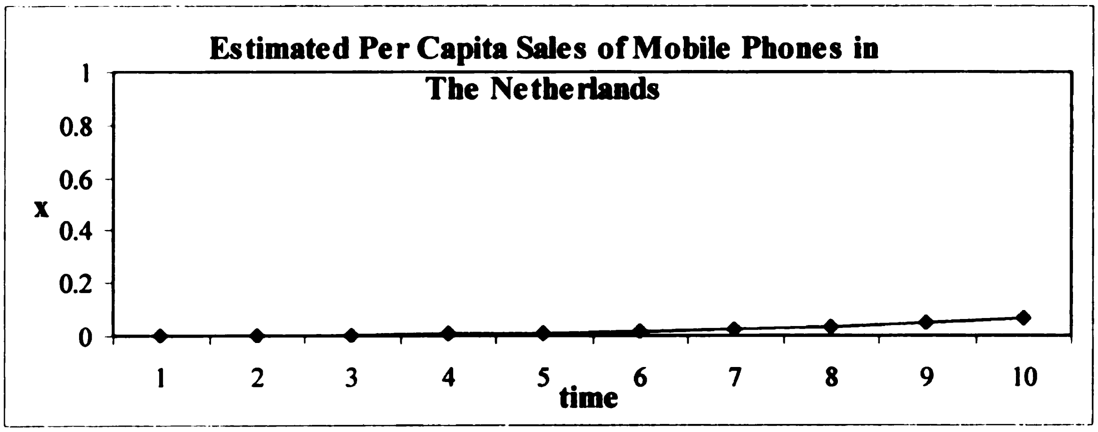

Estimated Per Capita Sales of CD Players in The Netherlands
x
time


Estimated Per Capita Sales of Home Computers in The Netherlands
x
time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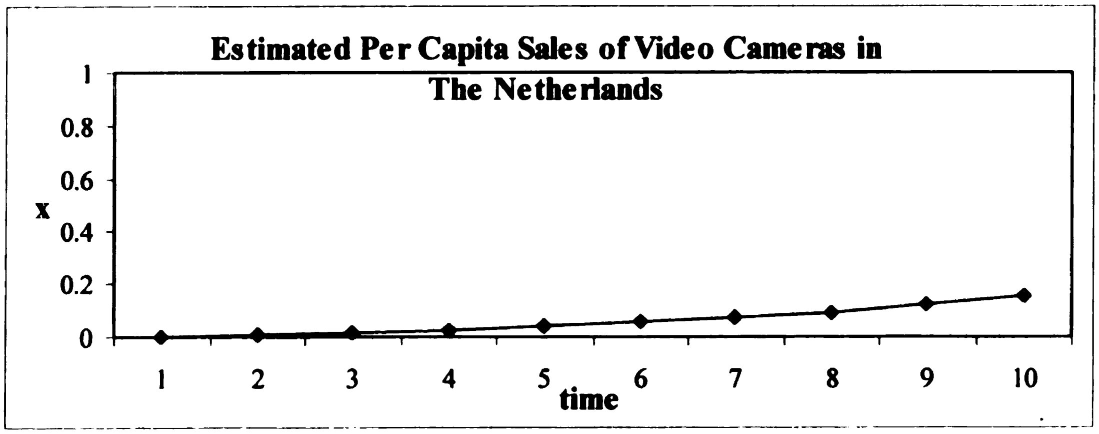
x
time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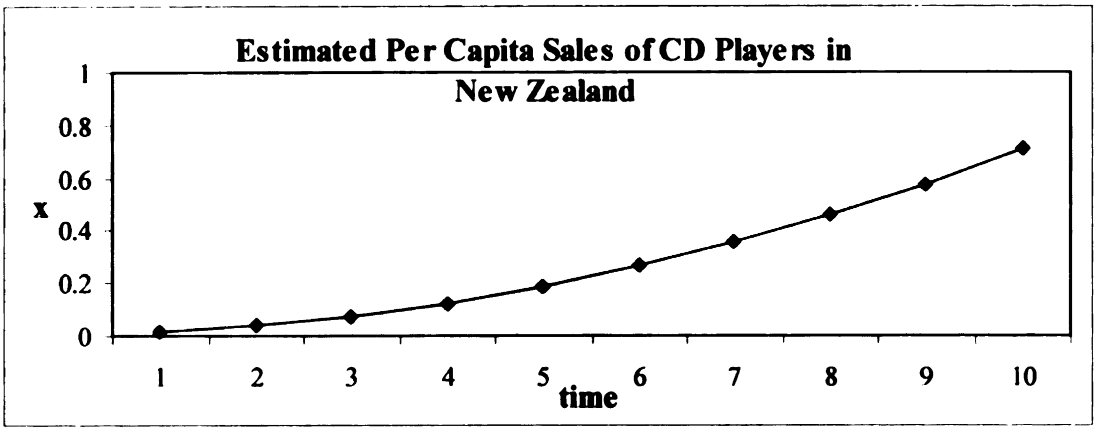
x
time


Estimated Per Capita Sales of CD Players in New Zealand
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x
0.4
0.2
0
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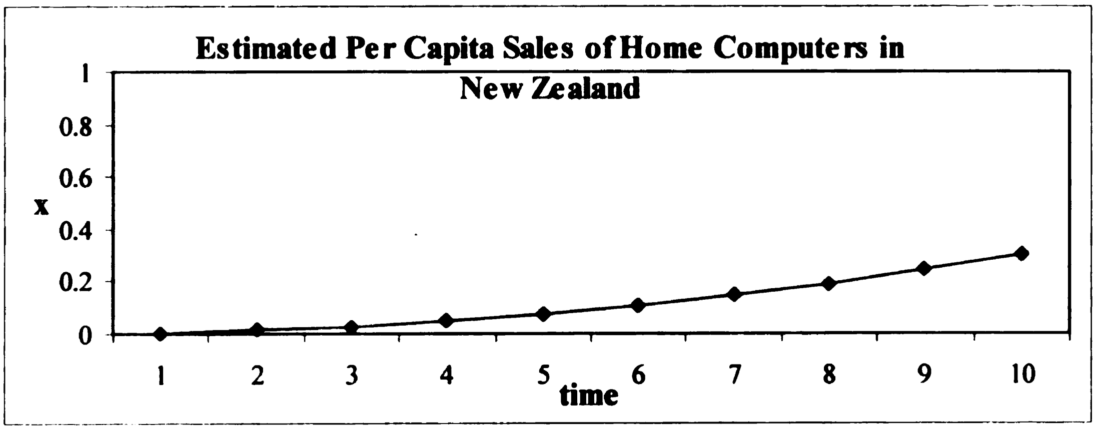
time


Estimated Per Capita Sales of Home Computers in New Zealand
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x
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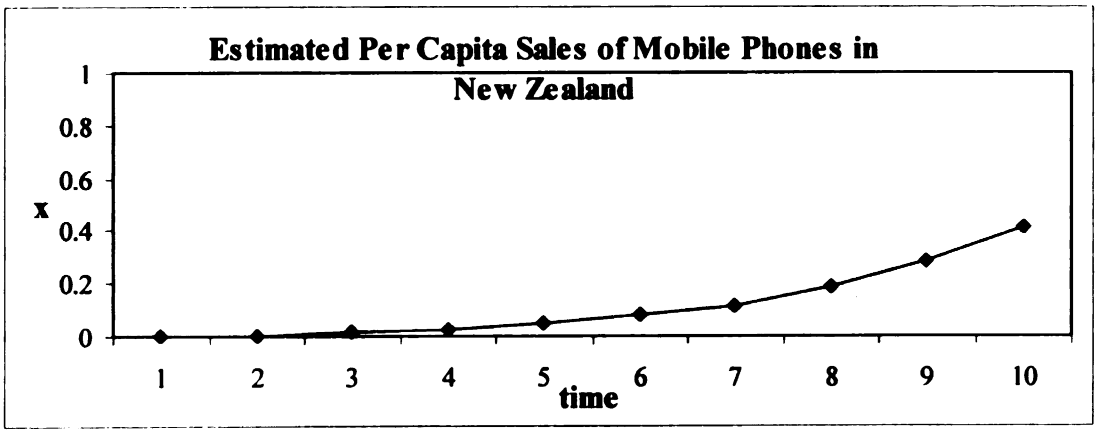
time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x
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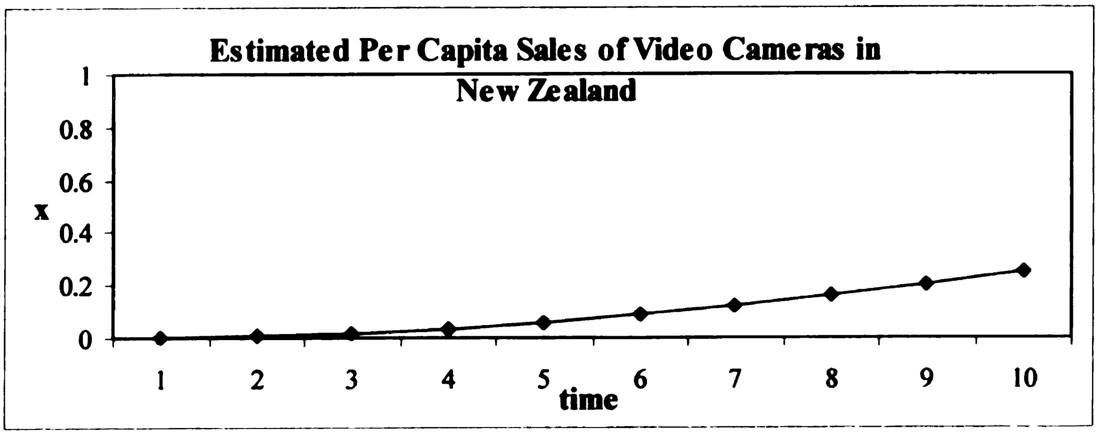
time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x
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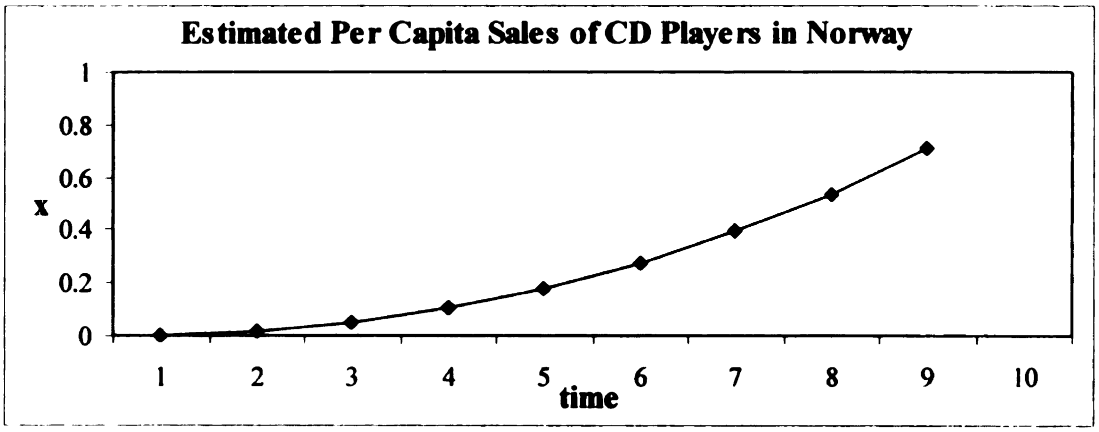
time



Estimated Per Capita Sales of CD Players in Norway
x
time
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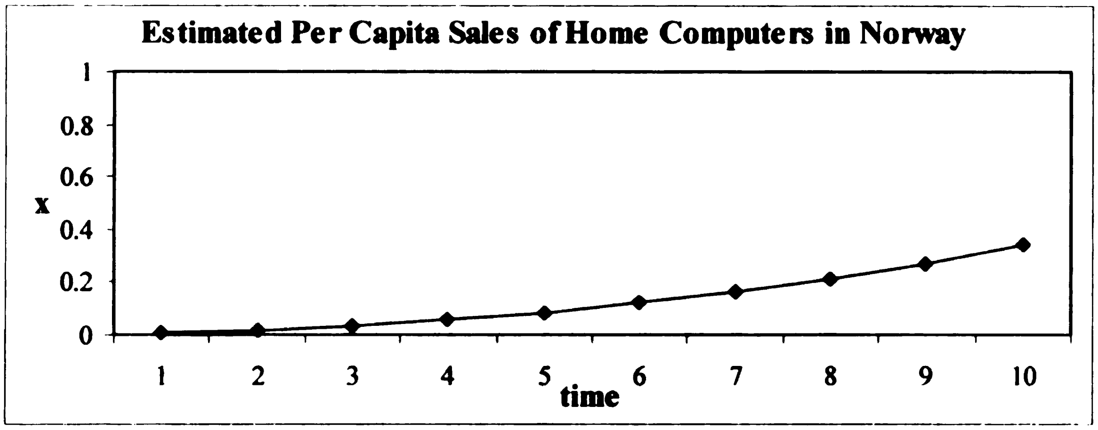

Estimated Per Capita Sales of Home Computers in Norway
x
time
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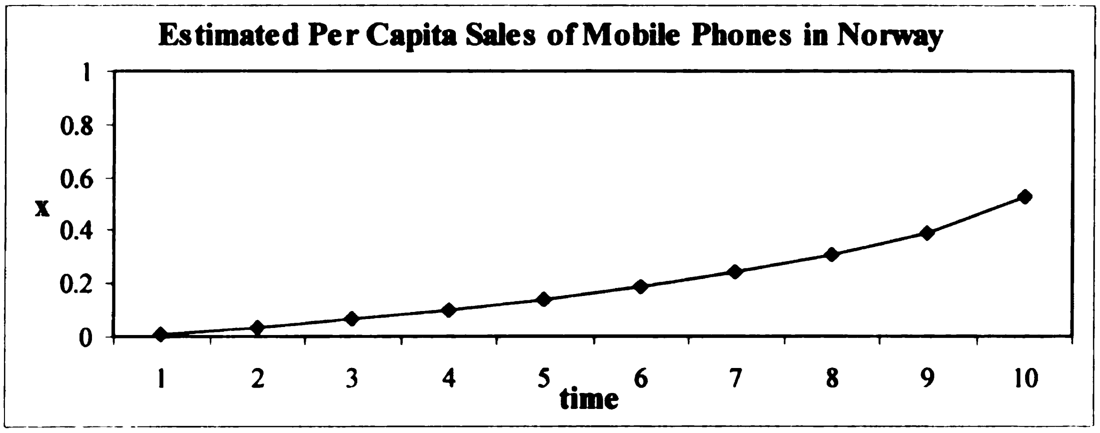
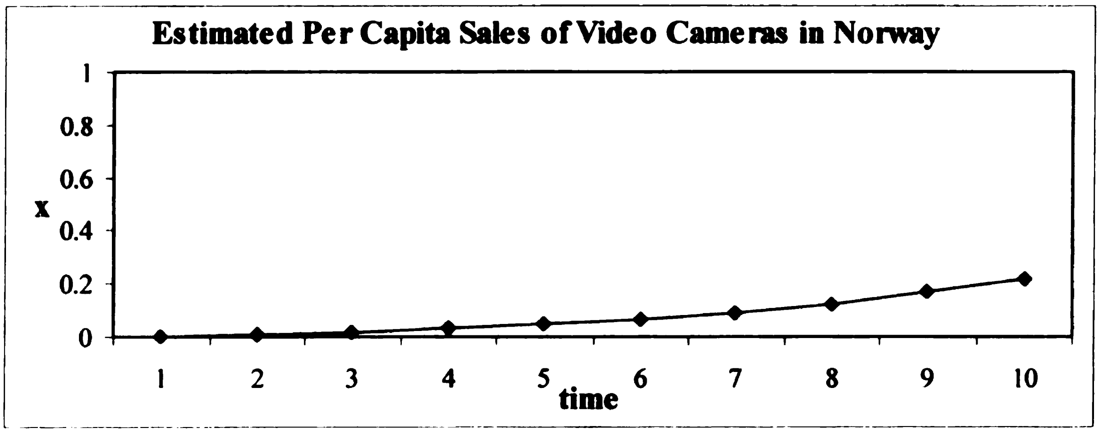
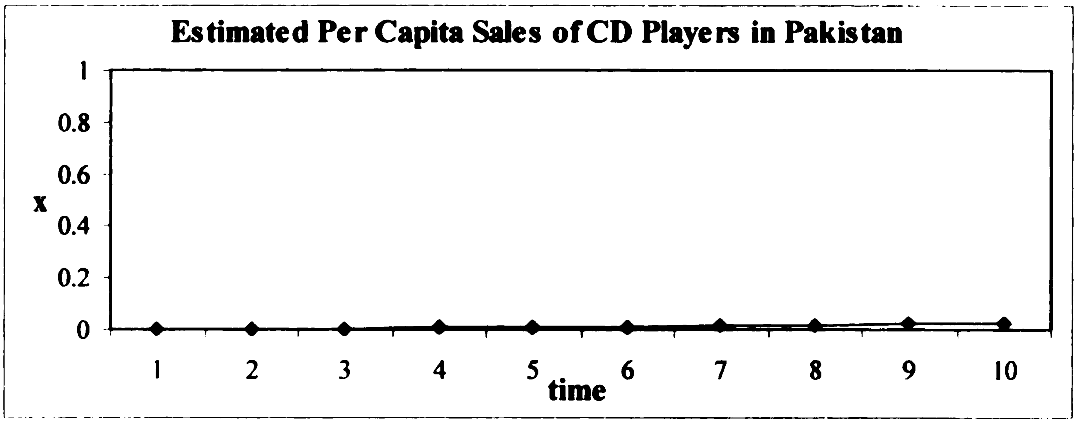
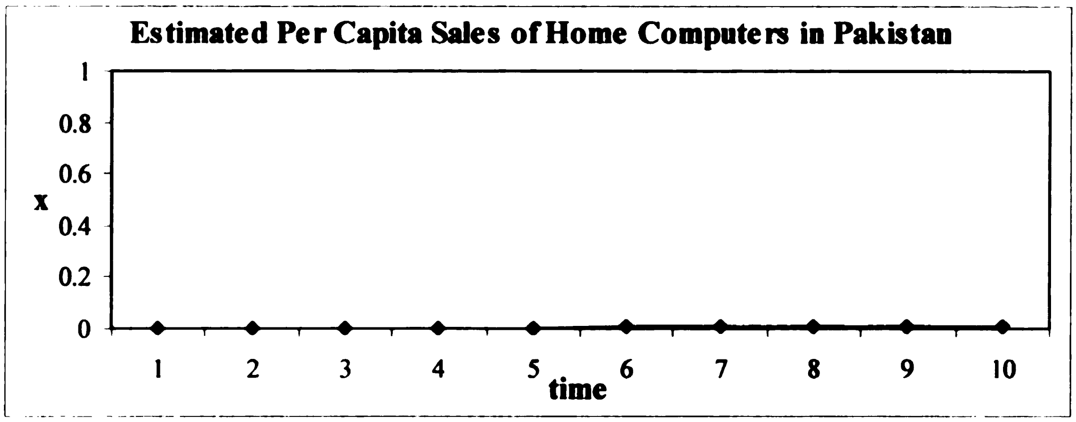


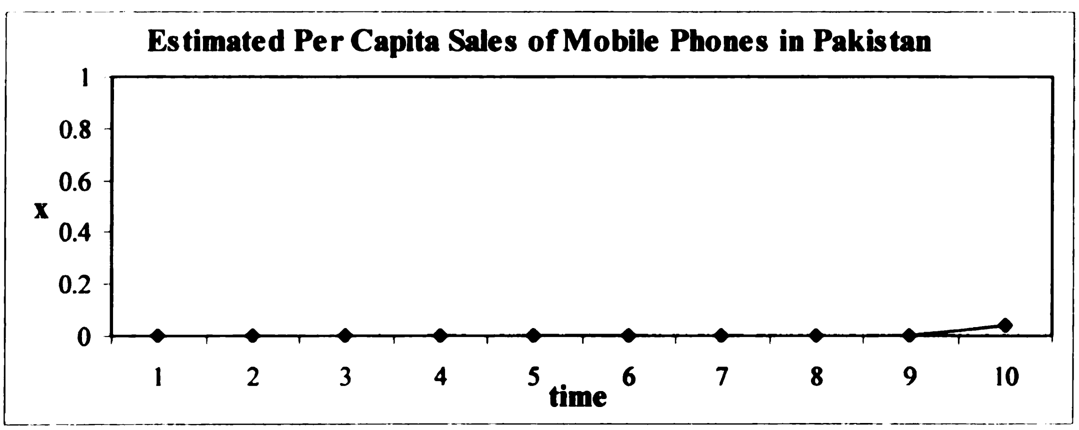
Estimated Per Capita Sales of Mobile Phones in Norway
x
time
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
7
8
9
10

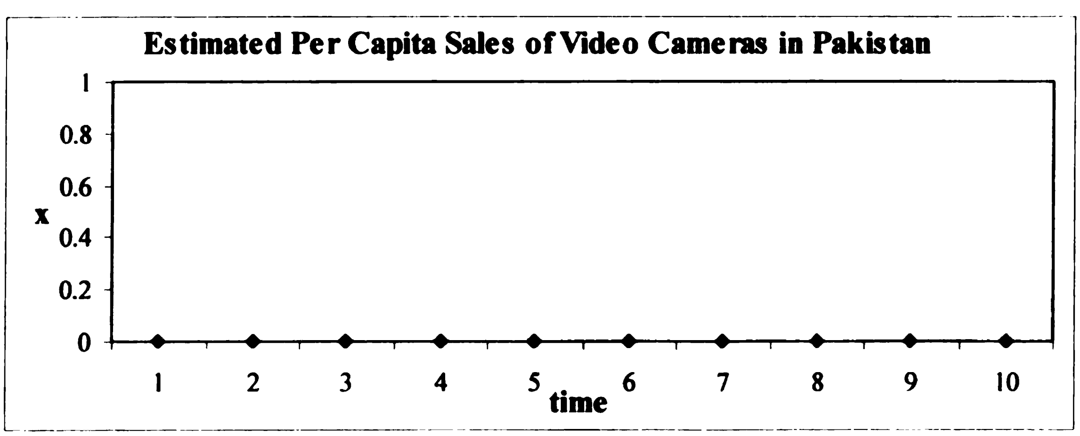


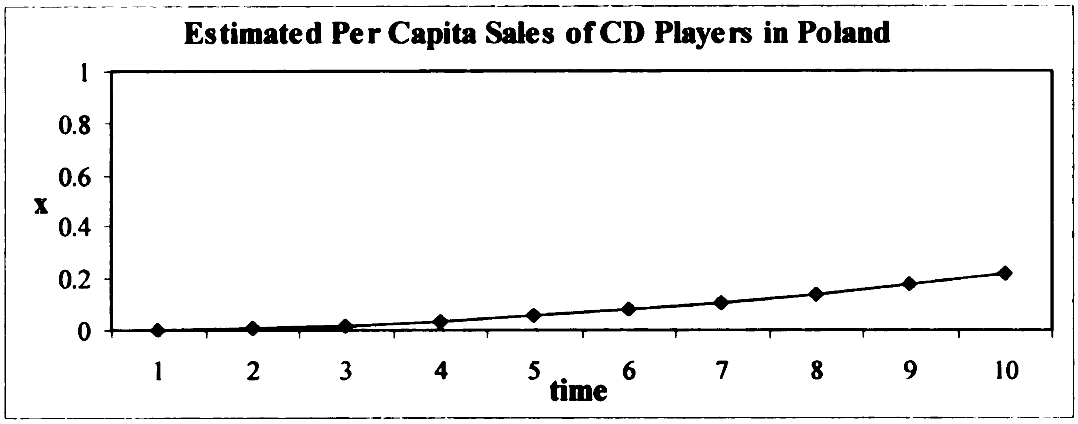
Estimated Per Capita Sales of Video Cameras in Norway
x
time
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
7
8
9
10


Estimated Per Capita Sales of CD Players in Pakistan
x
time


Estimated Per Capita Sales of Home Computers in Pakistan
x
time


Estimated Per Capita Sales of Mobile Phones in Pakistan
x
time


Estimated Per Capita Sales of Video Cameras in Pakistan
x
time


Estimated Per Capita Sales of CD Players in Poland
x
time
0
0.2
0.4
0.6
0.8
1
1
2
3
4
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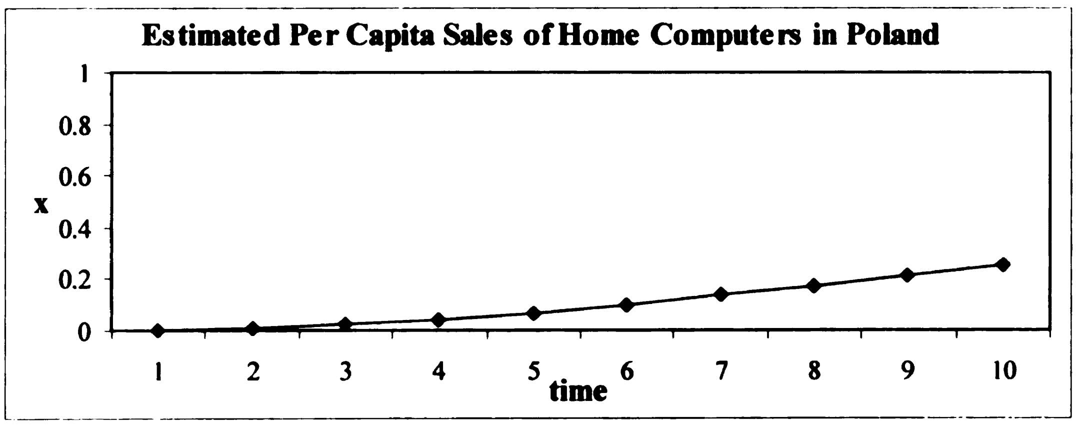
6
7
8
9
10


Estimated Per Capita Sales of Home Computers in Poland
x
time
0
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0.4
0.6
0.8
1
1
2
3
4
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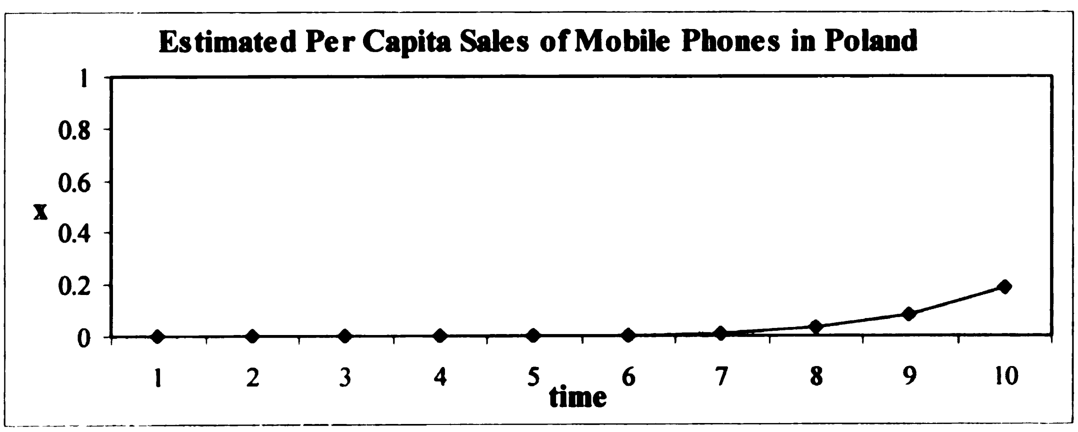
6
7
8
9
10


Estimated Per Capita Sales of Mobile Phones in Poland
x
time
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0.4
0.6
0.8
1
1
2
3
4
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6
7
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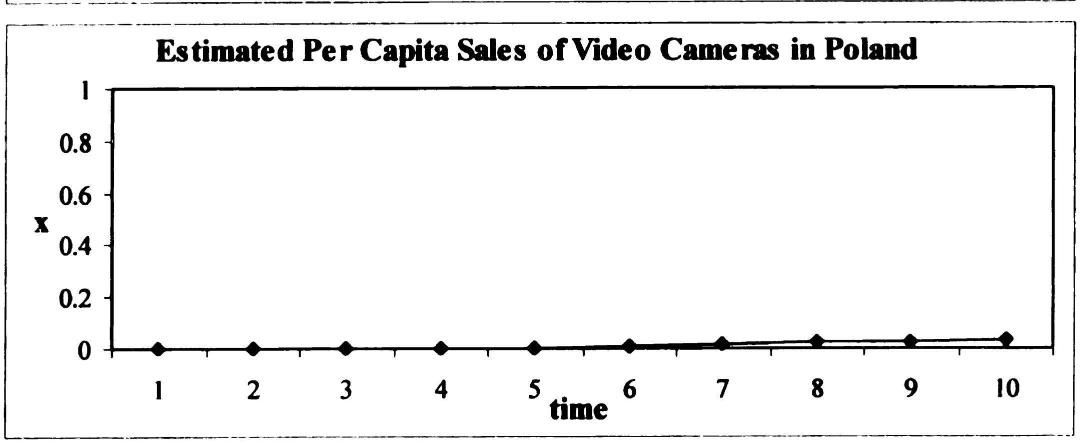
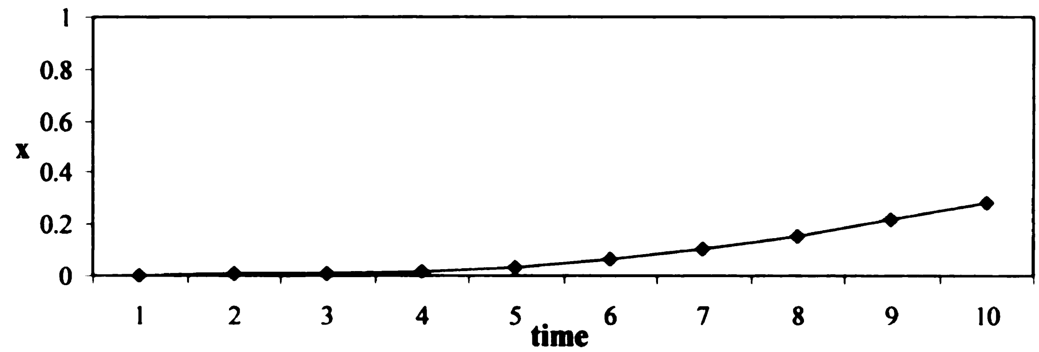
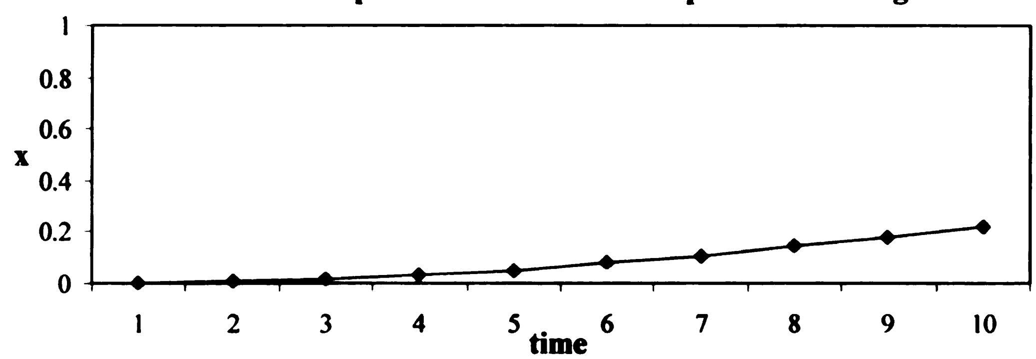
9
10


Estimated Per Capita Sales of Video Cameras in Poland
x
time
0
0.2
0.4
0.6
0.8
1
1
2
3
4
5
6
7
8
9
10

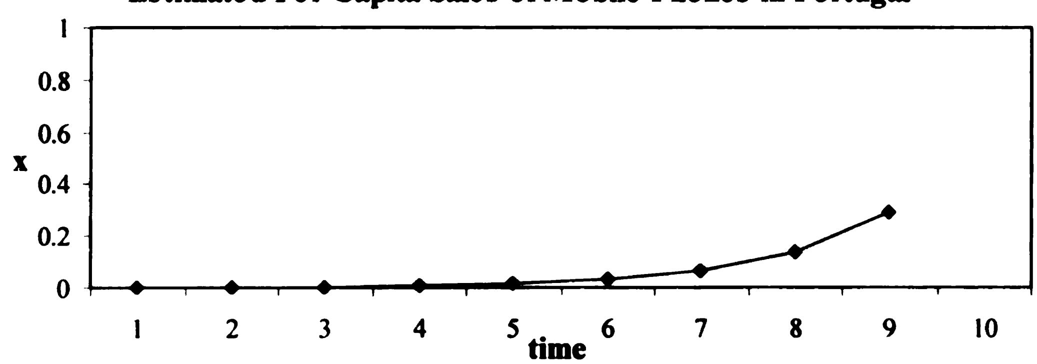
Estimated Per Capita Sales of CD Players in Portugal



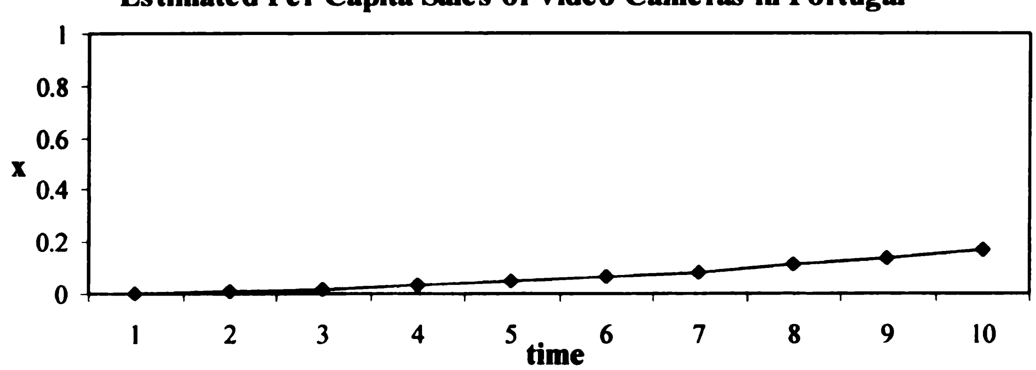
Estimated Per Capita Sales of Home Computers in Portugal

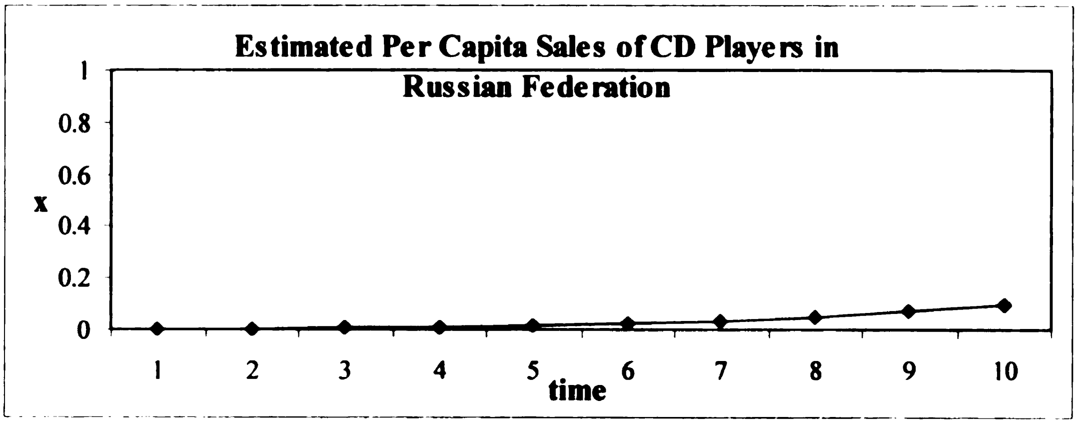


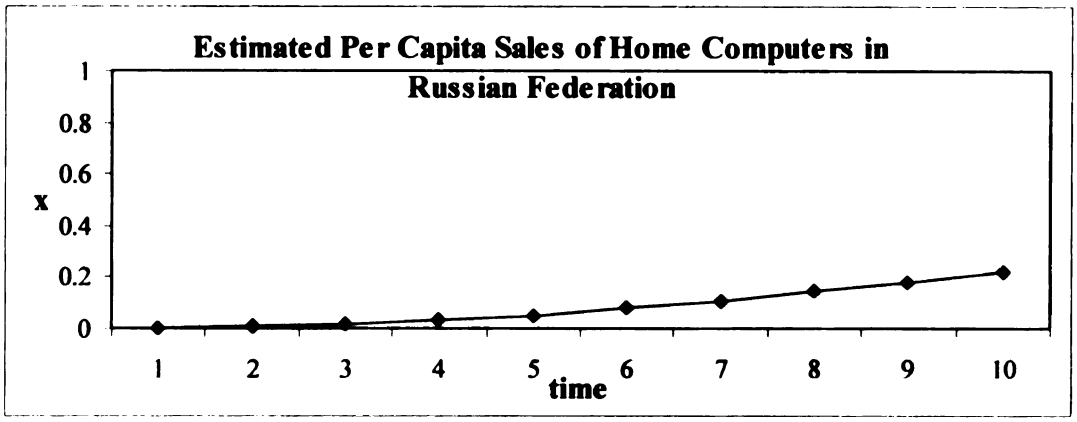
Estimated Per Capita Sales of Mobile Phones in Portugal

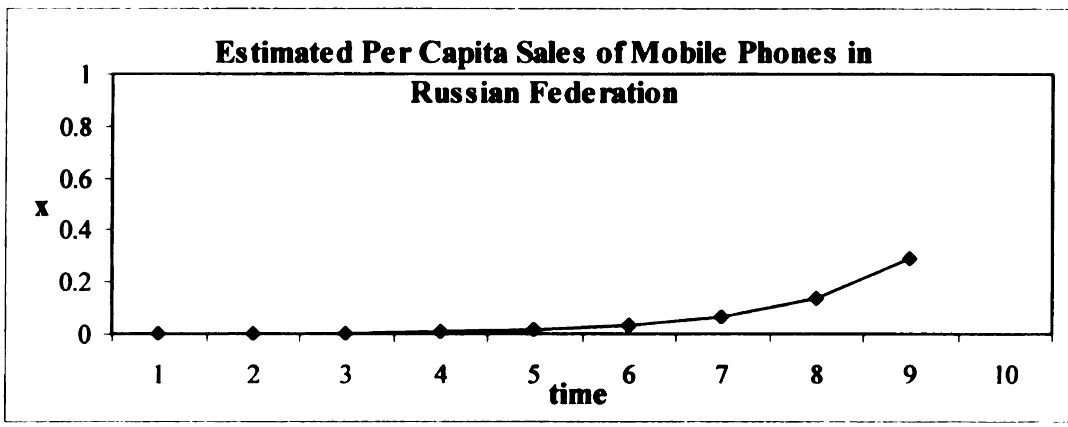


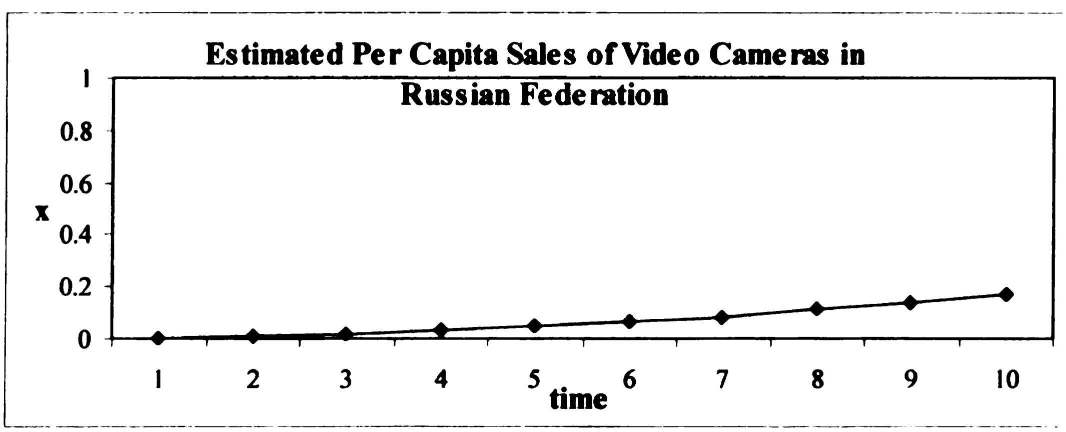
Estimated Per Capita Sales of Video Cameras in Portugal

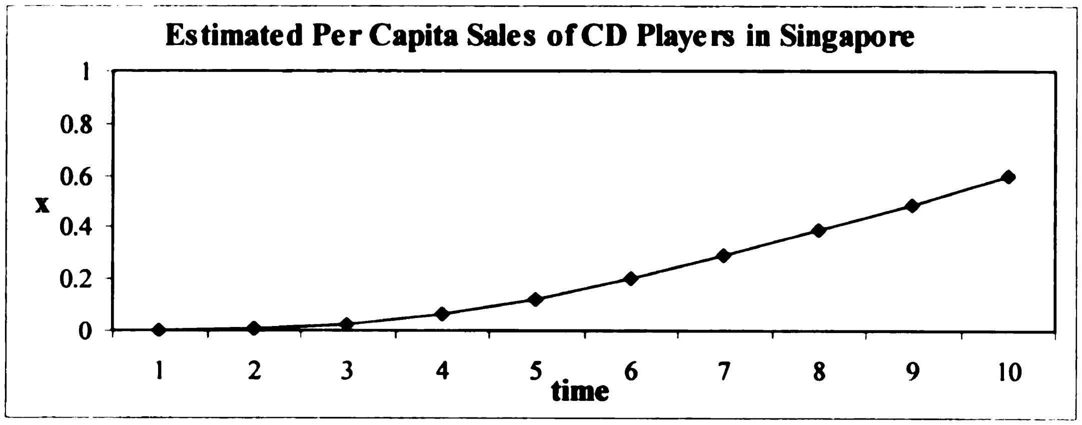


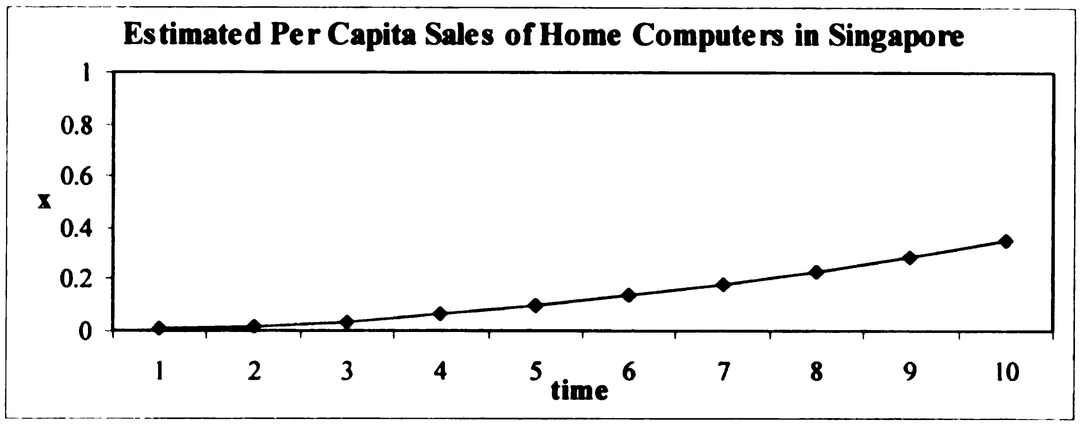

Estimated Per Capita Sales of CD Players in Russian Federation
1
0.8
0.6
x
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time

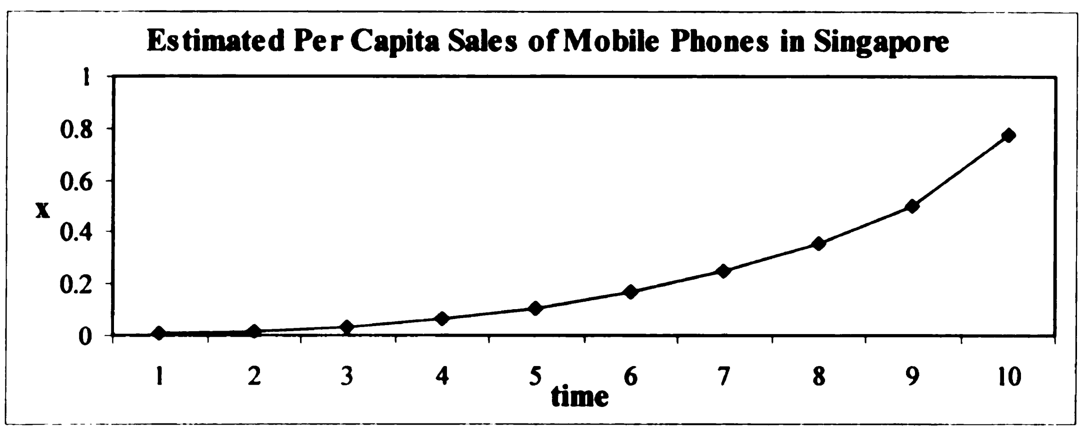

Estimated Per Capita Sales of Home Computers in Russian Federation
1
0.8
0.6
x
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time

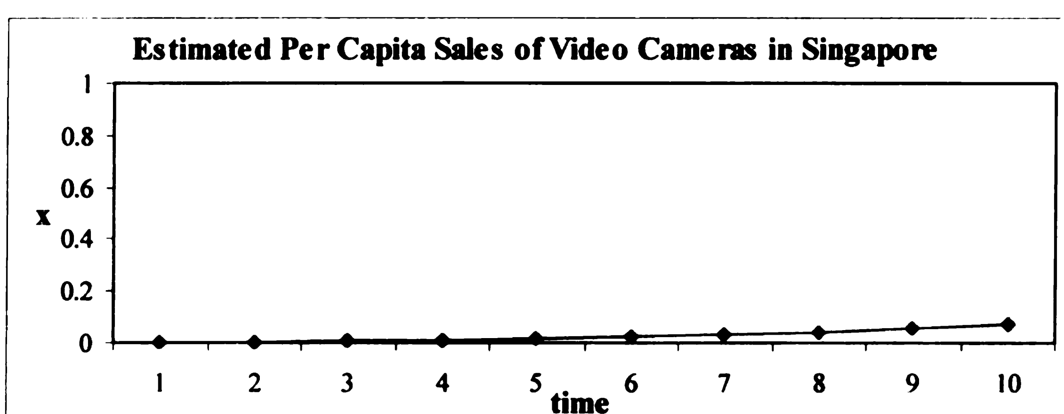

Estimated Per Capita Sales of Mobile Phones in Russian Federation
1
0.8
0.6
x
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time

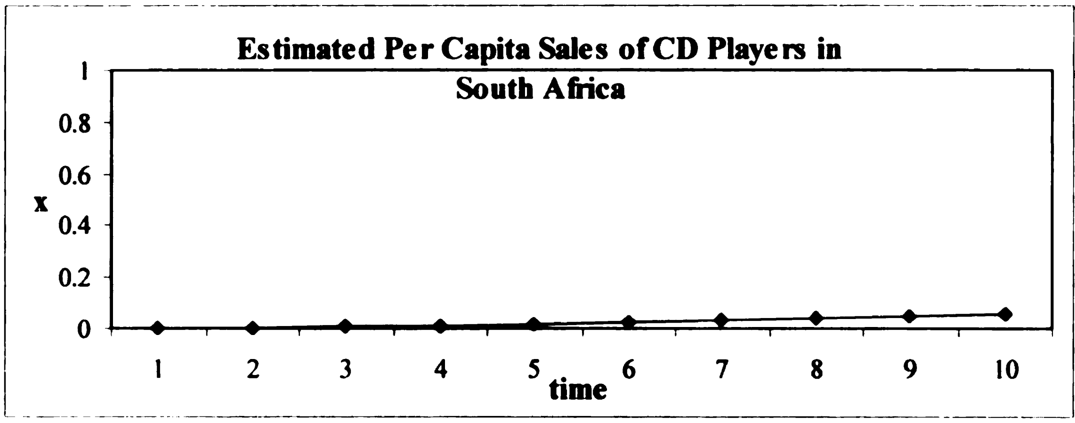

Estimated Per Capita Sales of Video Cameras in Russian Federation
1
0.8
0.6
x
0.4
0.2
0
1 2 3 4 5 6 7 8 9 10
time


Estimated Per Capita Sales of CD Players in Singapore
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

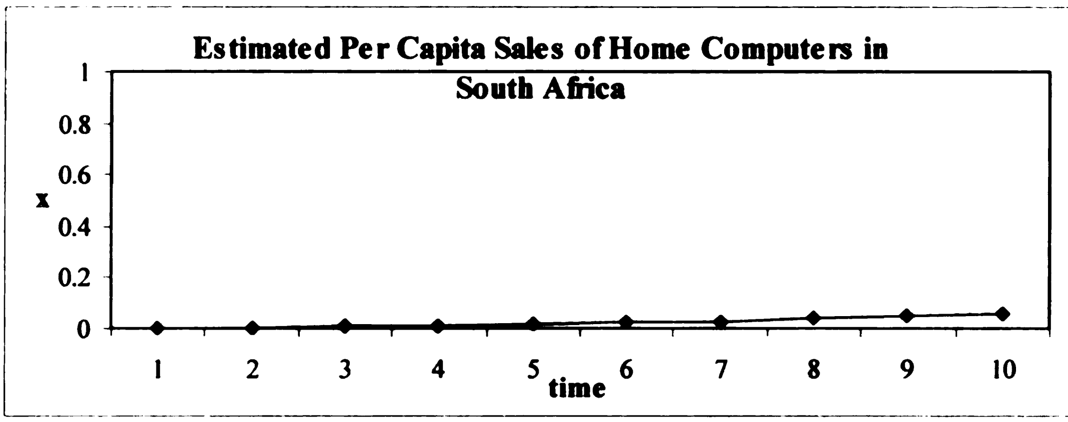

Estimated Per Capita Sales of Home Computers in Singapore
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10


Estimated Per Capita Sales of Mobile Phones in Singapore
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

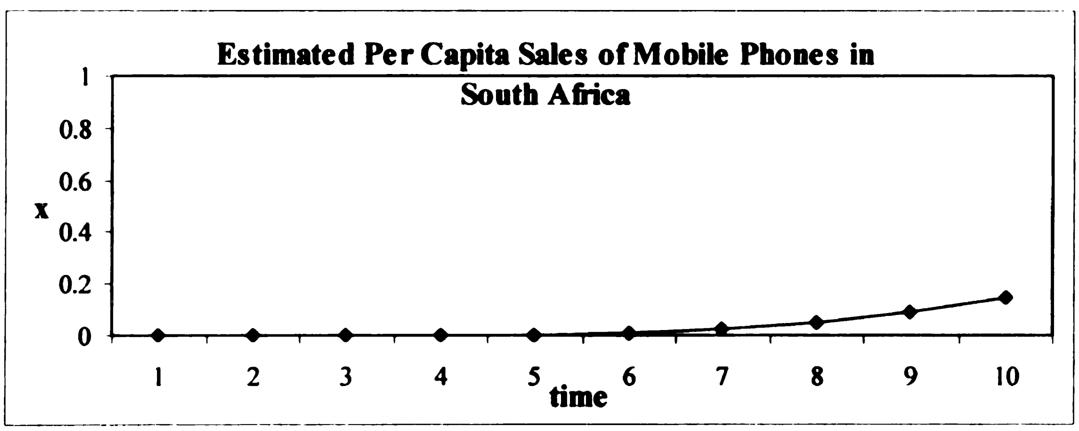

Estimated Per Capita Sales of Video Cameras in Singapore
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10



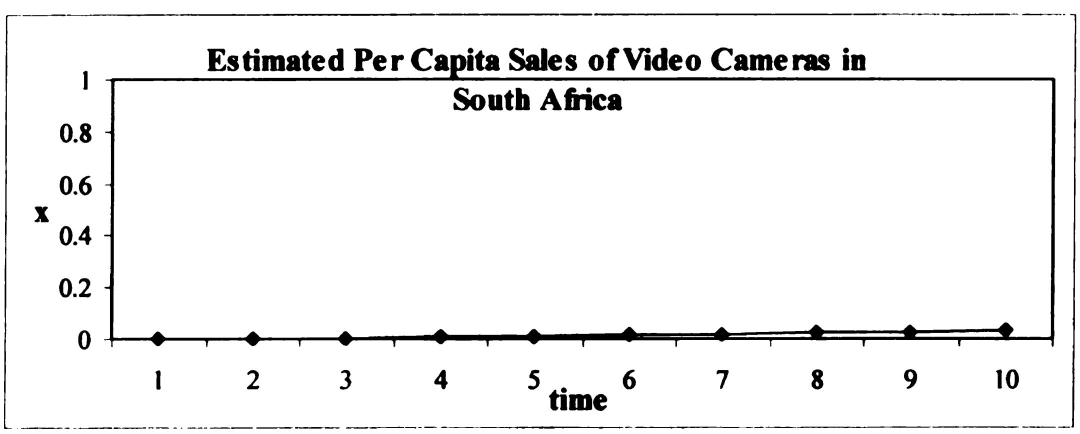
Estimated Per Capita Sales of CD Players in South Africa
x
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10
time



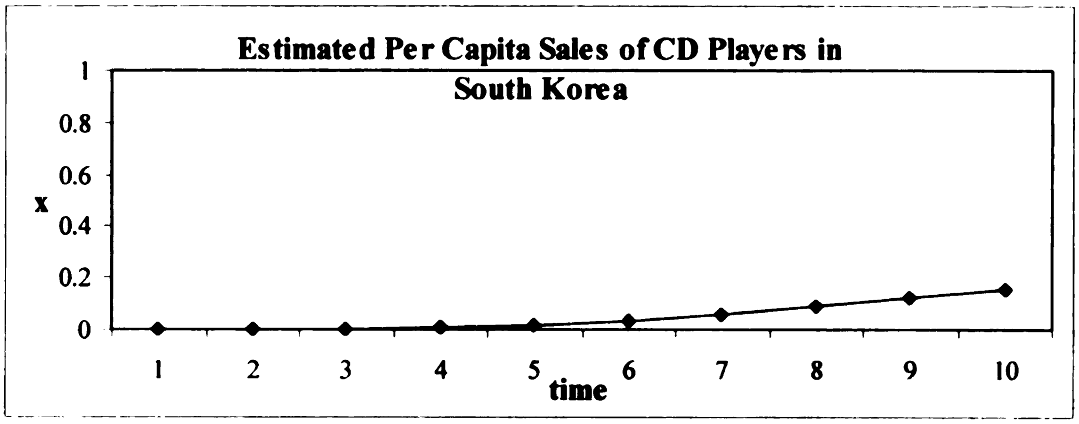
Estimated Per Capita Sales of Home Computers in South Africa
x
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10
time

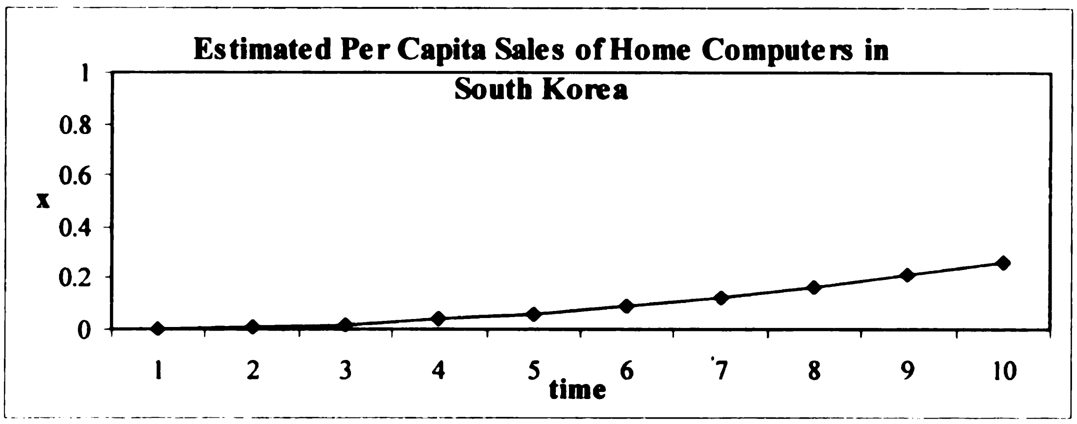


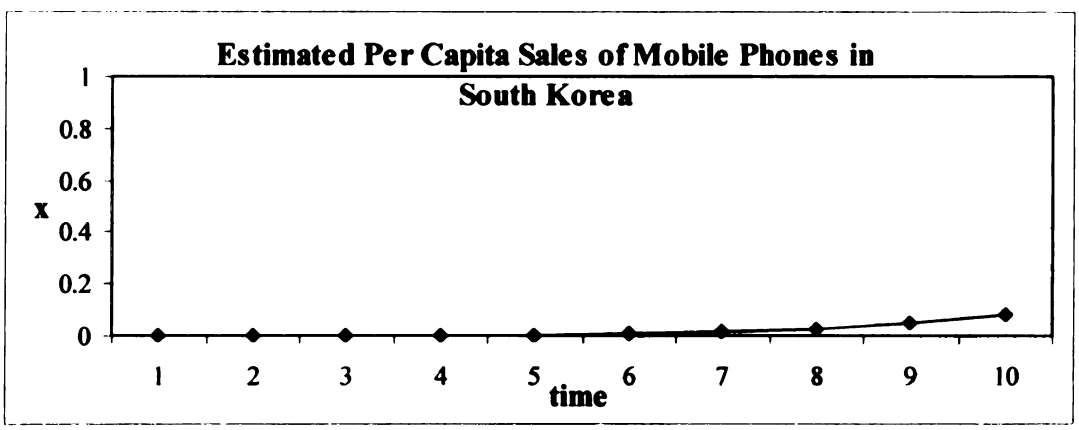
Estimated Per Capita Sales of Mobile Phones in South Africa
x
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10
time

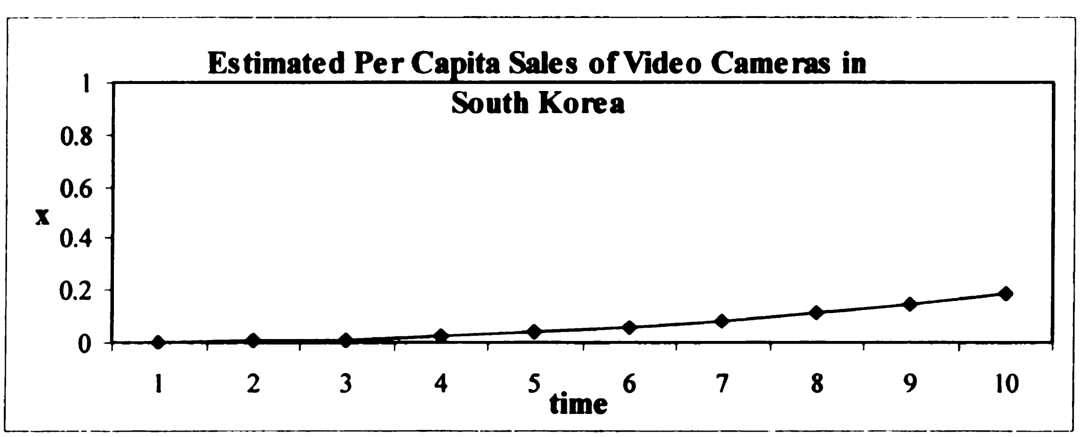


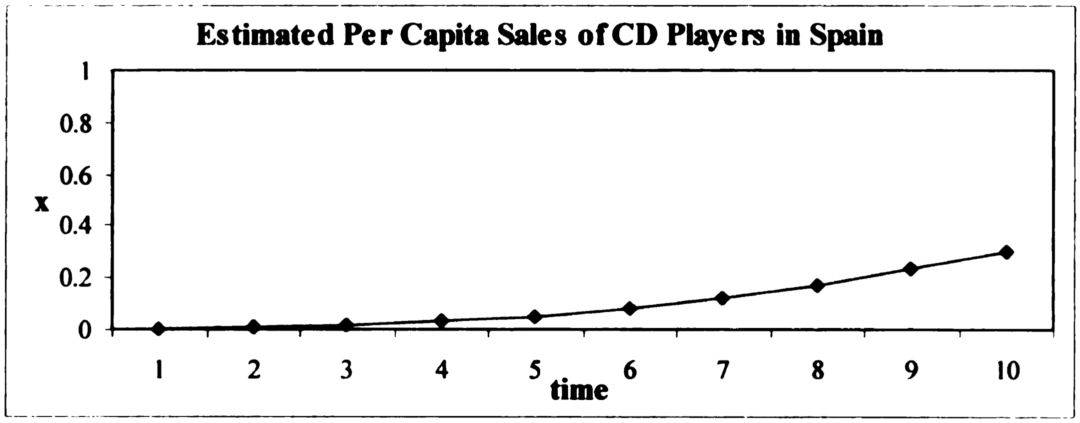
Estimated Per Capita Sales of Video Cameras in South Africa
x
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10
time

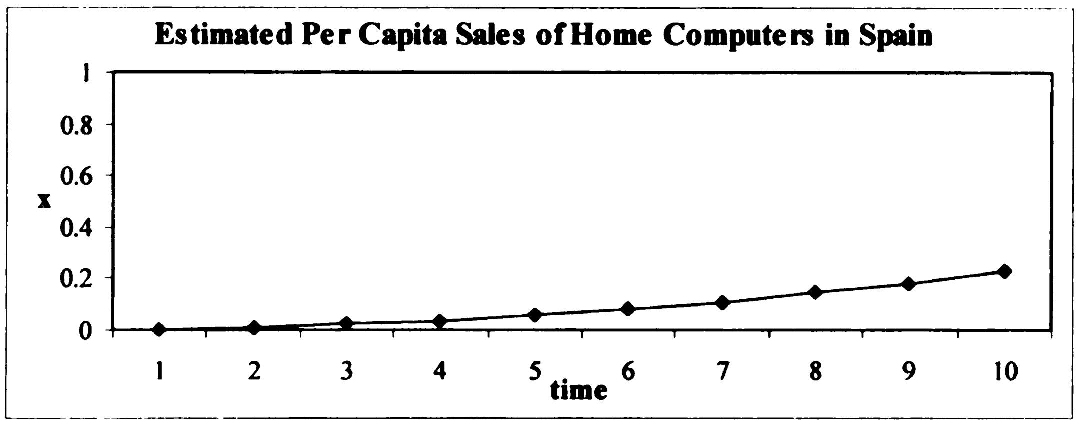

Estimated Per Capita Sales of CD Players in South Korea
x
time

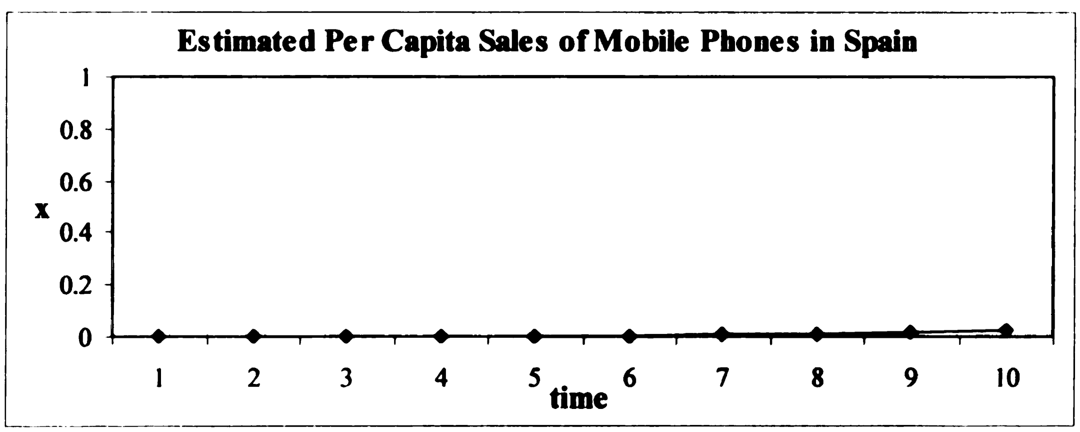

Estimated Per Capita Sales of Home Computers in South Korea
x
time

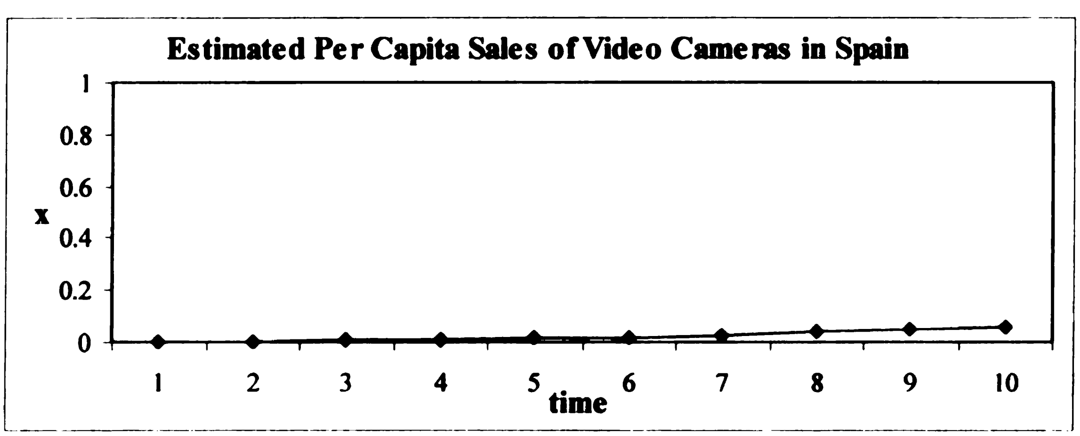

Estimated Per Capita Sales of Mobile Phones in South Korea
x
time

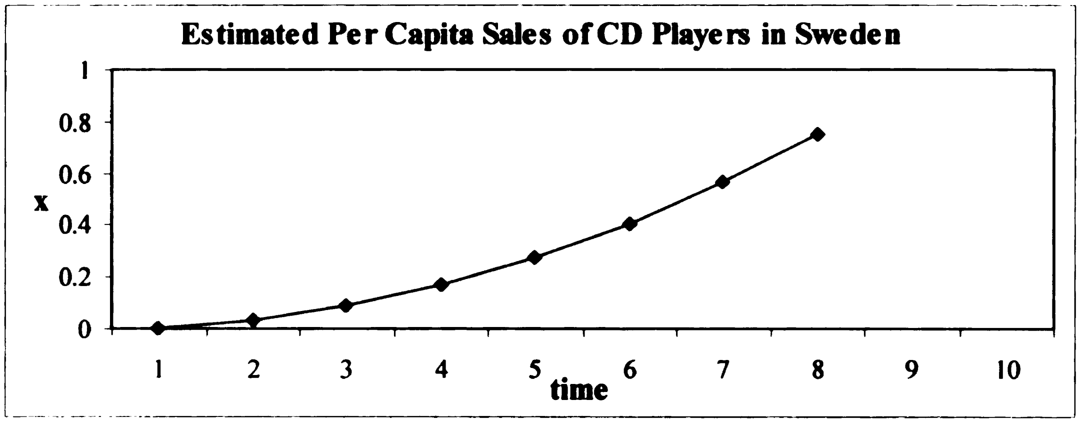

Estimated Per Capita Sales of Video Cameras in South Korea
x
time

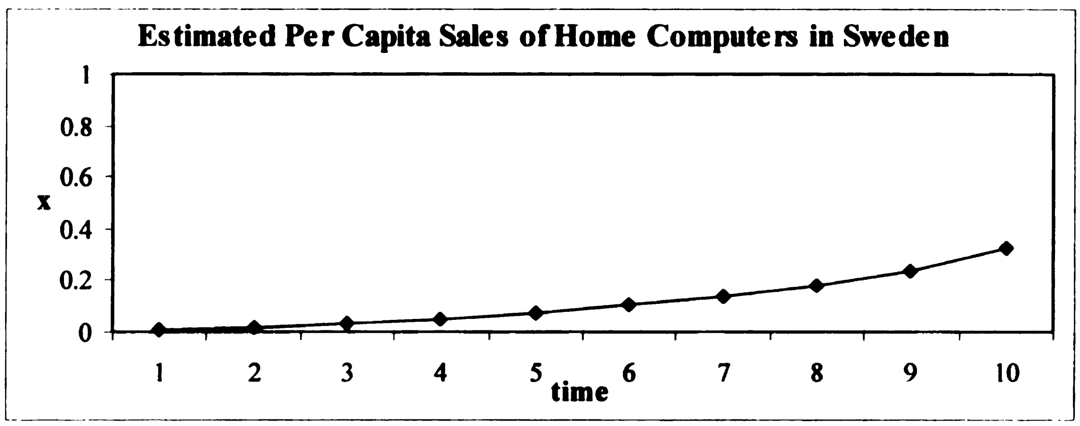

Estimated Per Capita Sales of CD Players in Spain
x
time

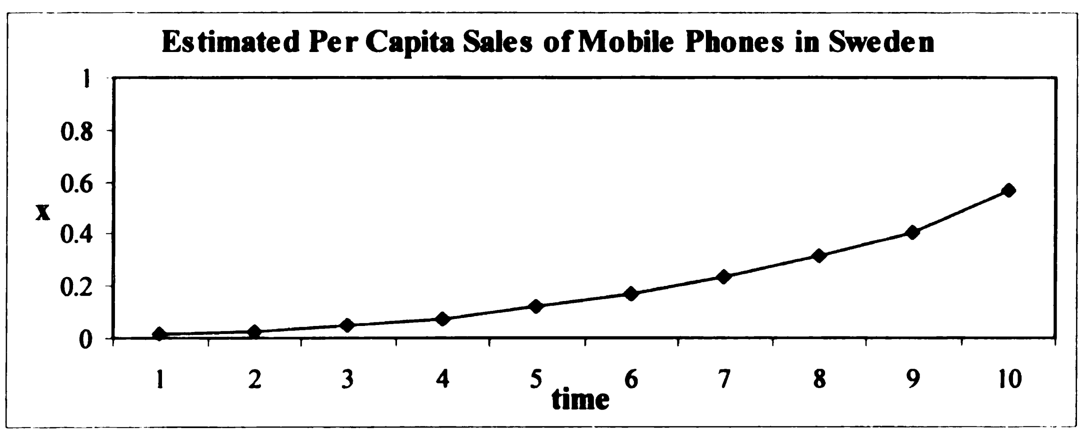

Estimated Per Capita Sales of Home Computers in Spain
x
time

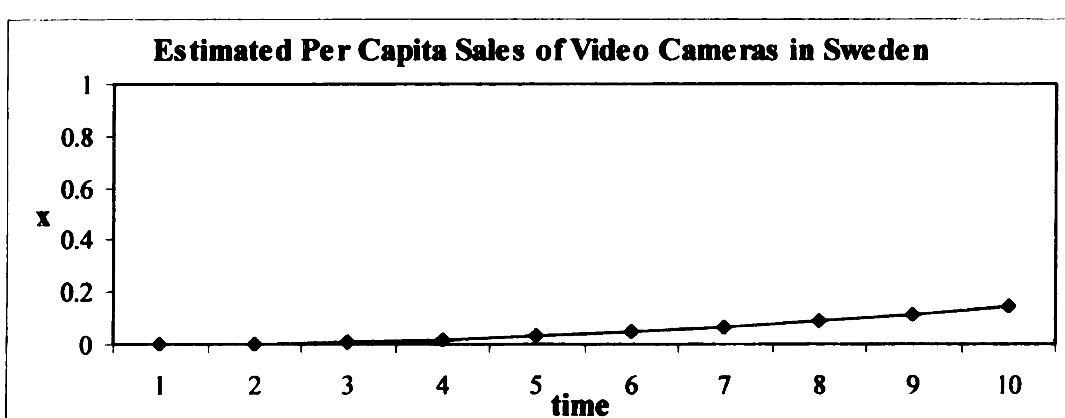

Estimated Per Capita Sales of Mobile Phones in Spain
x
time

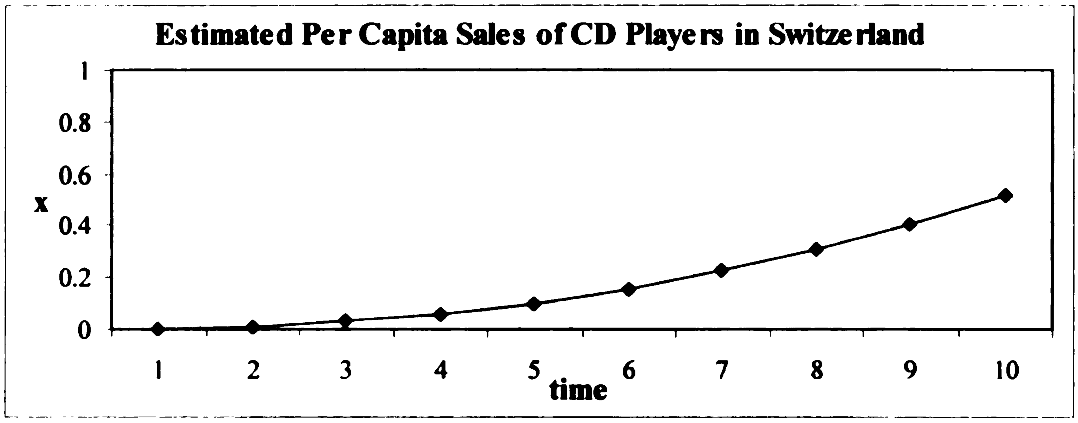

Estimated Per Capita Sales of Video Cameras in Spain
x
time


Estimated Per Capita Sales of CD Players in Sweden
x
time


Estimated Per Capita Sales of Home Computers in Sweden
x
time


Estimated Per Capita Sales of Mobile Phones in Sweden
x
time


Estimated Per Capita Sales of Video Cameras in Sweden
x
time


Estimated Per Capita Sales of CD Players in Switzerland
x
time
0
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0.4
0.6
0.8
1
1
2
3
4
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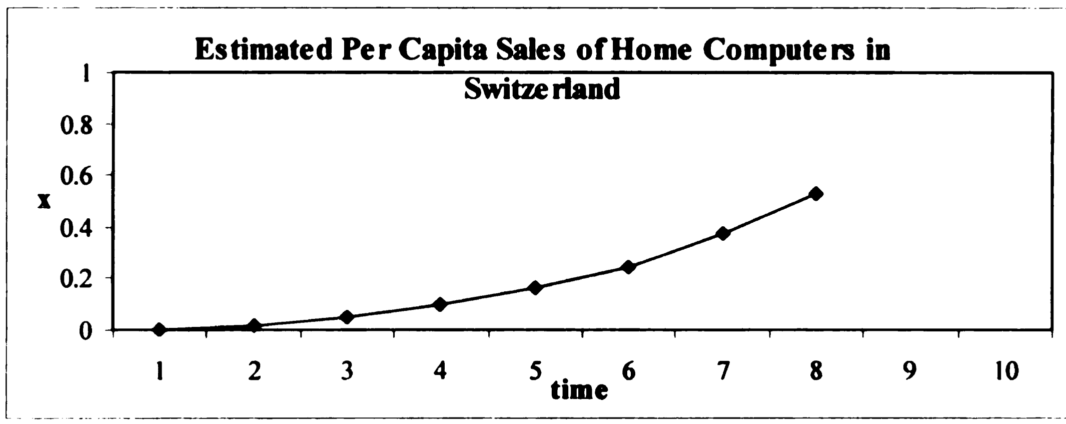
6
7
8
9
10


Estimated Per Capita Sales of Home Computers in Switzerland
x
time
0
0.2
0.4
0.6
0.8
1
1
2
3
4
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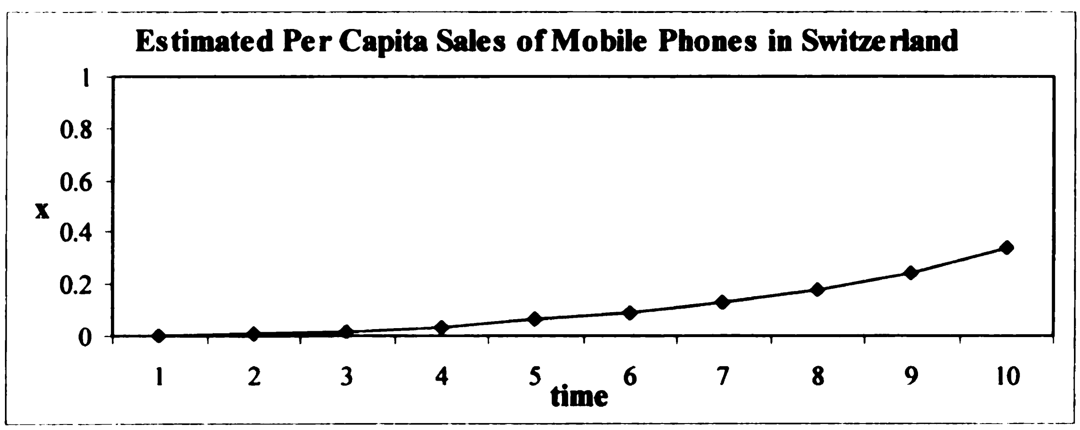
6
7
8
9
10


Estimated Per Capita Sales of Mobile Phones in Switzerland
x
time
0
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0.4
0.6
0.8
1
1
2
3
4
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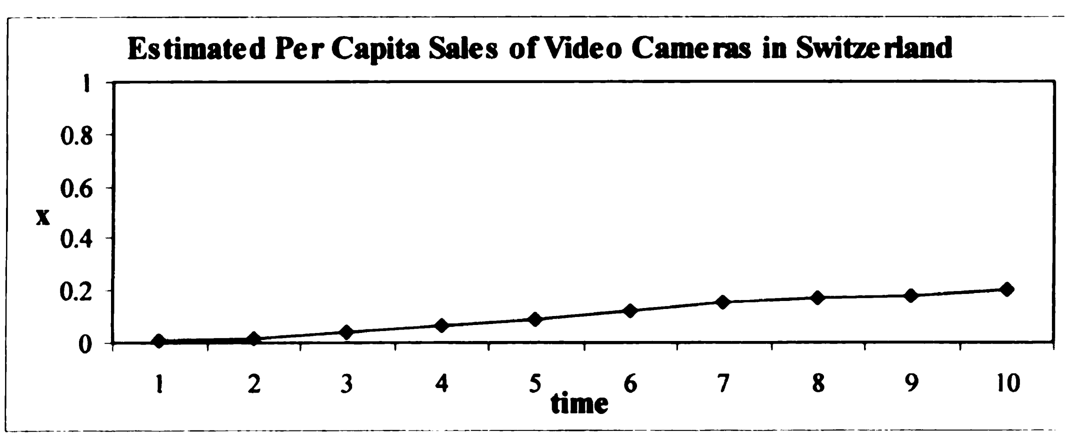
7
8
9
10


Estimated Per Capita Sales of Video Cameras in Switzerland
x
time
0
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0.4
0.6
0.8
1
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2
3
4
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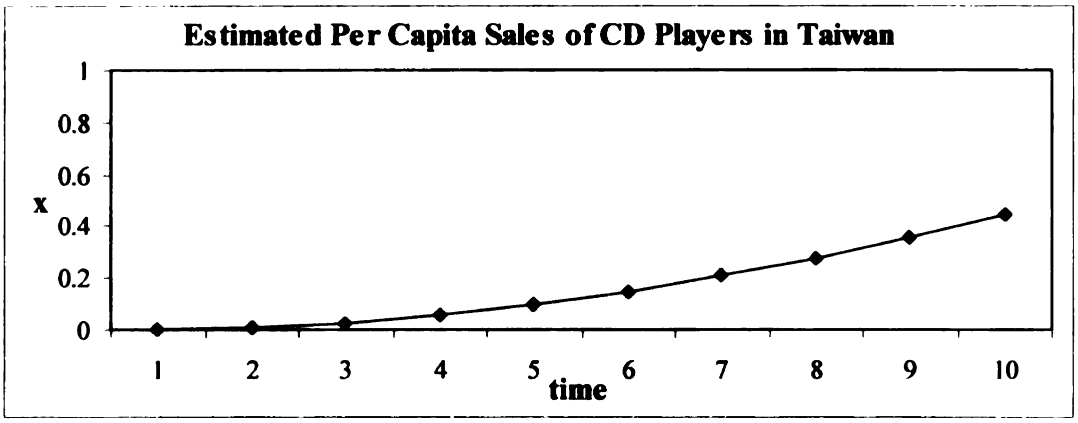
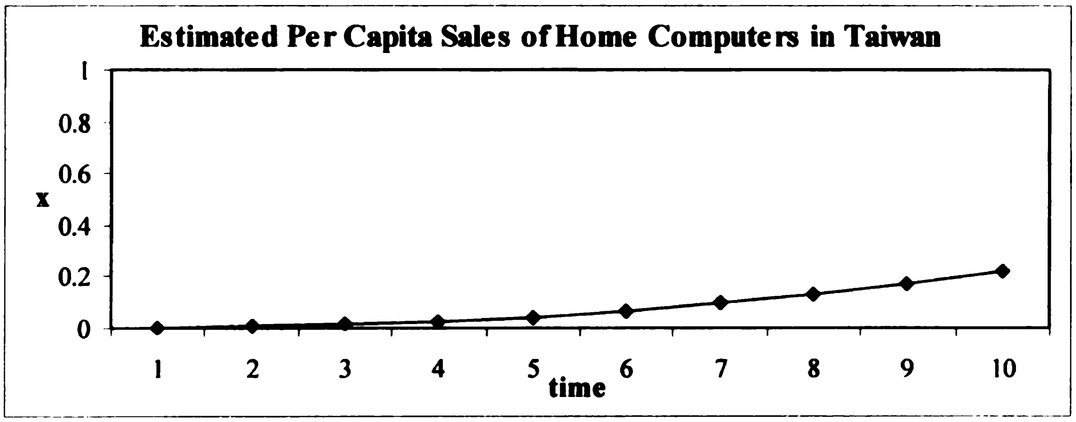
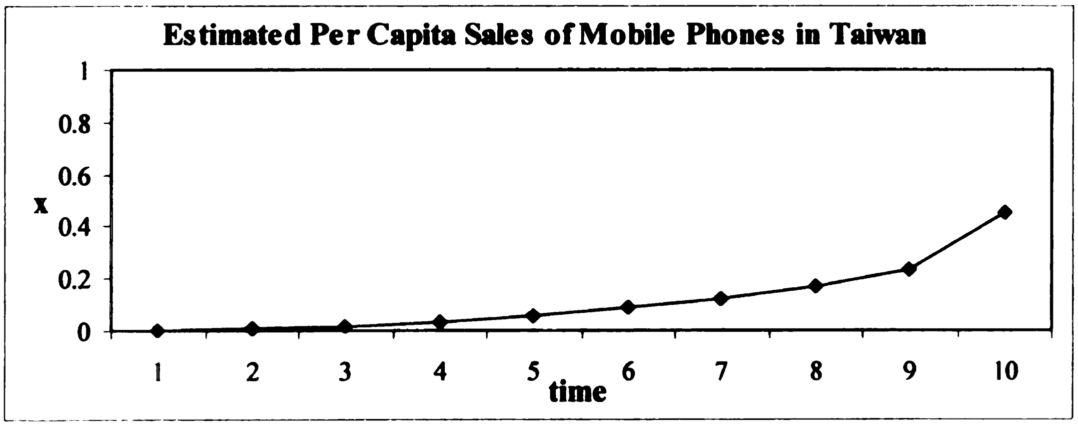
7
8
9
10



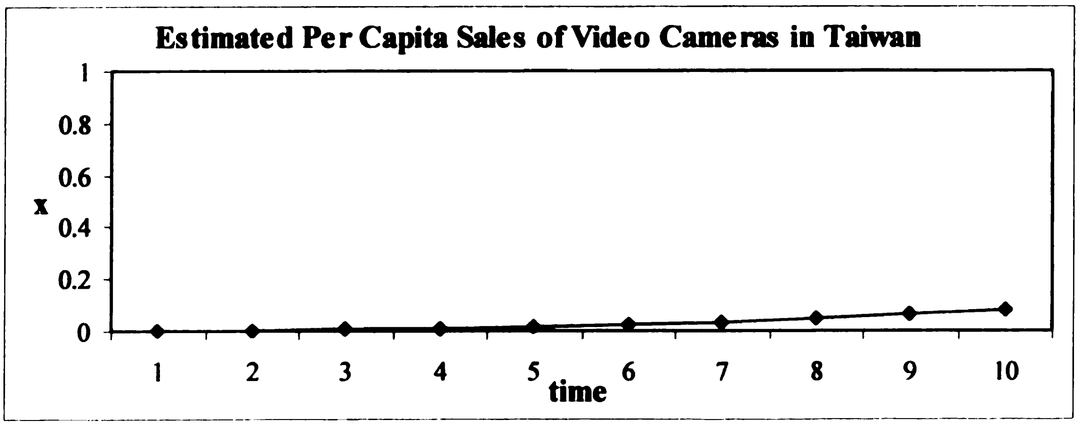
Estimated Per Capita Sales of CD Players in Taiwan
x
time



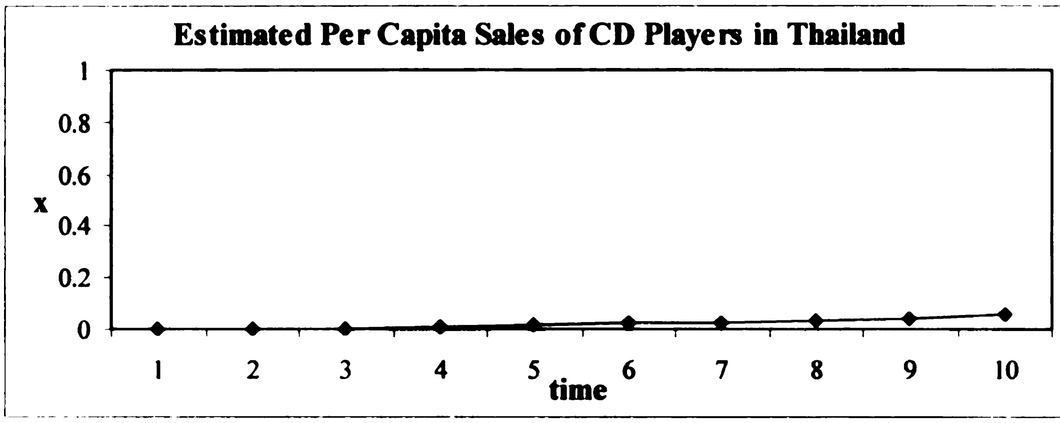
Estimated Per Capita Sales of Home Computers in Taiwan
x
time

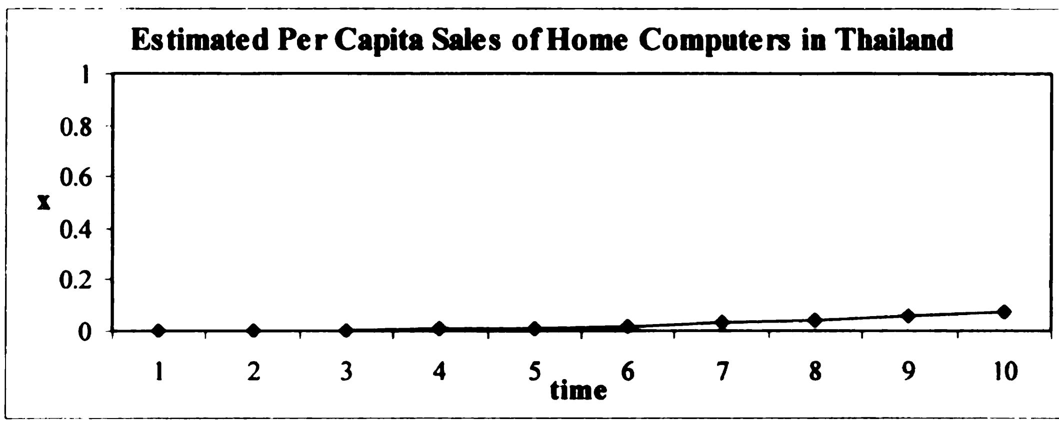


Estimated Per Capita Sales of Mobile Phones in Taiwan
x
time



Estimated Per Capita Sales of Video Cameras in Taiwan
x
time


Estimated Per Capita Sales of CD Players in Thailand
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10


Estimated Per Capita Sales of Home Computers in Thailand
x
time
0
0.2
0.4
0.6
0.8
1
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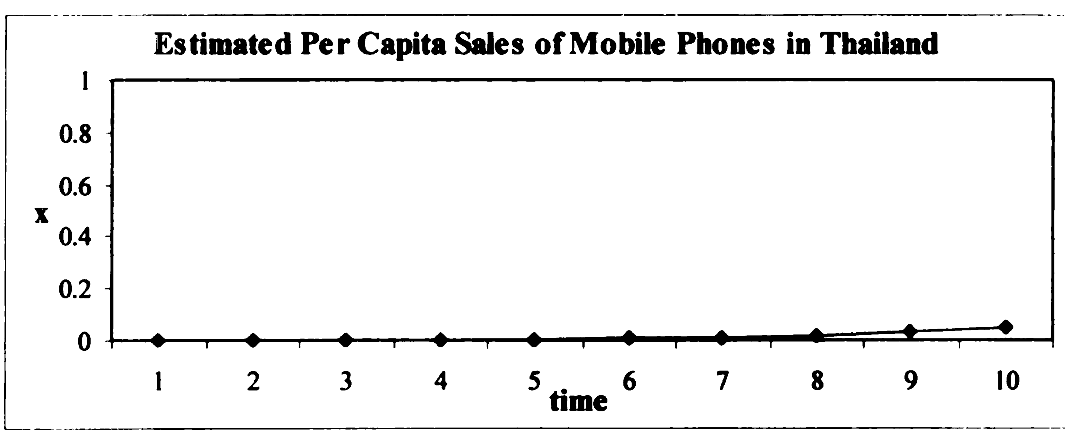
Estimated Per Capita Sales of Mobile Phones in Thailand
x
time
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0.4
0.6
0.8
1
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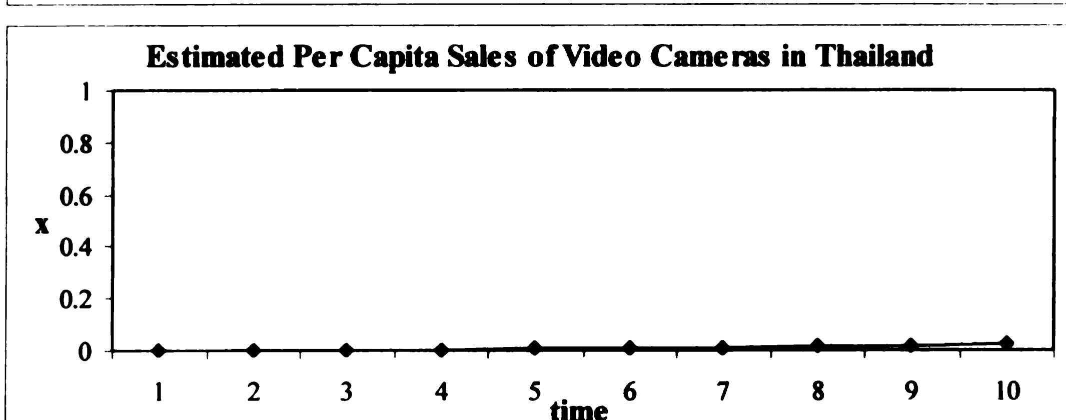
Estimated Per Capita Sales of Video Cameras in Thailand
x
time
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0.2
0.4
0.6
0.8
1
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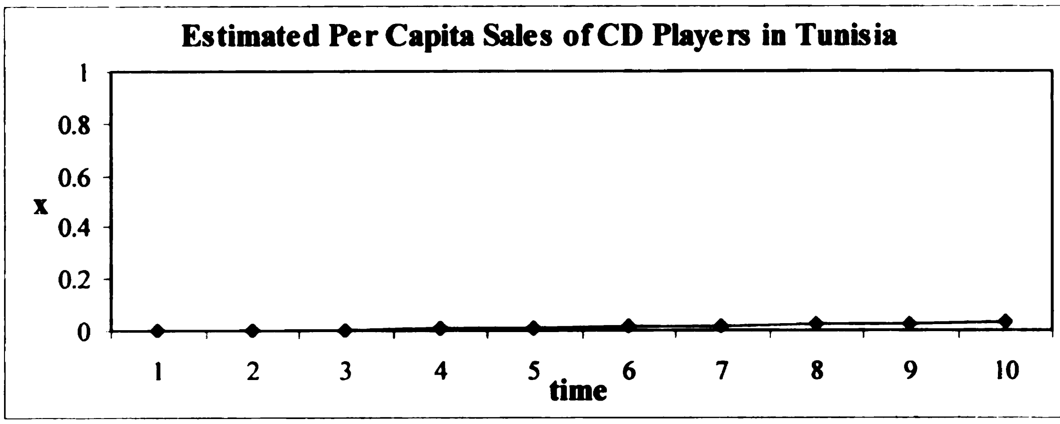
Estimated Per Capita Sales of CD Players in Tunisia
x
time
0
0.2
0.4
0.6
0.8
1
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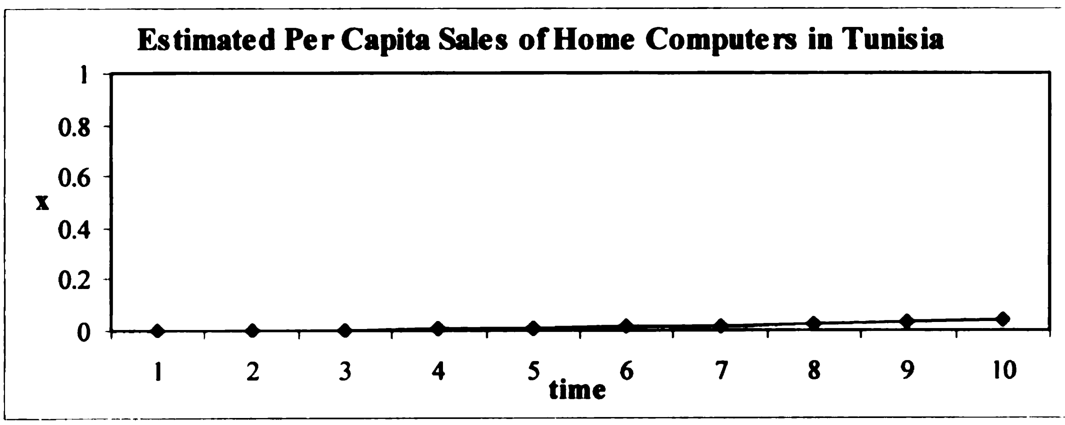
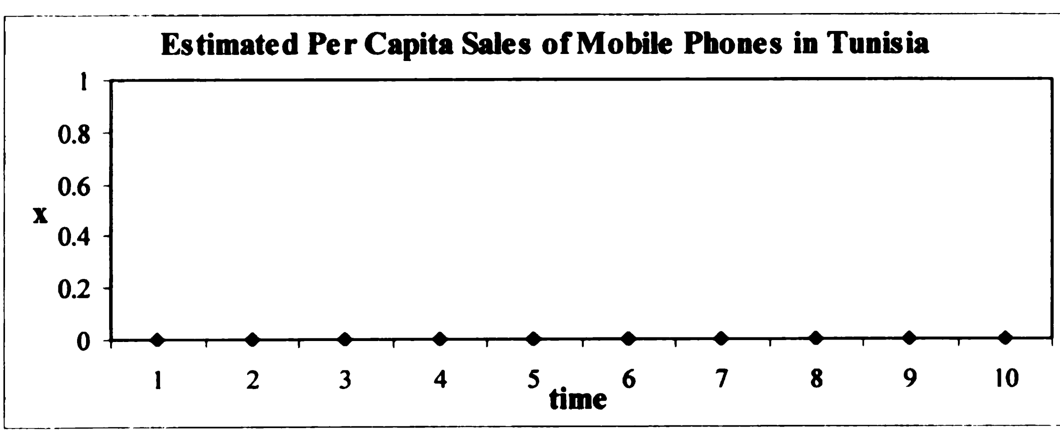
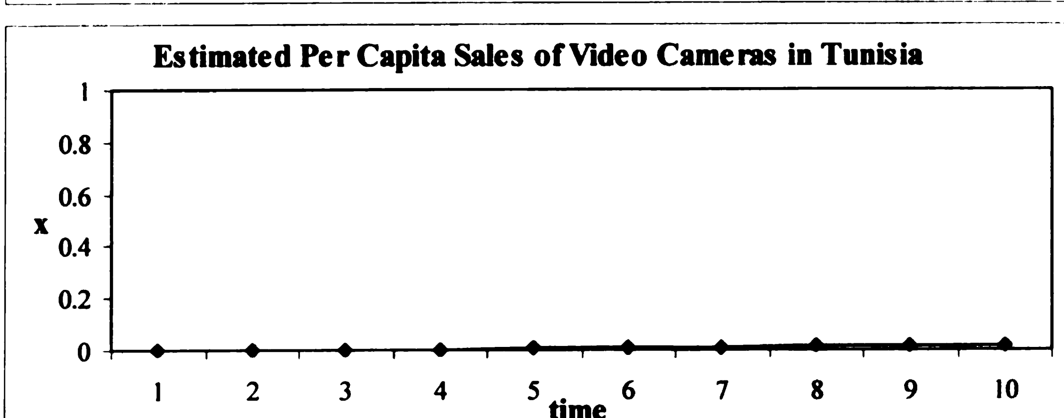
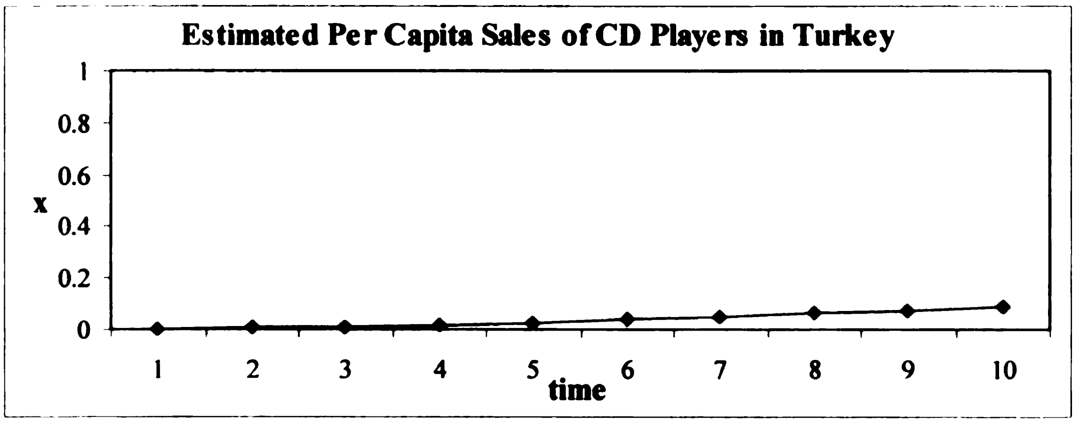
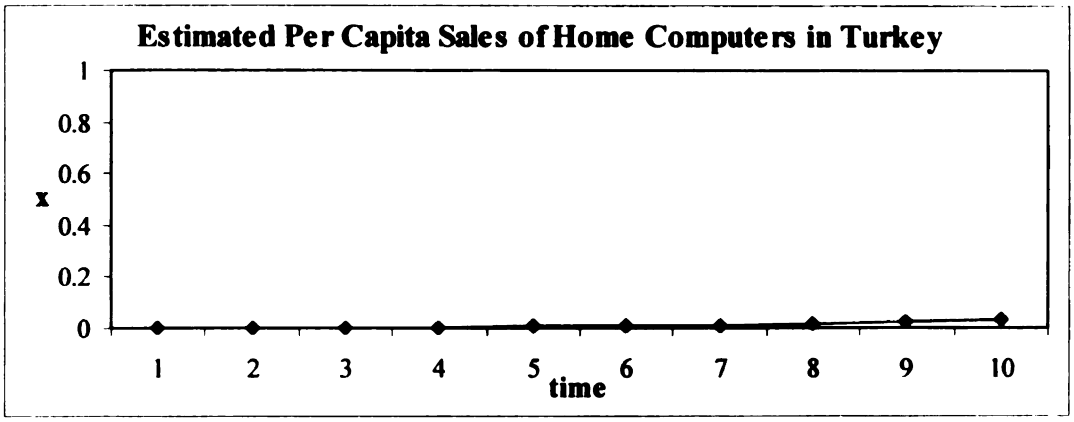
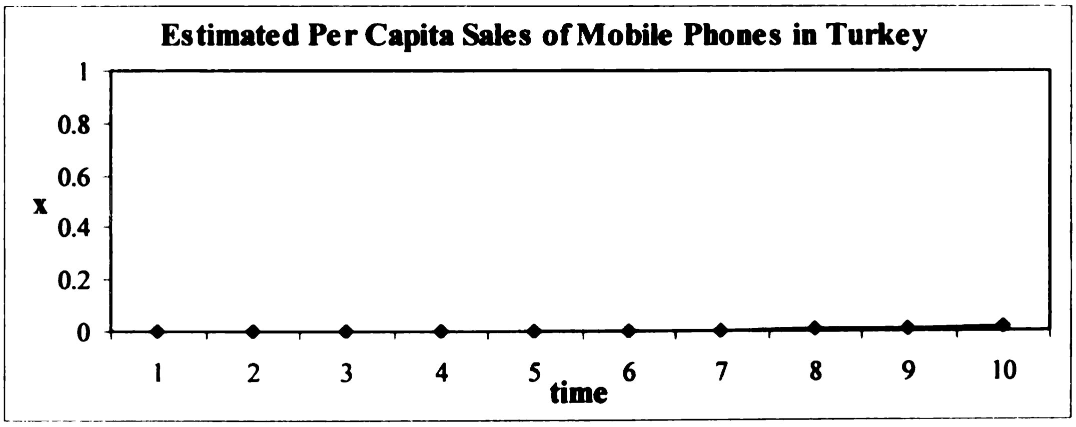

Estimated Per Capita Sales of Home Computers in Tunisia
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

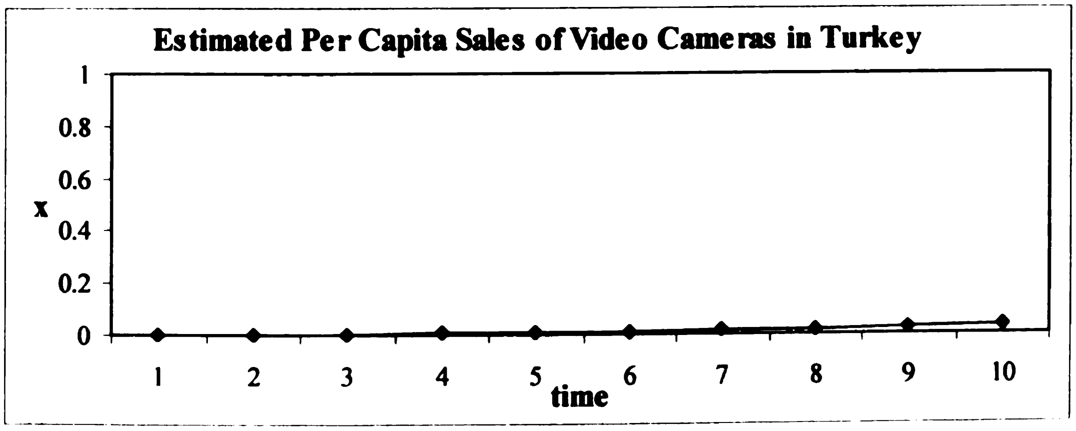

Estimated Per Capita Sales of Mobile Phones in Tunisia
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

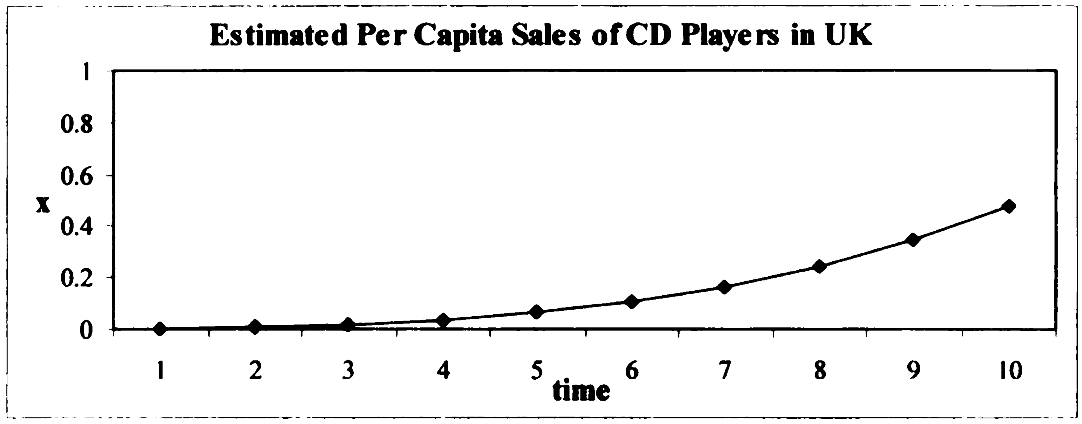

Estimated Per Capita Sales of Video Cameras in Tunisia
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

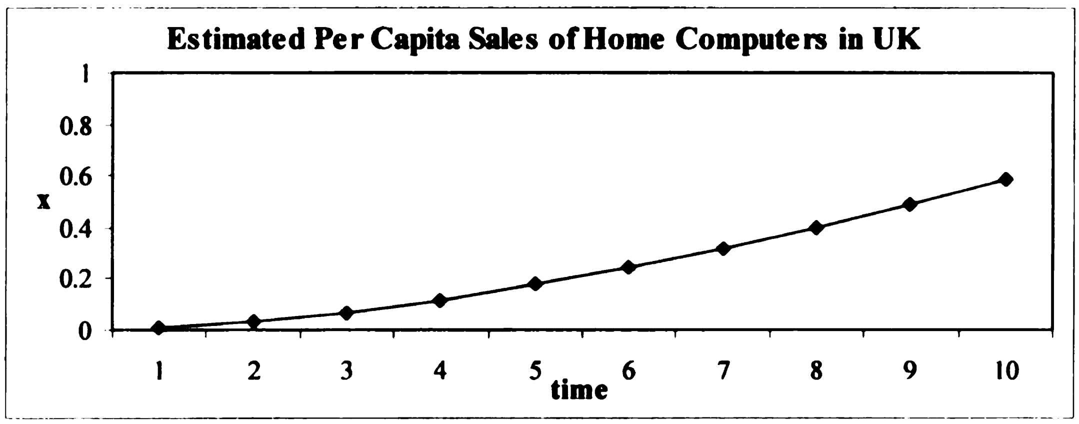

Estimated Per Capita Sales of CD Players in Turkey
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

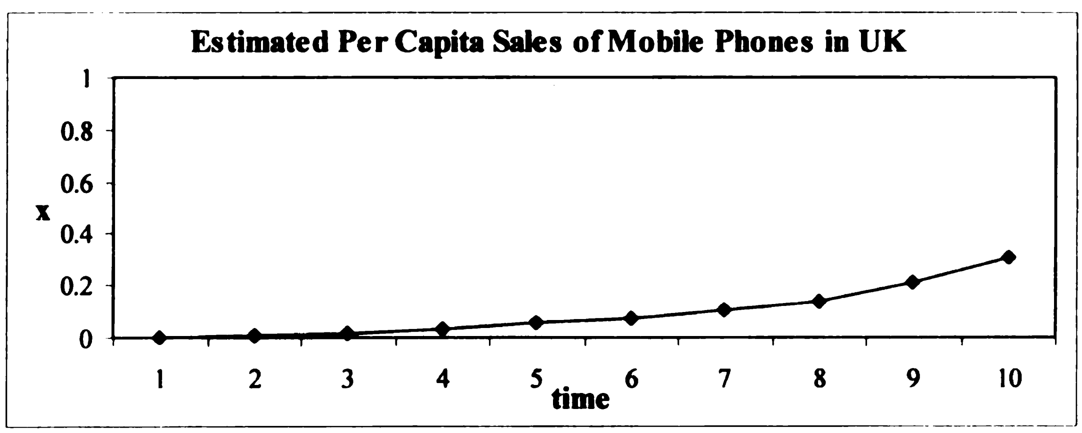

Estimated Per Capita Sales of Home Computers in Turkey
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

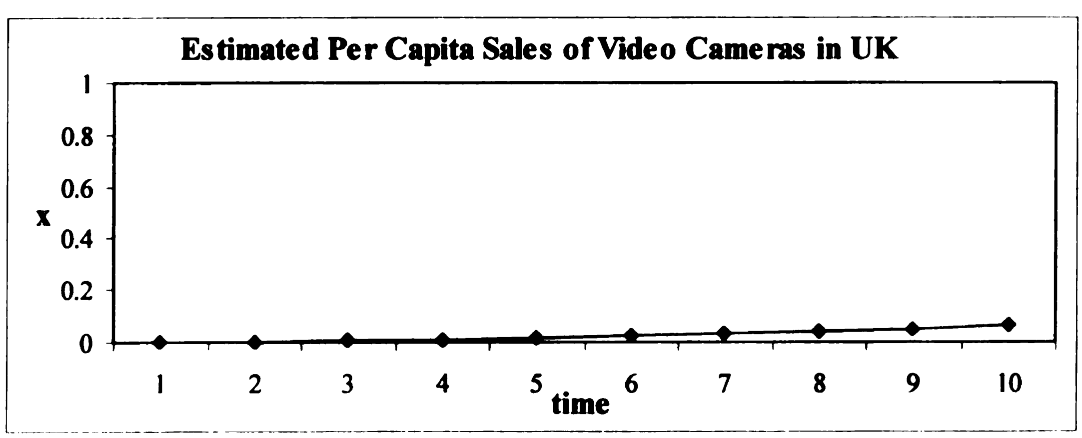

Estimated Per Capita Sales of Mobile Phones in Turkey
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

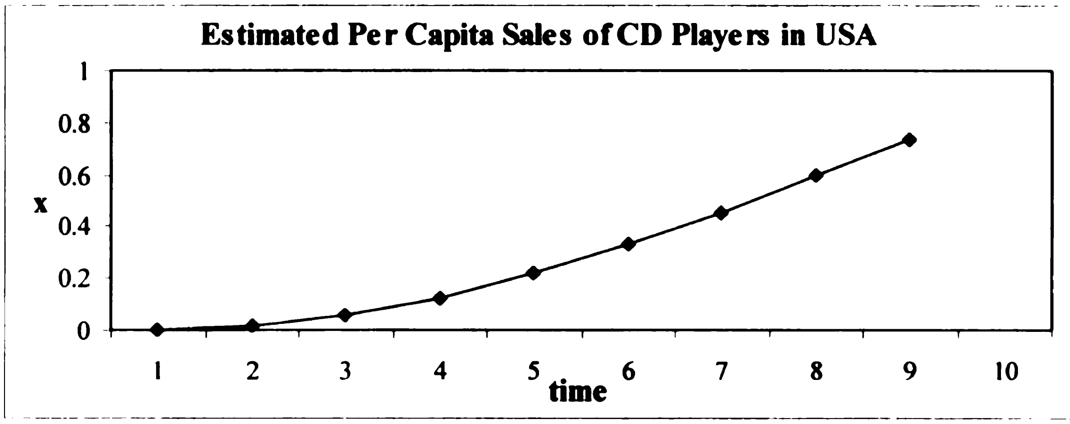

Estimated Per Capita Sales of Video Cameras in Turkey
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

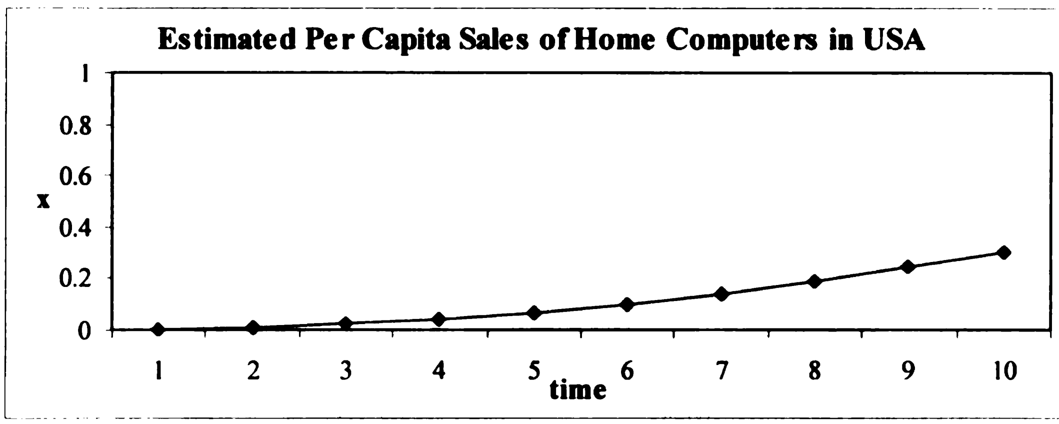

Estimated Per Capita Sales of CD Players in UK
x
time

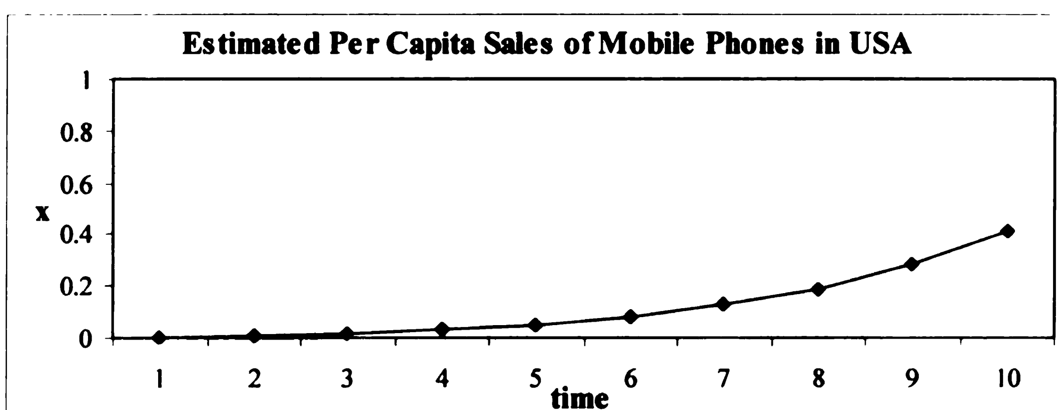

Estimated Per Capita Sales of Home Computers in UK
x
time

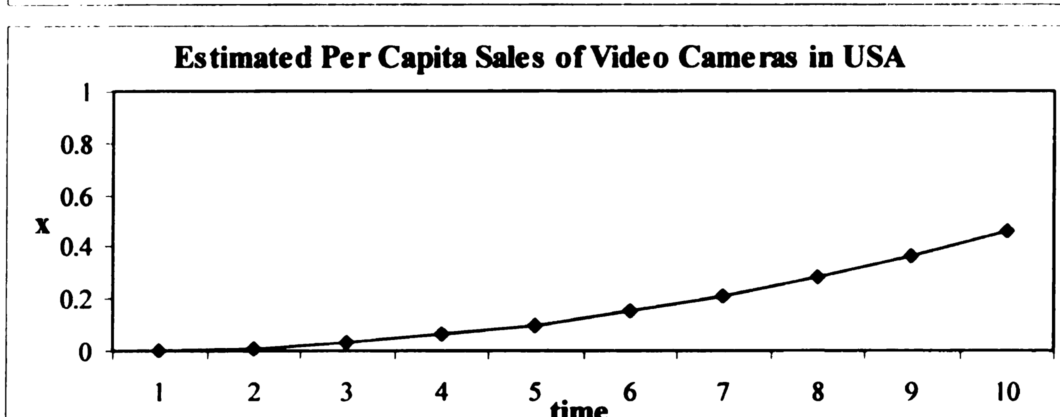

Estimated Per Capita Sales of Mobile Phones in UK
x
time


Estimated Per Capita Sales of Video Cameras in UK
x
time


Estimated Per Capita Sales of CD Players in USA
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

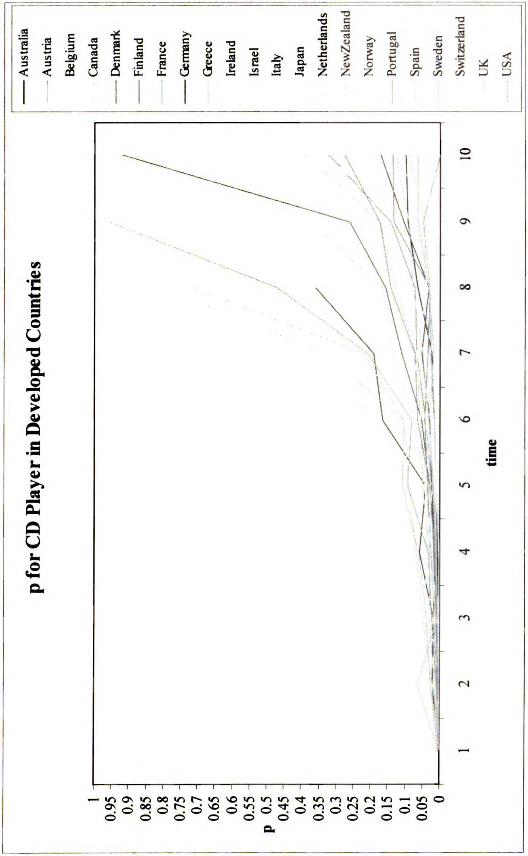

Estimated Per Capita Sales of Home Computers in USA
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10


Estimated Per Capita Sales of Mobile Phones in USA
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

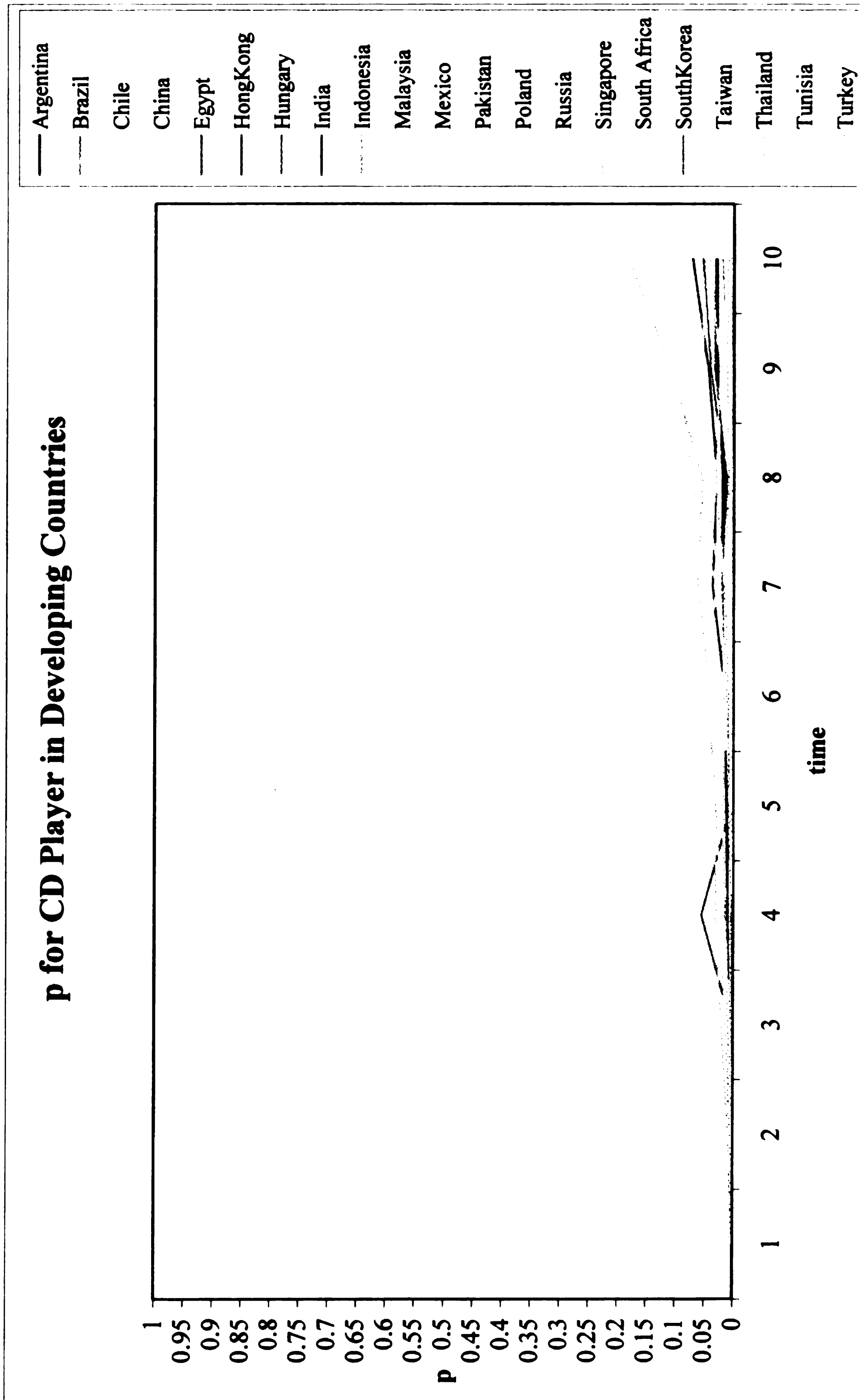

Estimated Per Capita Sales of Video Cameras in USA
x
time
0
0.2
0.4
0.6
0.8
1
1 2 3 4 5 6 7 8 9 10

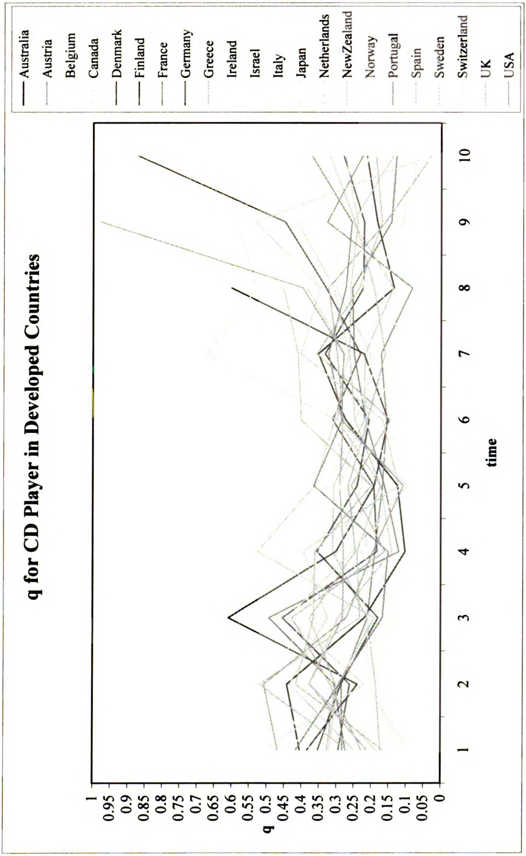
APPENDIX D

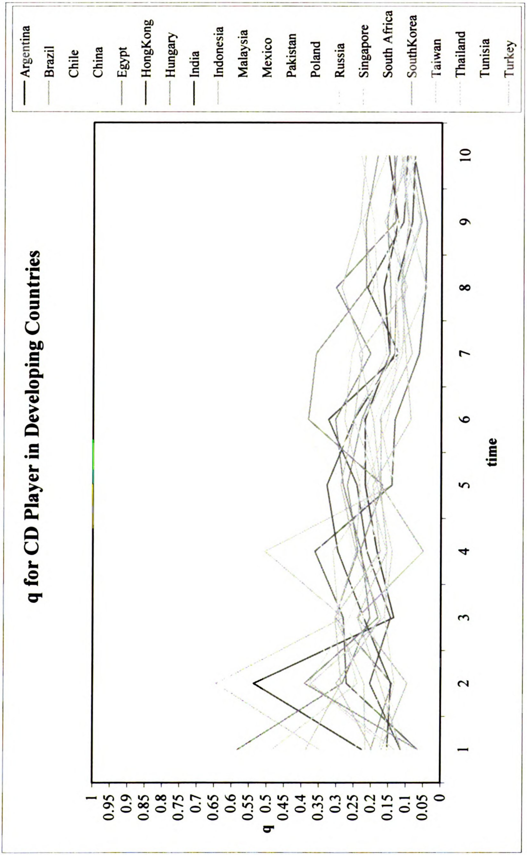
p and *q* Over Time in Developed Countries and Developing Countries for Each Product

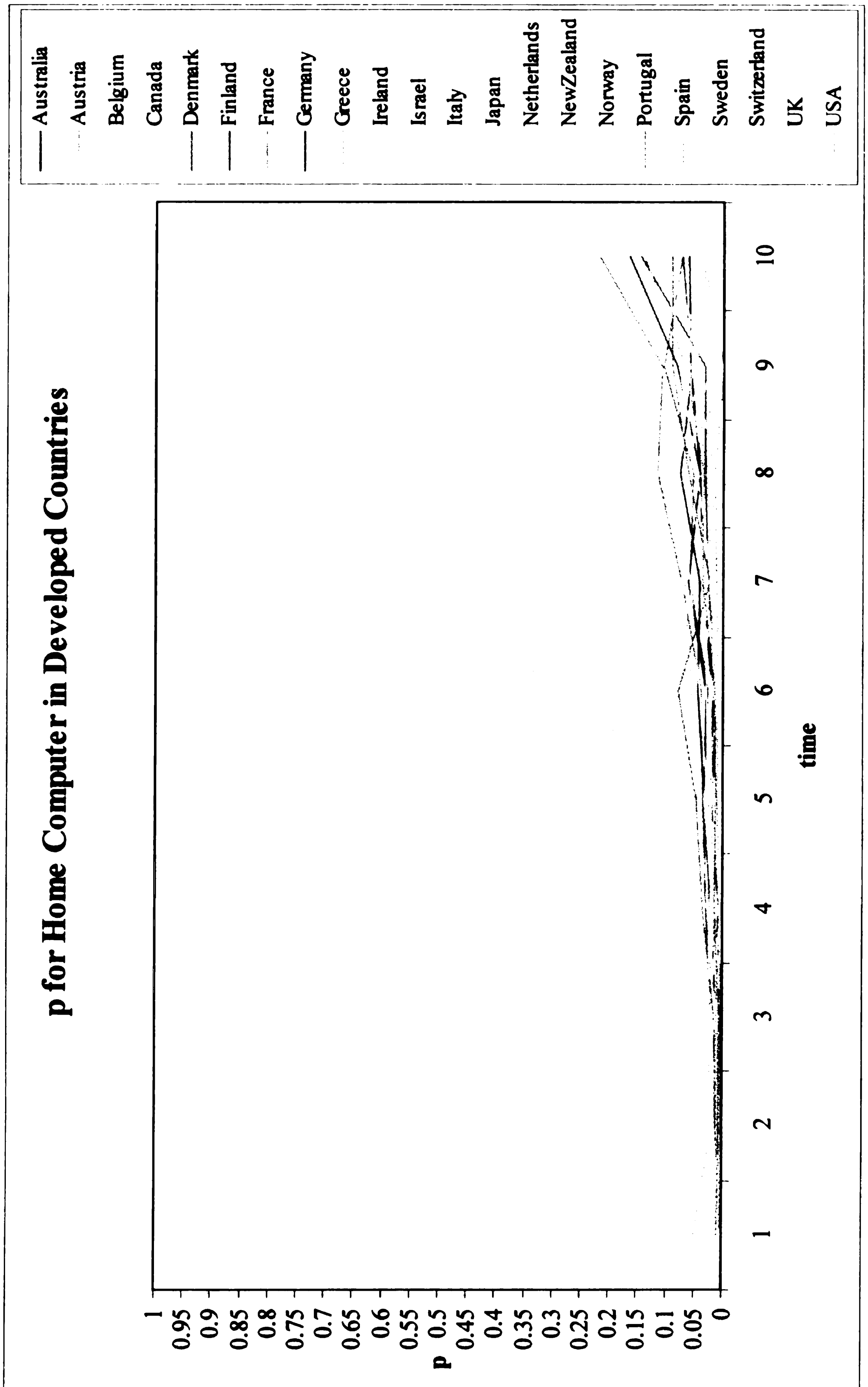


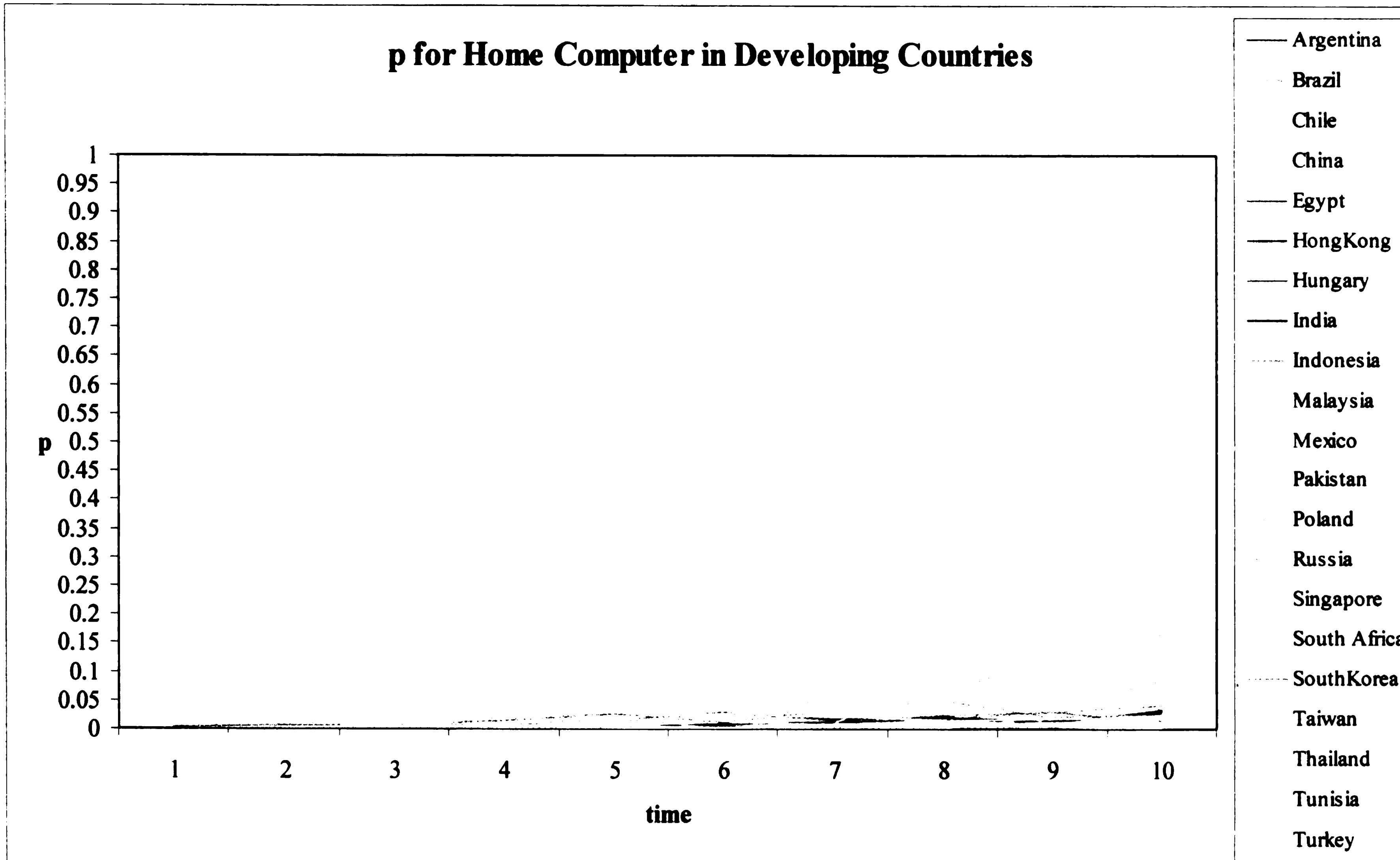
p for CD Player in Developed Countries
p
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Israel
Italy
Japan
Netherlands
NewZealand
Norway
Portugal
Spain
Sweden
Switzerland
UK
USA

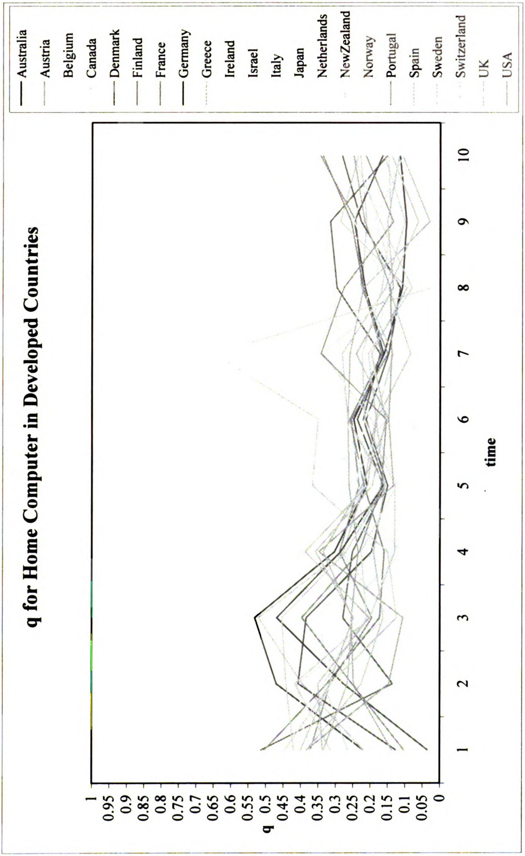

p for CD Player in Developing Countries
p
time
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
Argentina
Brazil
Chile
China
Egypt
HongKong
Hungary
India
Indonesia
Malaysia
Mexico
Pakistan
Poland
Russia
Singapore
South Africa
SouthKorea
Taiwan
Thailand
Tunisia
Turkey

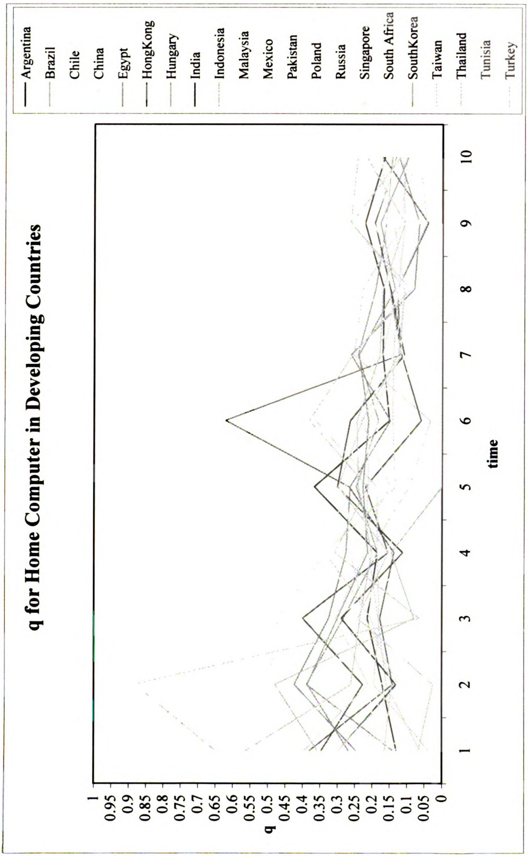

q for CD Player in Developed Countries
q
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Israel
Italy
Japan
Netherlands
NewZealand
Norway
Portugal
Spain
Sweden
Switzerland
UK
USA


q for CD Player in Developing Countries
q
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Argentina
Brazil
Chile
China
Egypt
HongKong
Hungary
India
Indonesia
Malaysia
Mexico
Pakistan
Poland
Russia
Singapore
South Africa
SouthKorea
Taiwan
Thailand
Tunisia
Turkey

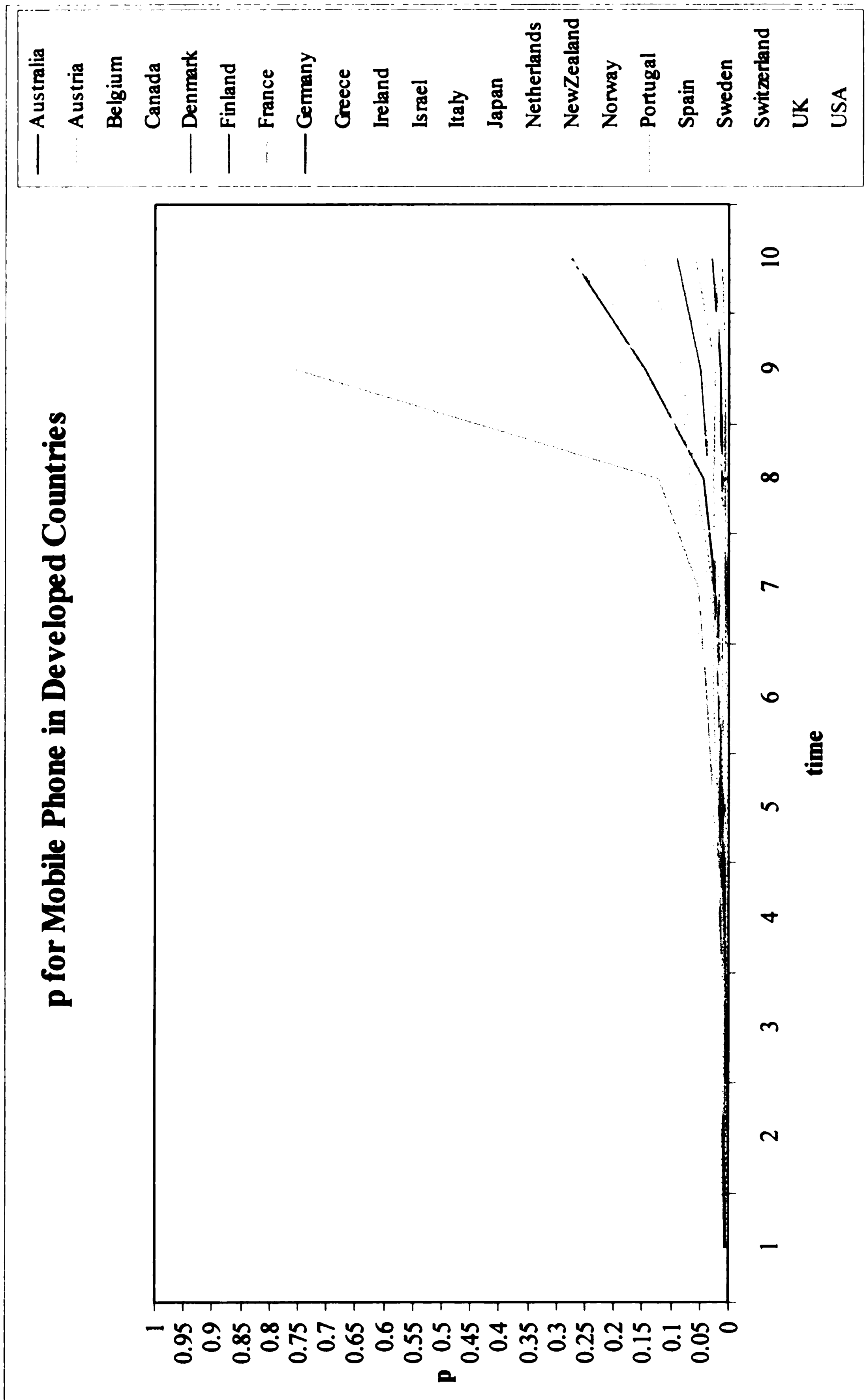

p for Home Computer in Developed Countries
p
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Israel
Italy
Japan
Netherlands
NewZealand
Norway
Portugal
Spain
Sweden
Switzerland
UK
USA


p for Home Computer in Developing Countries
p
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Argentina
Brazil
Chile
China
Egypt
HongKong
Hungary
India
Indonesia
Malaysia
Mexico
Pakistan
Poland
Russia
Singapore
South Africa
SouthKorea
Taiwan
Thailand
Tunisia
Turkey

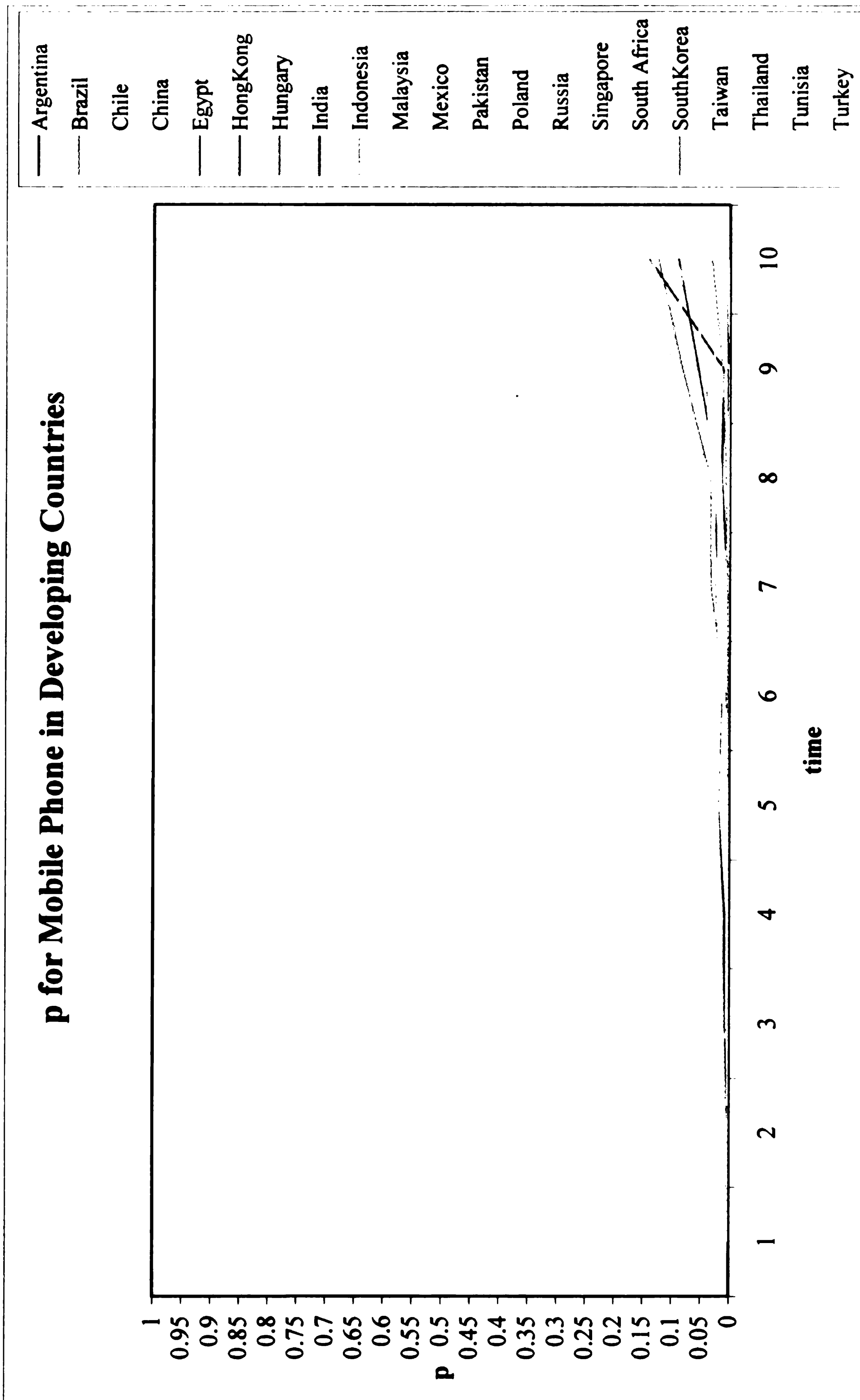

q for Home Computer in Developed Countries
q
time
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Israel
Italy
Japan
Netherlands
NewZealand
Norway
Portugal
Spain
Sweden
Switzerland
UK
USA

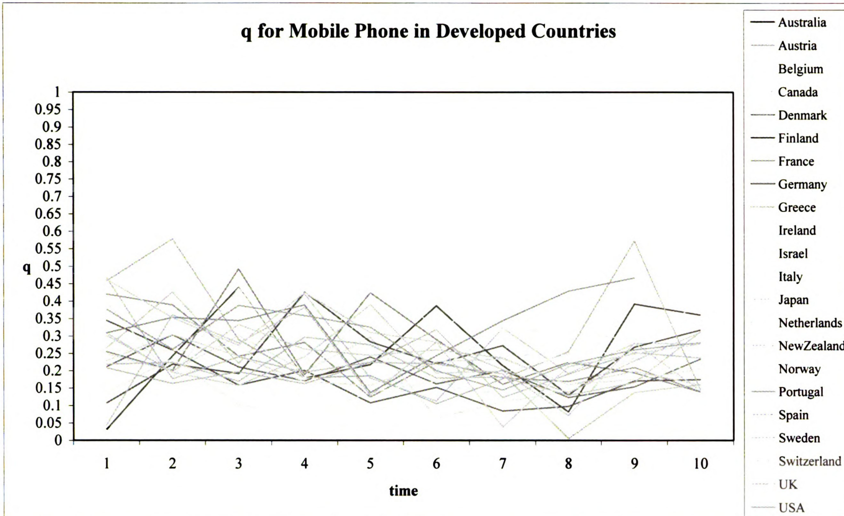


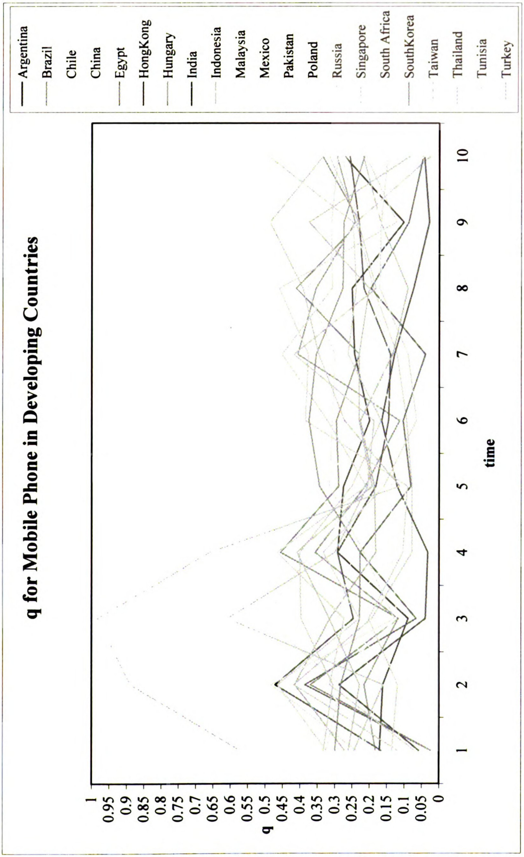
q for Home Computer in Developing Countries
q
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
time
1
2
3
4
5
6
7
8
9
10
Argentina
Brazil
Chile
China
Egypt
HongKong
Hungary
India
Indonesia
Malaysia
Mexico
Pakistan
Poland
Russia
Singapore
South Africa
SouthKorea
Taiwan
Thailand
Tunisia
Turkey



p for Mobile Phone in Developed Countries
p
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
time
1
2
3
4
5
6
7
8
9
10
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Israel
Italy
Japan
Netherlands
NewZealand
Norway
Portugal
Spain
Sweden
Switzerland
UK
USA


p for Mobile Phone in Developing Countries
p
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Argentina
Brazil
Chile
China
Egypt
HongKong
Hungary
India
Indonesia
Malaysia
Mexico
Pakistan
Poland
Russia
Singapore
South Africa
SouthKorea
Taiwan
Thailand
Tunisia
Turkey


q for Mobile Phone in Developed Countries
q
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Israel
Italy
Japan
Netherlands
NewZealand
Norway
Portugal
Spain
Sweden
Switzerland
UK
USA


q for Mobile Phone in Developing Countries
q
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Argentina
Brazil
Chile
China
Egypt
HongKong
Hungary
India
Indonesia
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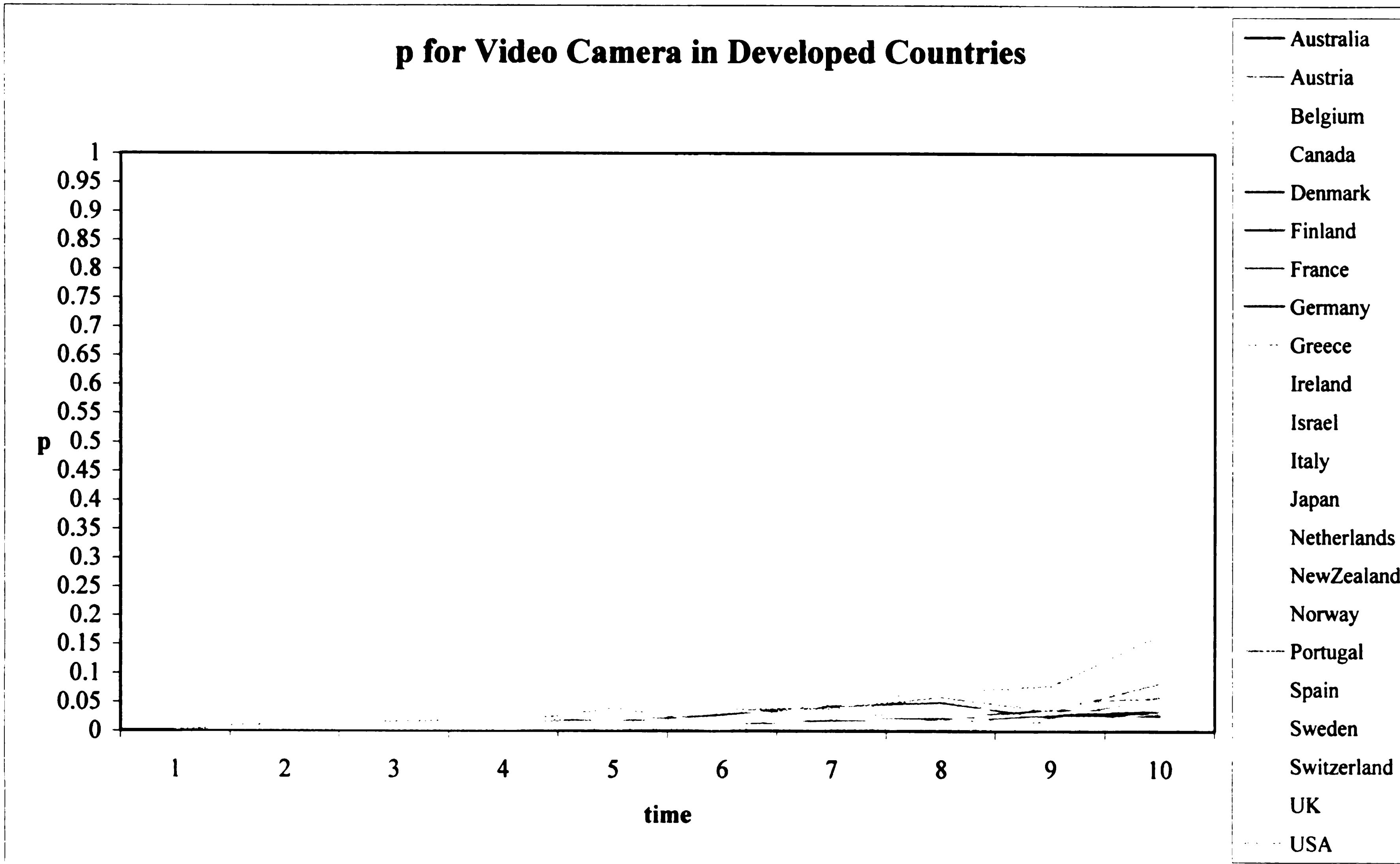
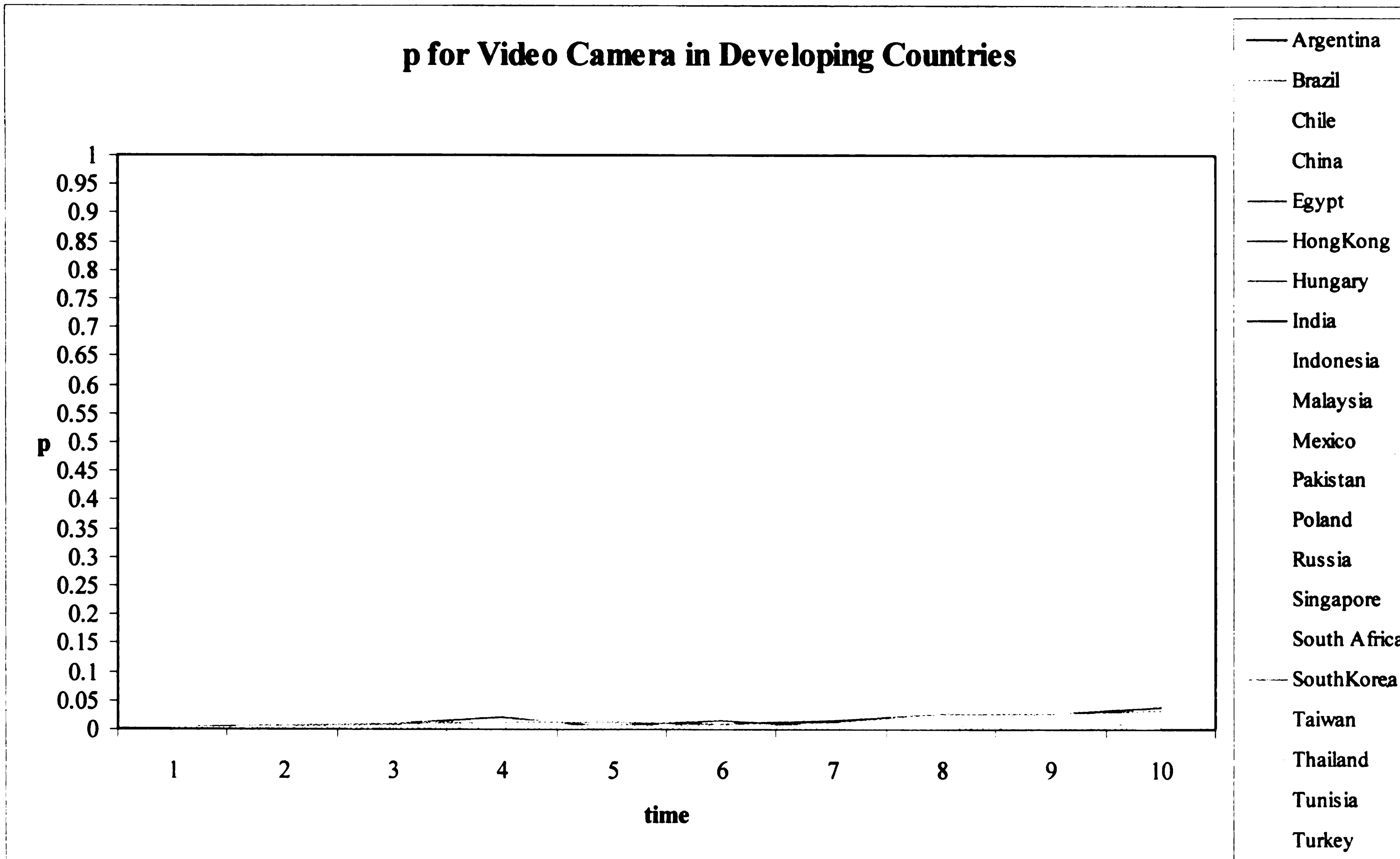
Mexico
Pakistan
Poland
Russia
Singapore
South Africa
SouthKorea
Taiwan
Thailand
Tunisia
Turkey


p for Video Camera in Developed Countries
p
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Israel
Italy
Japan
Netherlands
NewZealand
Norway
Portugal
Spain
Sweden
Switzerland
UK
USA


p for Video Camera in Developing Countries
p
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Argentina
Brazil
Chile
China
Egypt
HongKong
Hungary
India
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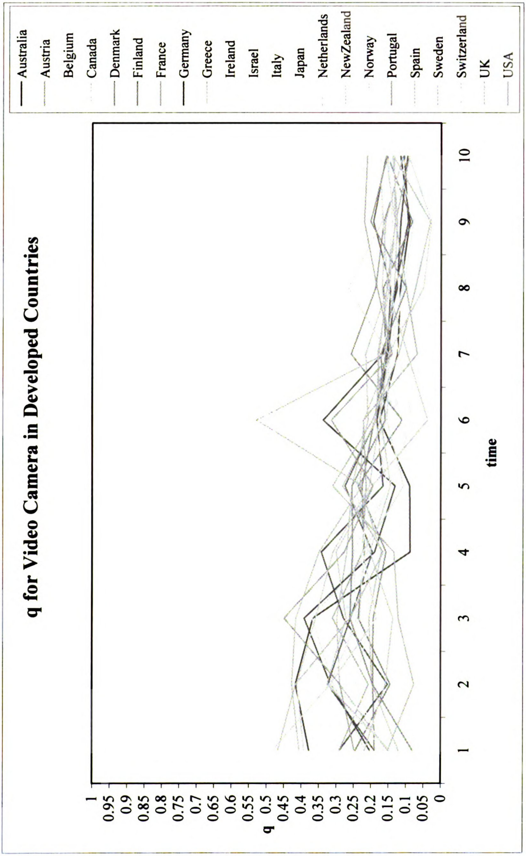
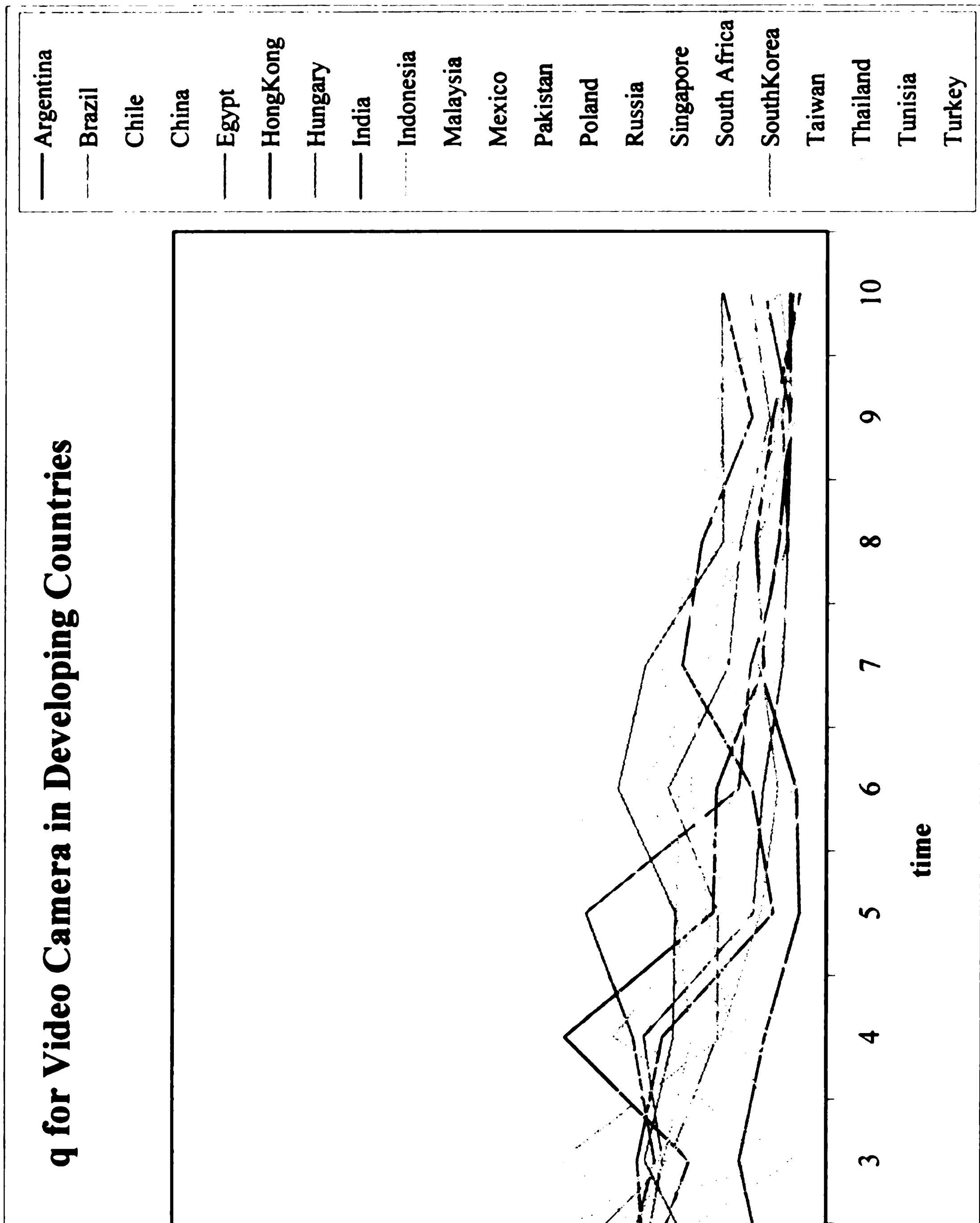
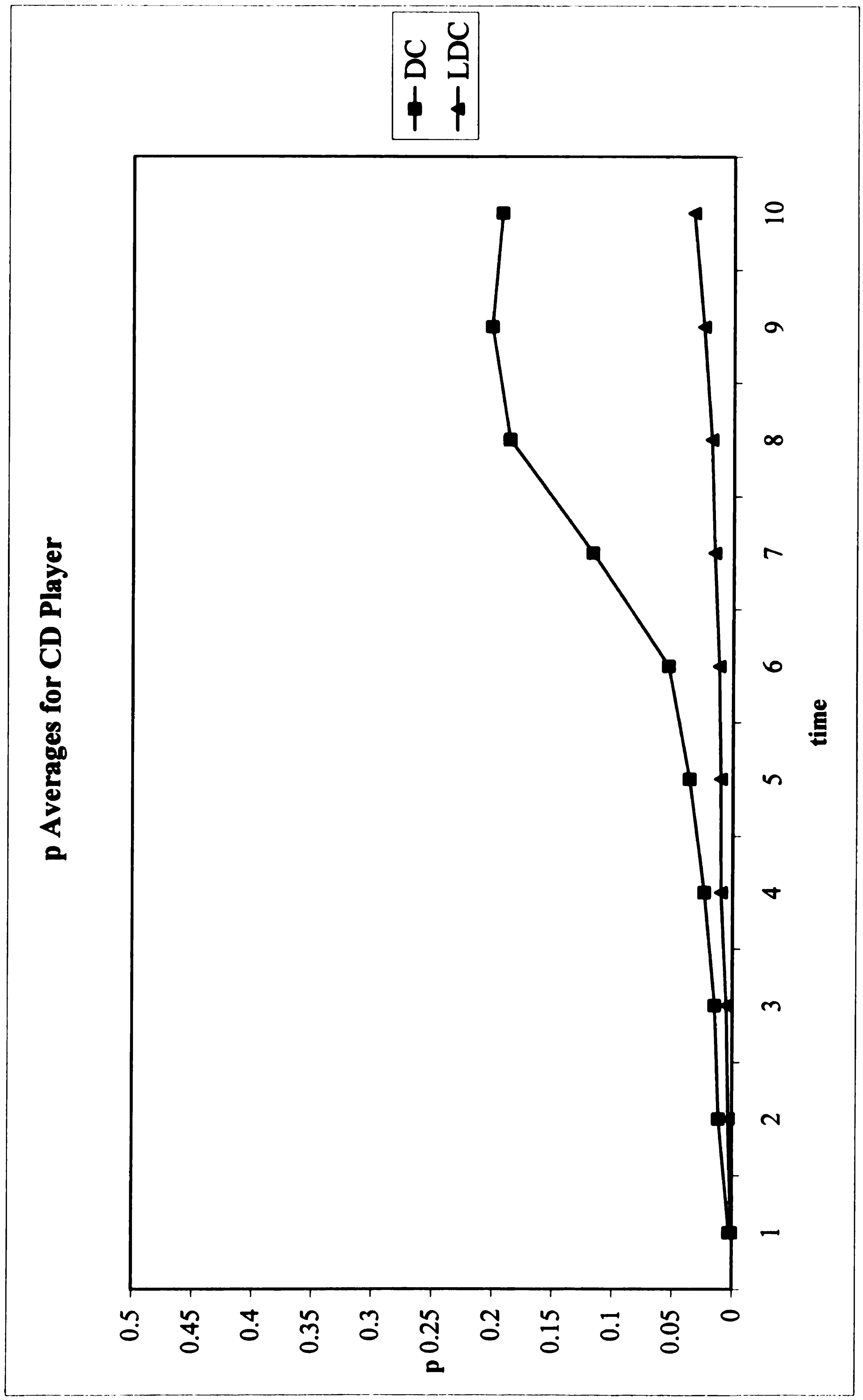
Malaysia
Mexico
Pakistan
Poland
Russia
Singapore
South Africa
SouthKorea
Taiwan
Thailand
Tunisia
Turkey

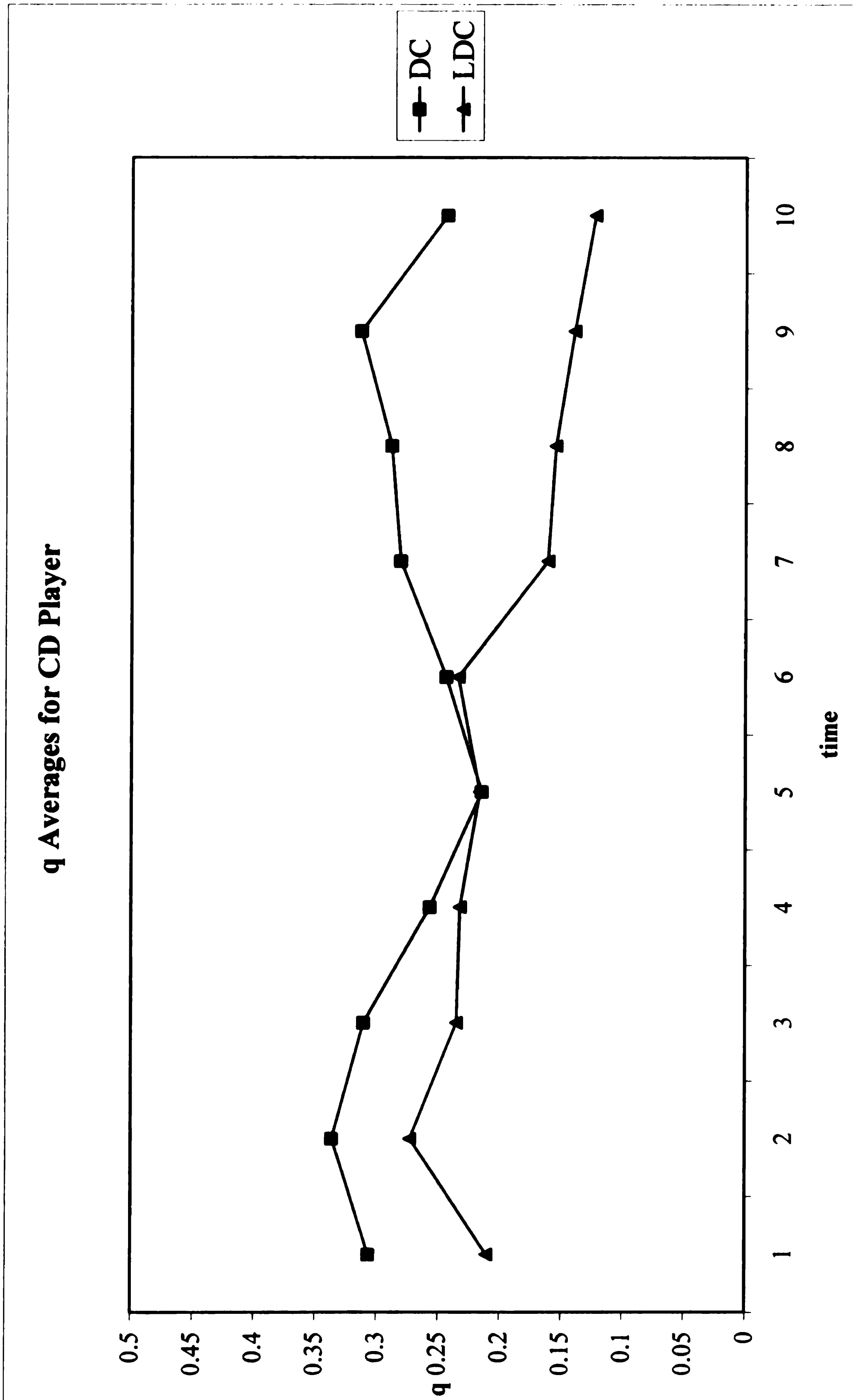

q for Video Camera in Developed Countries
q
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
time
1
2
3
4
5
6
7
8
9
10
Australia
Austria
Belgium
Canada
Denmark
Finland
France
Germany
Greece
Ireland
Israel
Italy
Japan
Netherlands
NewZealand
Norway
Portugal
Spain
Sweden
Switzerland
UK
USA

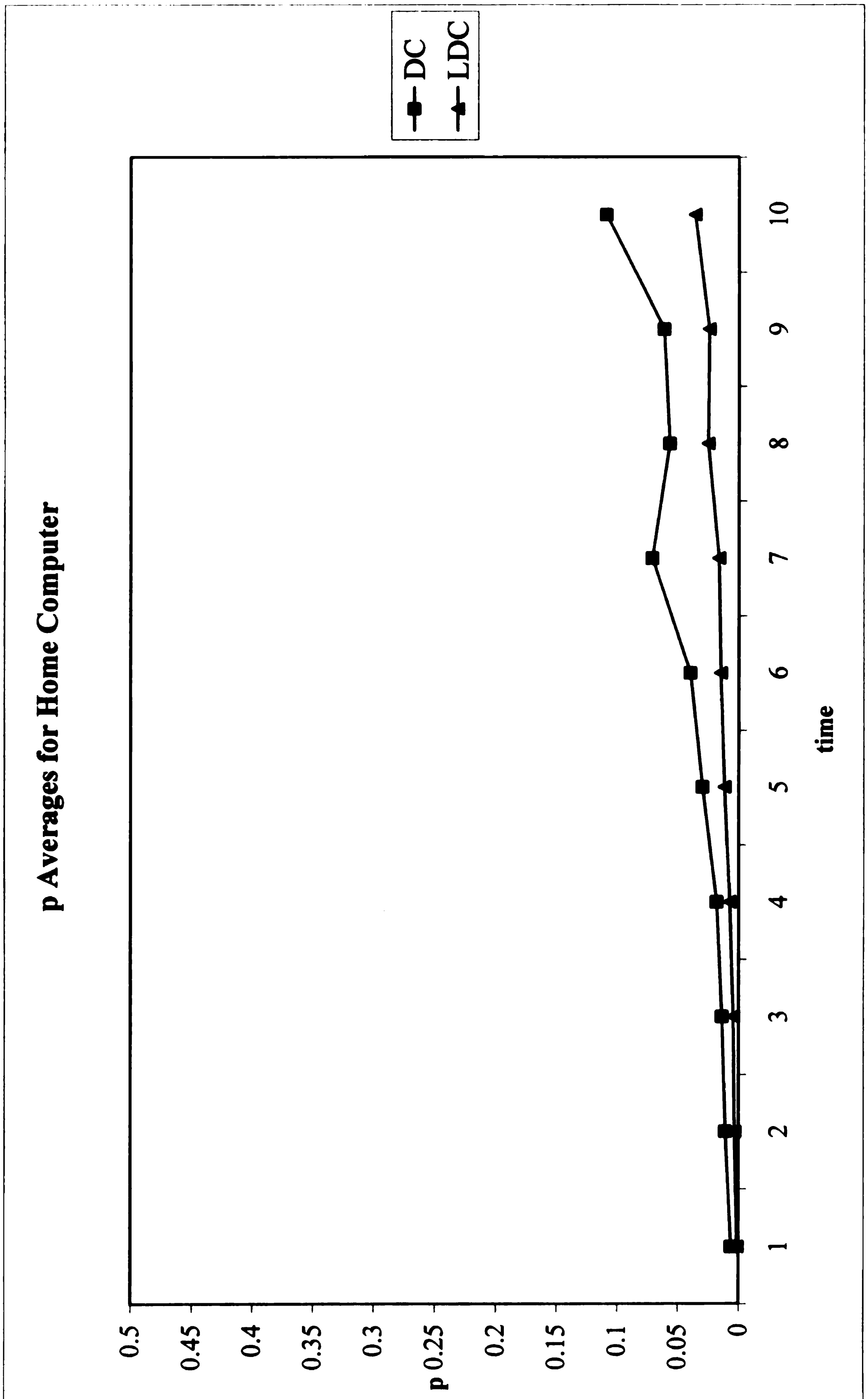

q for Video Camera in Developing Countries
q
1
0.95
0.9
0.85
0.8
0.75
0.7
0.65
0.6
0.55
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
Argentina
Brazil
Chile
China
Egypt
HongKong
Hungary
India
Indonesia
Malaysia
Mexico
Pakistan
Poland
Russia
Singapore
South Africa
SouthKorea
Taiwan
Thailand
Tunisia
Turkey

APPENDIX E

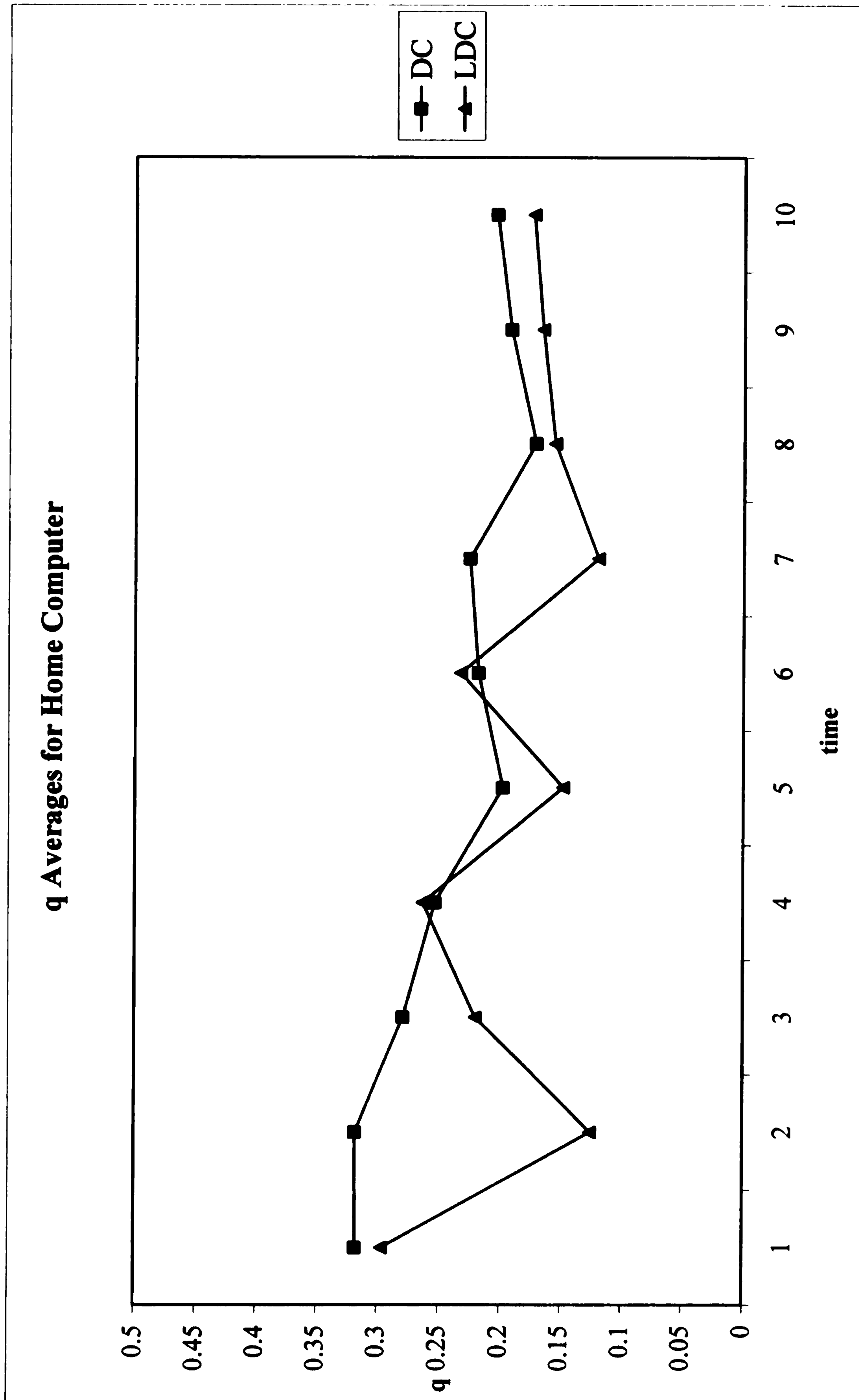
p and *q* Averages for Each Product in Developed Countries and Developing Countries

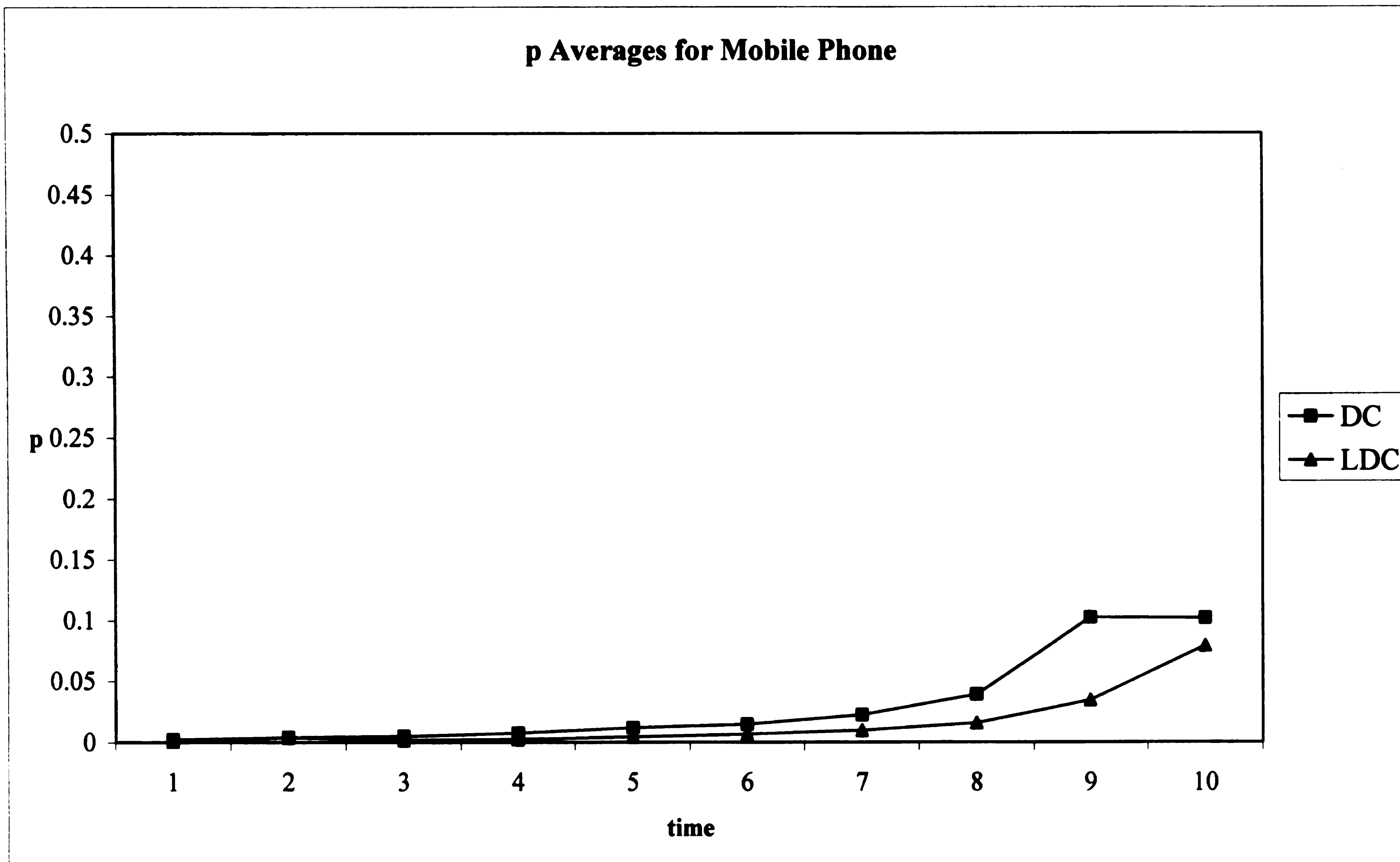

p Averages for CD Player
DC
LDC
p
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
time
1
2
3
4
5
6
7
8
9
10

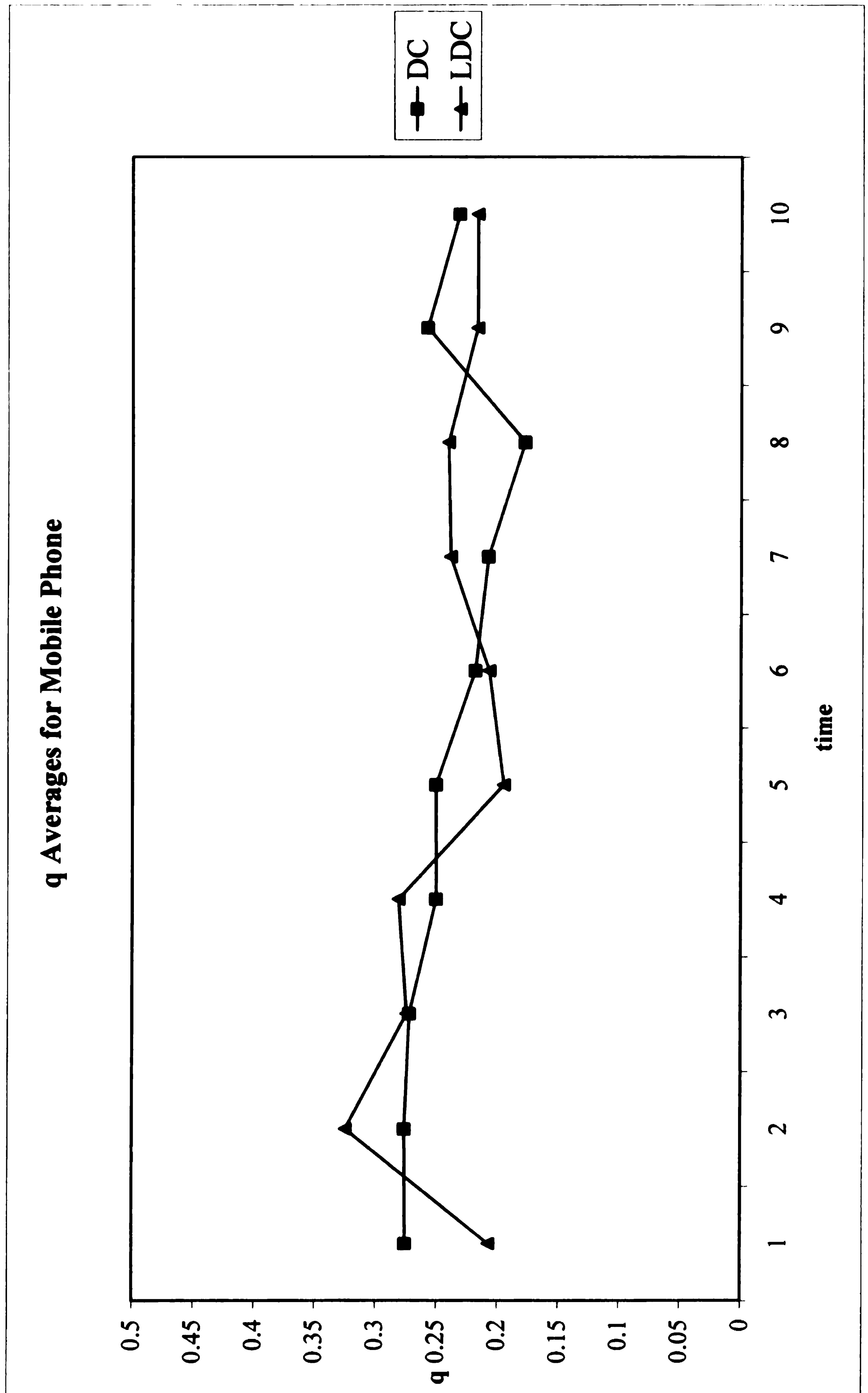

q Averages for CD Player
q
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35
0.4
0.45
0.5
time
1
2
3
4
5
6
7
8
9
10
DC
LDC

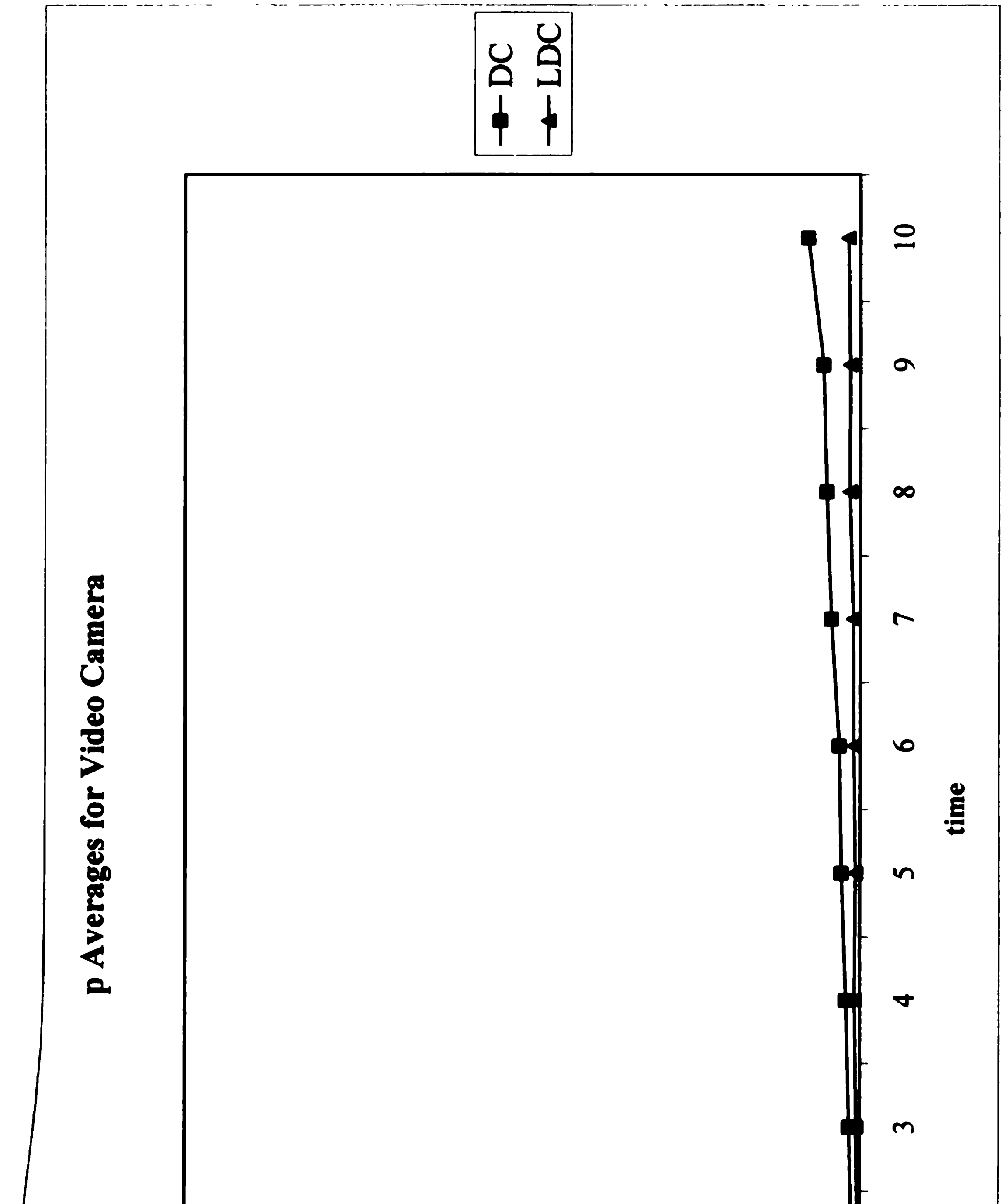


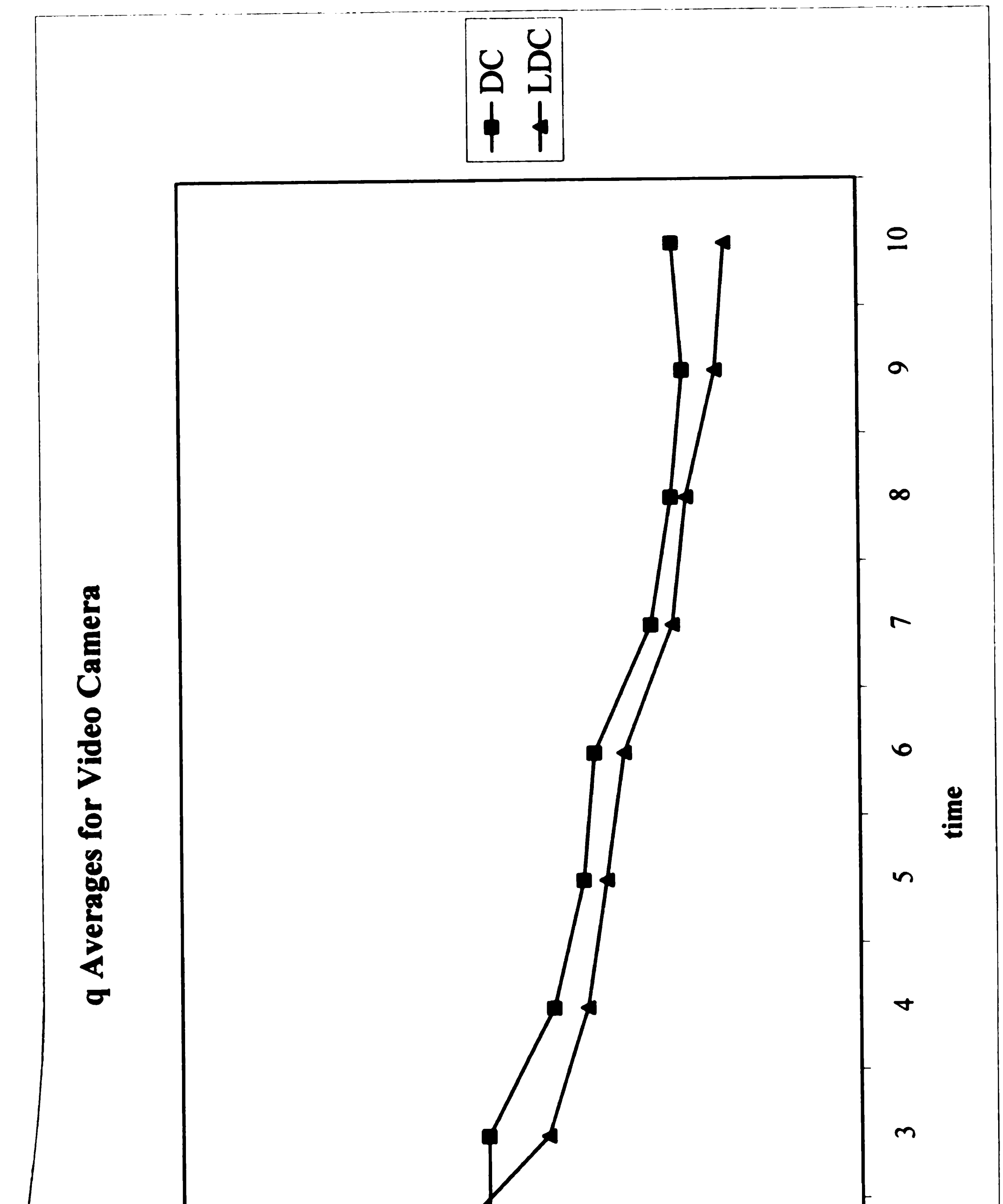
p Averages for Home Computer
DC
LDC
p
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
time
1
2
3
4
5
6
7
8
9
10


q Averages for Home Computer
DC
LDC
q
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time


p Averages for Mobile Phone
DC
LDC
p
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time


q Averages for Mobile Phone
DC
LDC
q
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
time
1
2
3
4
5
6
7
8
9
10

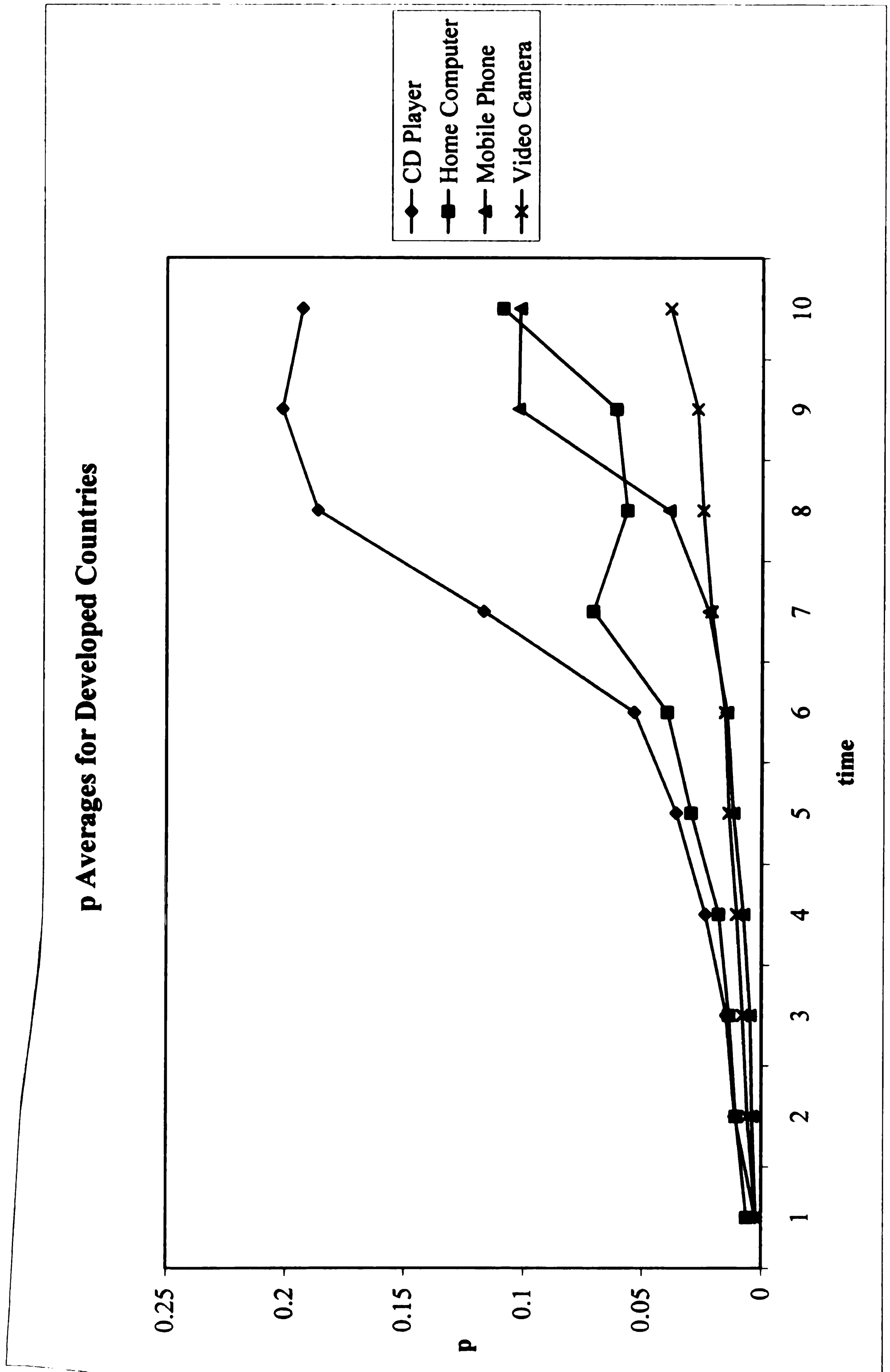

p Averages for Video Camera
p
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
DC
LDC

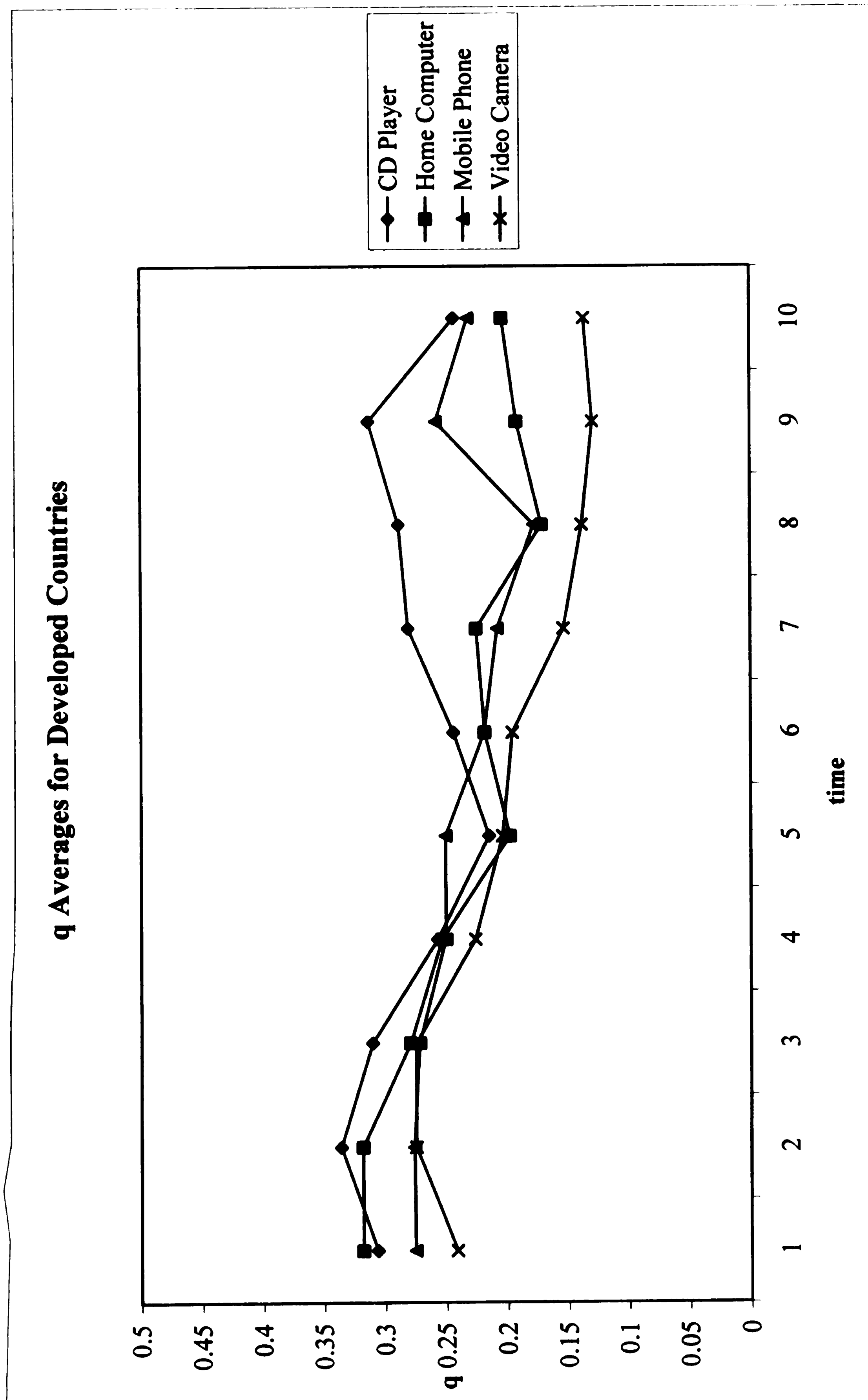


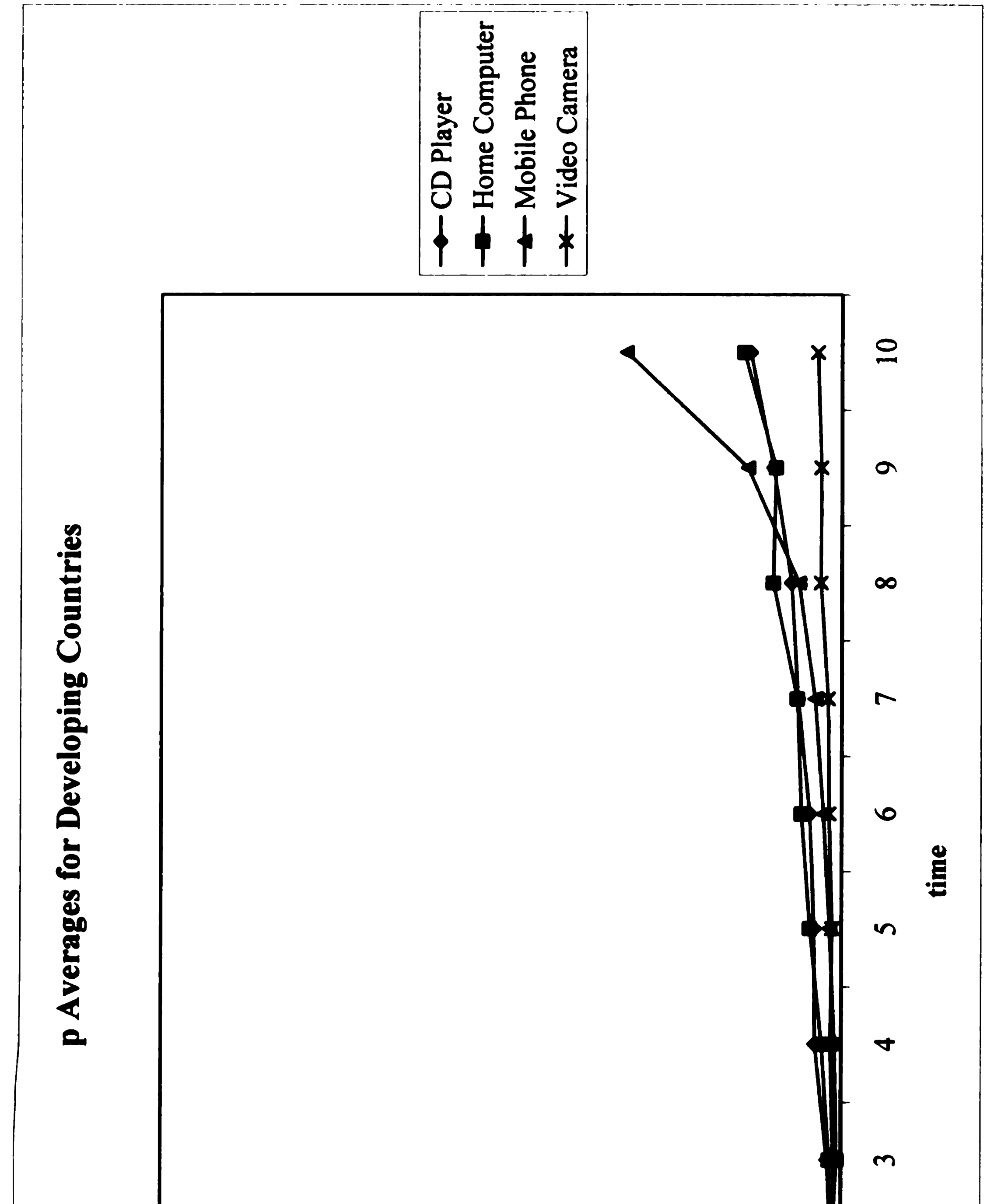
q Averages for Video Camera
q
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
time
1
2
3
4
5
6
7
8
9
10
DC
LDC

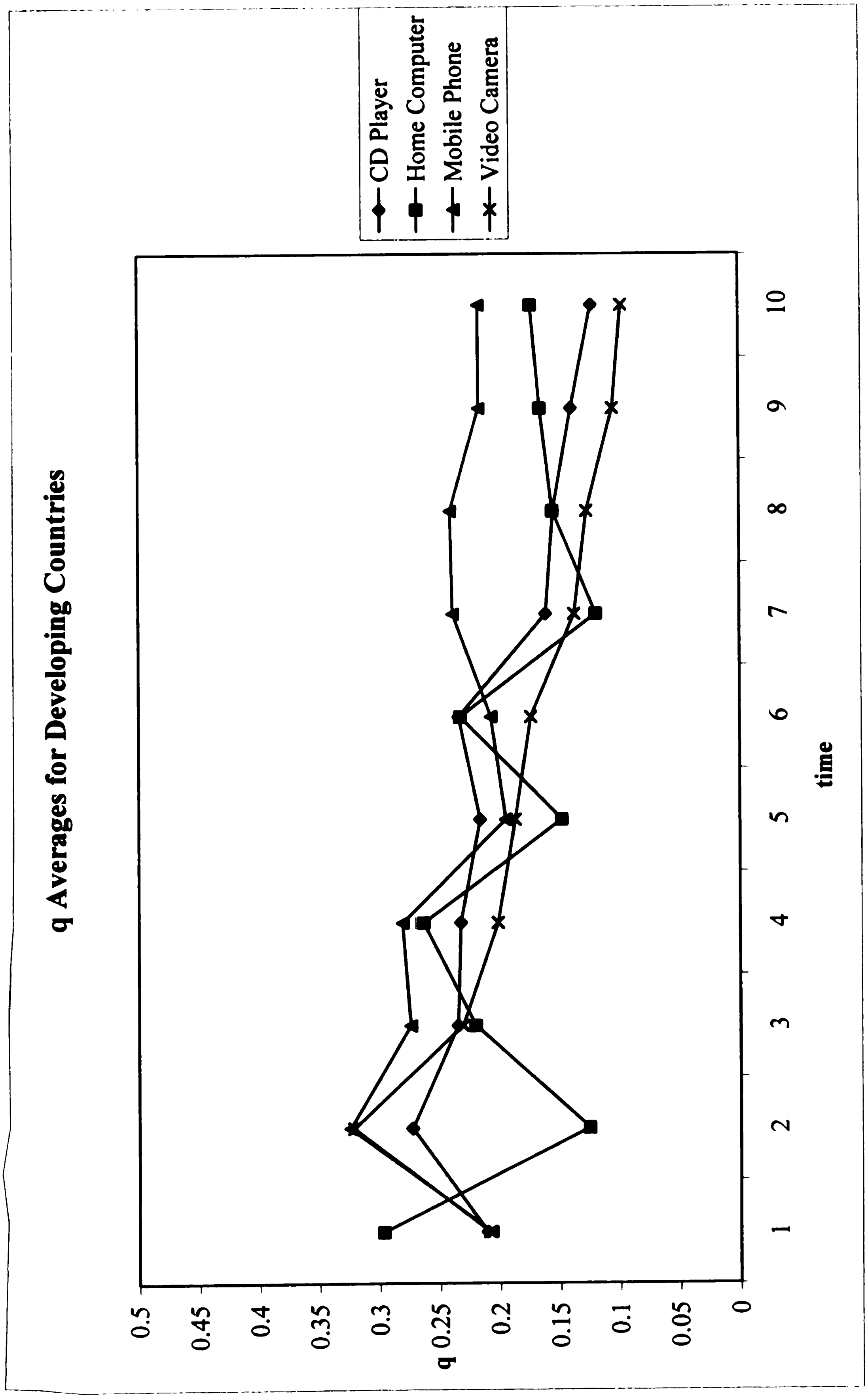
APPENDIX F

p and q Averages in Developed Countries and Developing Countries for Each Product


p Averages for Developed Countries
CD Player
Home Computer
Mobile Phone
Video Camera
p
0.25
0.2
0.15
0.1
0.05
0
time
1
2
3
4
5
6
7
8
9
10


q Averages for Developed Countries
CD Player
Home Computer
Mobile Phone
Video Camera
q
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time

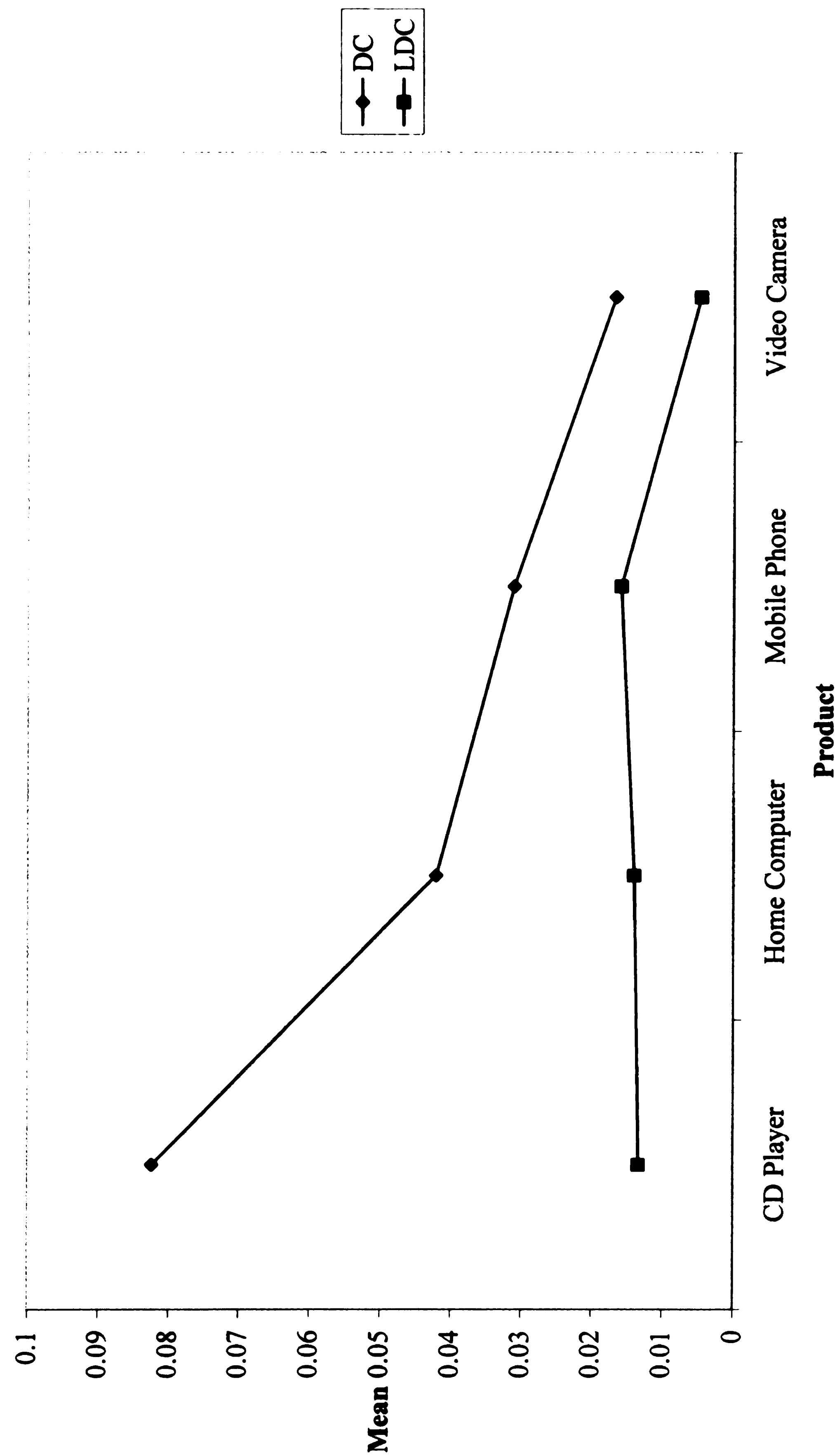

p Averages for Developing Countries
p
0.25
0.2
0.15
0.1
0.05
0
1
2
3
4
5
6
7
8
9
10
time
CD Player
Home Computer
Mobile Phone
Video Camera


q Averages for Developing Countries
CD Player
Home Computer
Mobile Phone
Video Camera
q
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
time
1
2
3
4
5
6
7
8
9
10

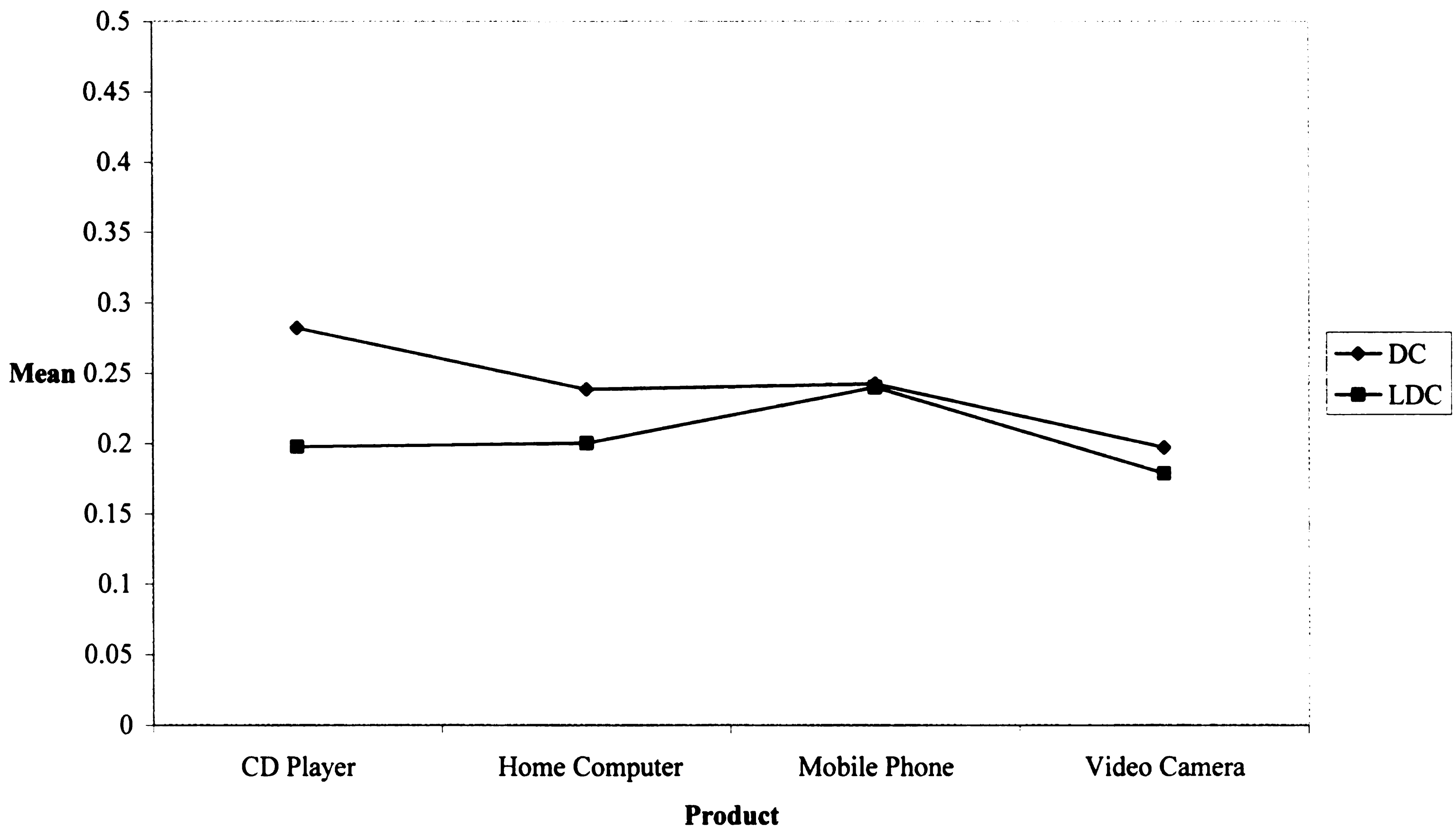
APPENDIX G

Interaction Effect of Country Type and Product Type on p, q, a, b and c

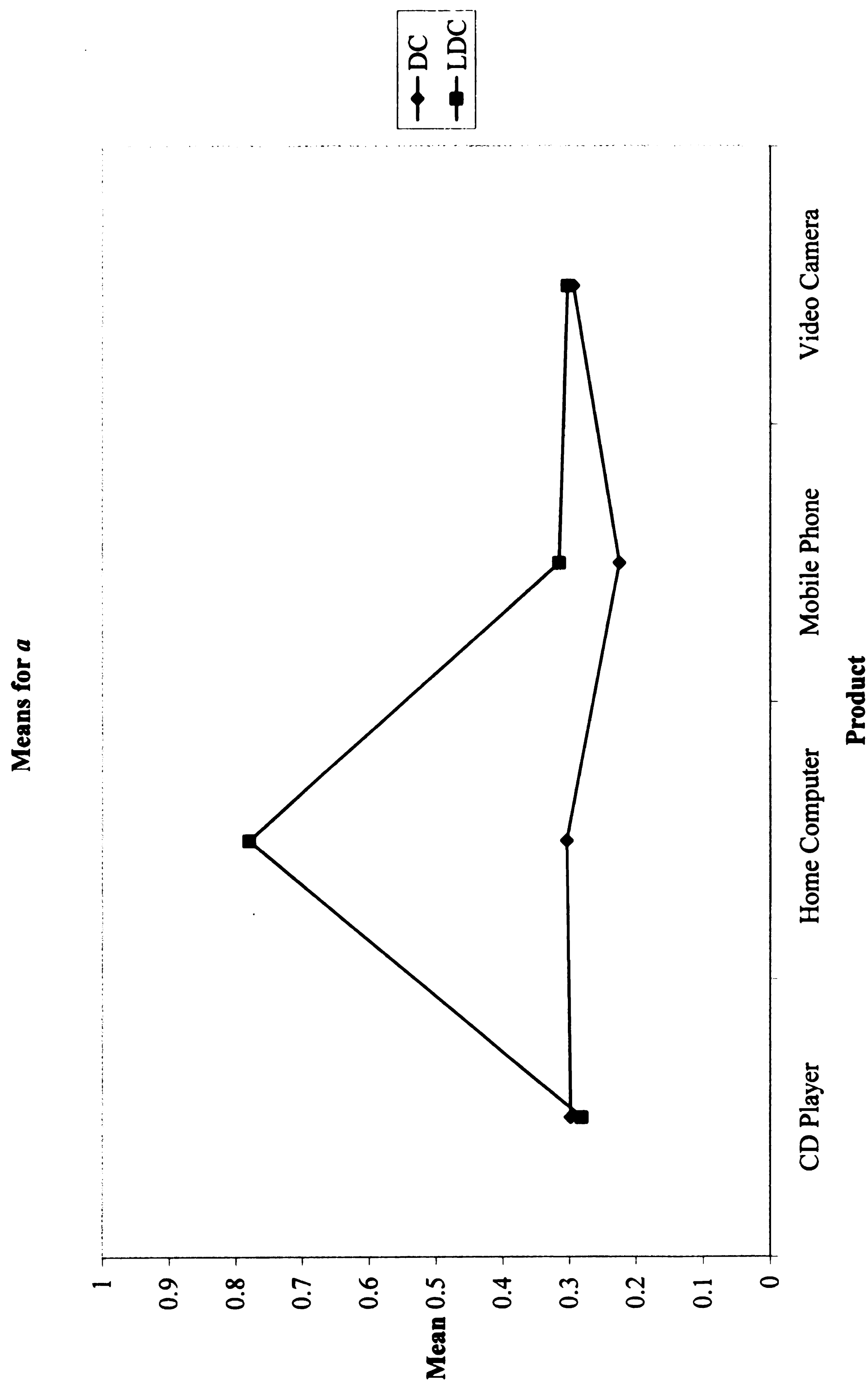
Means for *p*


DC
LDC
Mean
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
CD Player
Home Computer
Mobile Phone
Video Camera
Product

Means for *q*

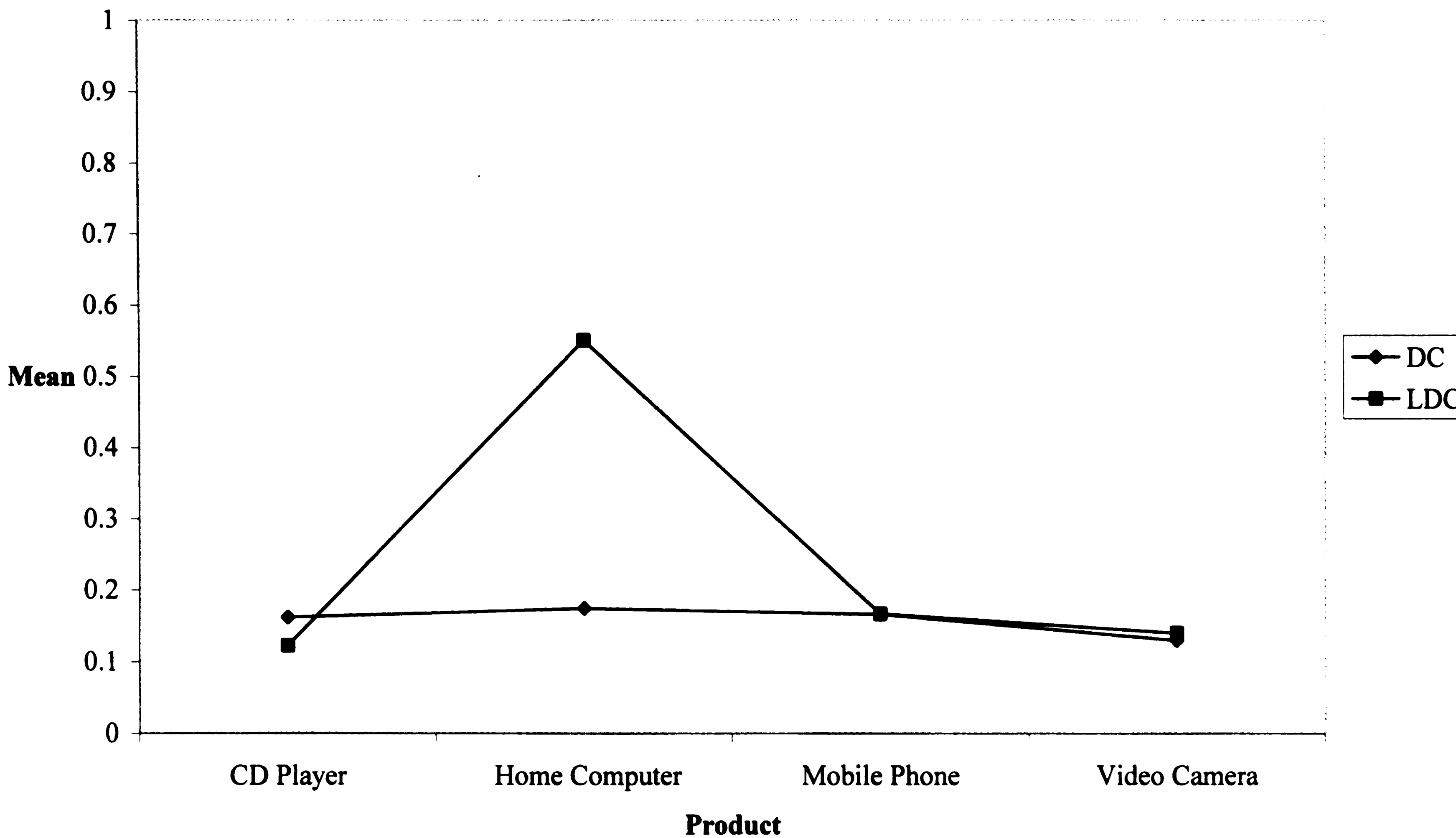


Mean
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
CD Player
Home Computer
Mobile Phone
Video Camera
Product
DC
LDC

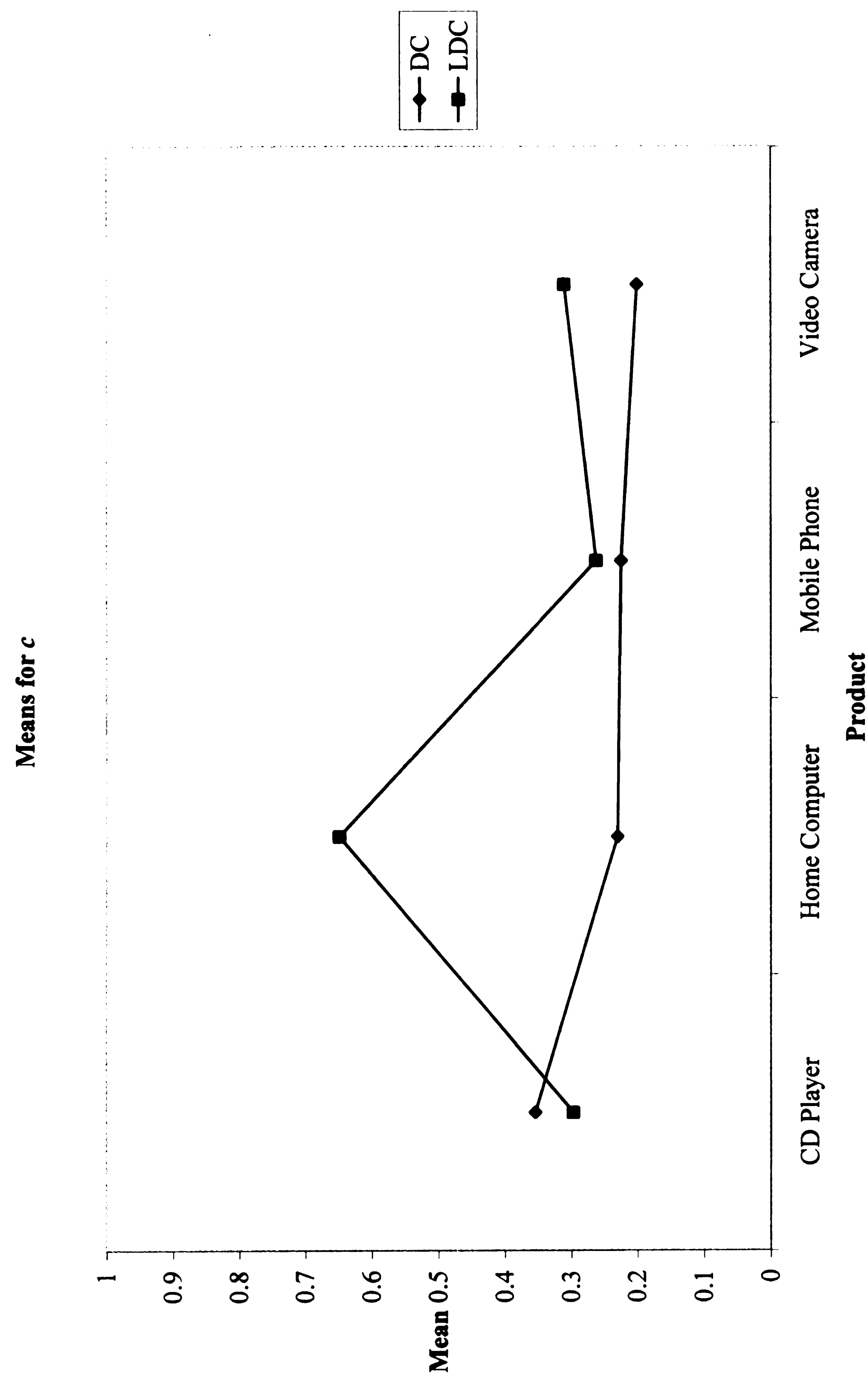


Means for *a*
Mean
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CD Player
Home Computer
Mobile Phone
Video Camera
Product
DC
LDC

Means for *b*



Mean
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CD Player
Home Computer
Mobile Phone
Video Camera
Product
DC
LDC



Means for c
Mean
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CD Player
Home Computer
Mobile Phone
Video Camera
Product
DC
LDC

REFERENCES

Anderson, E. B. (1970, "Asymptotic Properties of Conditional Maximum-Likelihood Estimators," *Journal of the Royal Statistical Society*, 32 (2), 283-301.

Ayal, Igal, and Jehiel Zif (1979), "Market Expansion Strategies in Multinational Marketing," *Journal of Marketing*, 43 (Spring), 84-94.

Bass, Frank M. (1969), "A New Product Growth Model for Consumer Durables," *Management Science*, 18 (January), 215-227.

---- (1980), "The Relationship Between Diffusion Rates, Experience Curves, and Demand Elasticities for Consumer Durables Technical Innovations," *Journal of Business*, 53 (July), 51-67.

---- (1995), "Empirical Generalizations and Marketing Science: A Personal View," Marketing Science, 14 (3), part 2, G6-G19.

----, Trichy V. Krishnan, and Dipak Jain (1994), "Why the Bass Model Fits Without Decision Variables," *Marketing Science*, 13 (Summer), 204-23.

----, Dipak Jain, and Trichy V. Krishnan (2000), "Modeling the Marketing-Mix Influence in New-Product Diffusion," "Estimation Techniques for Macro Diffusion Models," in New-Product Diffusion Models, Vijay Mahajan, Eitan Muller, and Yoram Wind (eds.), 263-94, Norwell, MA: Kluwer.

Bretschneider, Stuart I. And Vijay Mahajan (1980), "Adaptive Technological Substitution Models," *Technological Forecasting and Social Change*, 18, 129-39.

Brown, Lawrence A. (1981), *Innovation Diffusion: A New Perspective*, New York: Method.

Carbone, Robert and Richard L. Longini (1977), "A Feedback Model for Automated Real Estate Assessment," *Management Science*, 24 (3), 241-48.

Cavusgil, S. Tamer (1985), "Guidelines for Export Market Research," *Business Horizons*, 28 (November-December), 27-33.

Cooley, Thomas, and E. C. Prescott (1973), "Systematic (Non-Random) Variation Models and Varying Parameter Regression: A Theory and Some Applications," *Annals of Economic and Social Measurement*, 2 (4), 463-73.

----, and ---- (1976), "Estimation in the Presence of Stochastic Parameter Variation," *Econometrica*, 44 (1), 167-84.

Cox, D.R. (1972), "Regression Models with Life Tables," *Journal of the Royal Statistical Society*, 13 (34), 187-200.

Craig, Samule C., Susan P. Douglas, and Andreas Grein (1992), "Patterns of Convergence and Divergence Among Industrialized Nations: 1960-1988," *Journal of International Business Studies*, 23 (4), 773-787.

Davidson, William H. and Richard Harrigan (1977), "Key Decisions in International Marketing: Introducing New Products Abroad," *Columbia Journal of World Business*, Winter, 15-23.

Day, George S., and Robin Wensley (1988), "Assessing Advantage: A framework for Diagnosing Competitive Superiority," *Journal of Marketing*, 52 (April), 1-20.

Dekimpe, Marnik G., Philip M. Parker, and Miklos Sarvary (1998), "Staged Estimation of International Diffusion Models: An Application to Global Cellular Telephone Adoption," *Technological Forecasting and Social Change*, 57, 105-32.

----, ----, and ---- (2000), "Global Diffusion of Technological Innovations: A Coupled Hazard Apprach," *Journal of Marketing Research*, 37, 47-59.

DeSarbo, Wayne S.,M. Wedel, M. Vriens, and V. Ramaswamy (1992), "Latent Class Metric Conjoint Analysis," *Marketing Letters*, 3, 273-88.

Dockner, Englebert, and Steffen Jorgensen (1988), "Optimal Advertising Policies for Diffusion Models of New Product Innovations in Monopolistic Situations," *Management Science*, 34 (March), 119-130.

Douglas, Susan and Samuel C. Craig (1995), *Global Marketing Strategy*, New York: McGraw-Hill.

Easingwood, Christopher (1987), "Early Product Life-Cycle Forms for Infrequently Purchased Major Products," *International Journal of Research in Marketing*, 4, 3-9.

---- (1988), "Product Life-Cycle Patterns for New Industrial Products," *R&D Management*, 18 (1), 23-32.

Eliashberg, Jehoshua, and Rabikar Chatterjee (1986), "Stochastic Issues in Innovation Diffusion Models," in *Innovation Diffusion Models for New Product Acceptance*, Vijay Mahajan and Yoram Wind (eds.), 151-203, Cambridge, MA: Ballinger.

Ganesh, Jainshankar (1998), "Converging Trends within the European Union: Insights from an Analysis of Diffusion Patterns," *Journal of International Marketing*, 6 (4), 32-48.

----, and V. Kumar (1996), "Capturing the Cross-National Learning Effect: An Analysis of an Industrial Technology Diffusion," *Journal of the Academy of Marketing Science*, 24 (Fall), 328-337.

----, ----, and Velavan Subramaniam (1997), "Learning Effect in Multinational Diffusion of Consumer Durables: An Exploratory Investigation," *Journal of the Academy of Marketing Science*, 25 (Summer), 214-28.

Gatignon, Hubert, Jehoshua Eliashberg, and Thomas S. Robertson (1989), "Modeling Multinational Diffusion Patterns: An Efficient Methodology," *Marketing Science*, 8 (Summer), 231-247.

Gouldner, Alvin W. (1957), "Cosmopolitans and Locals: Toward an Analysis of Latent Social Roles. I", *Administrative Science Quarterly*, 2, 281-306.

Haagerstrand, T. (1953), *Innovation of Spatial Process*, Translated by A. Pred, Chicago: University of Chicago Press.

Hall, Edward T. (1976), *Beyond Culture*, New York: Doubleday.

---- (1987), *Hidden Differences*, New York: Doubleday.

Hanssens, Dominique, Leonard J. Parsons, Randall Schultz (1990), *Market Response Models: Econometric and Time Series Analysis*, Norwell, MA: Kluwer.

Harvey, A. C., and G. D. A. Phillips (1982), "The Estimation of Regression Models with Time-Varying Parameters," in *Games, Economic Dynamics, Time Series Analysis*, Diestler M., E. Furst, and G. Schwudiauer, eds., Wein-Wurzburg:Pysica-Verlag.

Heeler, Roger M. and Thomas P. Hustad (1980), "Problems in Predicting New Product Growth for Consumer Durables," *Management Science*, 10 (October), 1007-1020.

Helsen, Kristian, Kamel Jedidi, and Wayne S. Desarbo (1993), "A New Approach to Country Segmentation Utilizing Multinational Diffusion Patterns," *Journal of Marketing*, 57 (October), 60-71.

Hofstede, Geert (1980), "Culture and Organizations," *International Studies of Management and Organizations*, 10 (4), 15-41.

Horsky, Dan (1990), "A Diffusion Model Incorporating Product Benefits, Price, Income and Information," *Marketing Science*, 9 (Fall), 342-65.

----, and Leonard S. Simon(1983), "Advertising and the Diffusion of New Products," *Marketing Science*, 2, (Winter), 1-17.

Islam, Towhidul and Nigel Meade (1997), "The Diffusion of Successive Generations of a Technology: A More General Model," *Technological Forecasting and Social Change*, 56, 49-60.

Jain, Dipak, Vijay Mahajan, and Eitan Muller (1991), "Innovation Diffusion in the Presence of Supply Restrictions," *Marketing Science*, 10 (1), 83-90.

----, and Ram C. Rao (1990), "Effect of Price on the Demand on Durables," *Journal of Business and Economic Statistics*, 8 (April), 163-70.

Judge, G. G., W. E. Griffiths, R. C. Hill, and T. C. Lee (1985), *The Theory and Practice of Econometrics*, 2nd edition, New York: John Wiley.

Kalish, Shlomo (1985), "A New Product Adoption Model with Price, Advertising, and Uncertainty," *Management Science*, 31 (December), 1569-1585.

----, and Subrata Sen (1986), "Diffusion Models and the Marketing Mix for Single Products," in *Innovation Diffusion Models for New Product Acceptance*, Vijay Mahajan and Yoram Wind (eds.), Cambridge, MA: Ballinger.

----, Vijay Mahajan, and Eitan Muller (1995), "Waterfall and Sprinkler New-Product Strategies in Competitive Global Markets," *International Journal of Research in Marketing*, 12 (2), 105-19.

Kalbfleisch, J. D. and R. L. Prentice (1980), *The Statistical Analysis of Failure Time Data*, New York: Wiley.

Kalman, R. E. (1960), "A New Approach to Linear Filtering and Prediction Problems," *Journal of Basic Engineering*, March, 35-45.

----, and R. S. Bucy (1961), "New Results in Linear Filtering and Prediction Theory," *Journal of Basic Engineering*, March, 95-108.

Kamakura, W. A. and S. K. Balasubramanian (1987), "Long-Term Forecasting with Innovation Diffusion Models: The Impact of Replacement Purchases," *Journal of Forecasting*, 6 (1), 1-20.

----, and ---- (1988), "Long-Term View of the Diffusion of Durables: A Study of the Role of Price and Adoption Influence Processes via Tests of Nested Models," *International Journal of Research in Marketing*, 5, 1-13.

Kimberly, John R. and M. J. Evanisko (1981), "Organizational Innovation: The Influence of Individual, Organizational, and Contextual Factors on Hospital Adoption of Technological and Administrative Innovations," *Academy of Management Journal*, 24, 689-712.

Krishnan, Trichy V., Frank M. Bass, and Dipak C. Jain (1999), "Optimal Pricing Strategy for New products," *Management Science*, 45 (December).

Kumar, V., Jainshankar Ganesh, and Raj Echambadi (1998), "Cross-National Diffusion Research: What Do We Know and How Certain Are We?," *Journal of Product Innovation Management*, 15, 255-68.

Leeflang, Peter C. H. , and W. Fred van Raaij (1995), "The Changing Consumer in the European Union: A Meta-Analysis," *International Journal of Research in Marketing*, 12 (5), 373-387.

Lenk, Peter J., and Ambar G. Rao (1990), "New Models from Old: Forecasting Product Adoption by Hierarchical Bayes Procedures," *Marketing Science*, 9 (1), 42-57.

Levitt, Theodore (1983), "Globalization of Markets," *Harvard Business Review*, 61 (May/June), 92-102.

Lewis, Frank L. (1986), *Optimal Estimation with an Introduction to Stochastic Control Theory*, New York: John Wiley & Sons.

Lilien, Gary L.,Arvind Rangaswamy, Christophe Van den Bulte (2000), "Diffusion Models: Managerial Applications and Software," in New-Product Diffusion Models, Vijay Mahajan, Eitan Muller, and Yoram Wind (eds.), 295-311, Norwell, MA: Kluwer.

Lindberg, Bertil C. (1982), "International Comparison of Growth in Demand for a New Durable Consumer Product," *Journal of Marketing Research*, 19 (August), 364-71.

Mahajan, Vijay, Chatlotte H. Mason, and V. Srinivasan (1986), "An Evaluation of Estimation Procedures for New-Product Diffusion Models," in *Innovation Diffusion Models for New Product Acceptance*, Vijay Mahajan and Yoram Wind (eds.), Cambridge, MA: Ballinger.

----, and ---- (1979), "Innovation Diffusion and New-Product Growth Models in Marketing," *Journal of Marketing*, 43 (Fall), 55-68.

---- and Eitan Muller (1994), "Innovation Diffusion in a Borderless Global Market: Will the 1992 Unification of the European Community Accelerate Diffusion of New Ideas, Products, and Technologies?," Technological Forecasting and Social Change, 45 (September), 221-235.

----, Eitan Muller, and Frank M. Bass (1990), "New Product Diffusion Models in Marketing: A Review and Directions for Research," *Journal of Marketing*, 54 (January), 1-26.

----, and Subash Sharma (1986), "Simple Algebraic Estimation Procedure for Innovation Diffusion Models of New Product Acceptance," *Technological Forecasting and Social Change*, 30, 331-46.

----, and Yoram Wind (1986), *Innovation Diffusion Models of New Product Acceptance*, Cambridge, MA: Ballinger.

McGee L.A., and S. F. Schmidt (1985), *Discovery of the Kalman Filter as a Practical Tool for Aerospace and Industry*, National Aeronautics and Space Administration, Technical Memorandum 86847, November.

Norton, John A., and Frank M. Bass (1987), "A Diffusion Theory Model of Adoption and Substitution for Successive Generations of High-Technology Products," *Management Science*, 33 (September), 1069-86.

Ohmae, Kenichi (1985), *The Triad Power*, New York: Free Press.

Peterson, Robert A., and Vijay Mahajan (1978), "Innovation Diffusion in a Dynamic Potential Adopter Population," Management Science, 24 (November), 1589-1603.

Porter, Michael E. (1985), *Competitive Advantage: Creating and Sustaining Superior Performance*, New York, NY: Free Press.

Putsis, Jr., William P. (1996), "Temporal Aggregation in Diffusion Models of First-Time Purchase: Does Choice of Frequency Matter?," *Technological Forecasting and Social Change*, 51, 265-79.

---- (1998), "Parameter Variation and New Product Diffusion," *Journal of Forecasting*, 17 (3/4), 231-57.

----, Sridhar Balasubramanian, Edward H. Kaplan, and Subrata K. Sen (1997), "Mixing Behavior in Cross-Country Diffusion," *Marketing Science*, 16 (4), 354-69.

----, and V. Srinivasan (2000), "Estimation Techniques for Macro Diffusion Models," in New-Product Diffusion Models, Vijay Mahajan, Eitan Muller, and Yoram Wind (eds.), 263-94, Norwell, MA: Kluwer

Robertson, Thomas S. (1971), *Innovative Behavior and Communication*, New York: Holt, Rinehart and Winston.

Robinson, Bruce, and Chet Lakhani (1975), "Dynamic Price Models for New Product Planning," *Management Science*, 21 (June), 1113-1122.

Rogers, Everett (1995), *Diffusion of Innovations*, 4th edition, New York: Free Press.

Sarris, Alexander H. (1973), "A Bayesian Approach to Estimation of Time-Varying Regression Coefficients," Annals of Economic and Social Measurement, 2 (4), 501-23.

Schmittlein David C., and Vijay Mahajan (1982), "Maximum Likelihood Estimation for an Innovation Diffusion Model of New-Product Acceptance," *Marketing Science*, 1 (1), 57-78.

Simon, Herman, and Karl-Heinz Sebastian (1987), "Diffusion and Advertising: German Telephone Campaign," *Management Science*, 33 (April), 451-466.

Srinivasan, V., and Charlotte H. Mason (1986), "Nonlinear Least Squares Estimation of New-Product Diffusion Models," *Marketing Science*, 5 (2), 169-78.

Stengel, Robert F. (1986), *Stochastic Optimal Control: Theory and Application*, New York: John Wiley & Sons.

Sultan, Fareena, John U. Farley, and Donald R. Lehmann (1990), "A Meta-Analysis of Applications of Diffusion Models," *Journal of Marketing Research*, 27 (February), 70-77.

Takada, Hirokazu and Dipak Jain (1991), "Cross-National Analysis of Diffusion of Consumer Durable Goods in Pacific Rim Countries," *Journal of Marketing*, 55 (April), 48-54.

Talukdar, Debabrata, K. Sudhir, and Andrew Ainslie (2002), "Investigating New Product Diffusion Across Products and Countries," *Marketing Science*, 21 (Winter), 97-114.

Van den Bulte, Christophe, and Gary L. Lilien (1997), "Bias and Systematic Change in the Parameter Estimates of Macro-Level Diffusion Models," *Marketing Science*, 16 (4), 338-54.

Yip, George S. (1992), *Total Global Strategy: Managing for Worldwide Competitive Advantage*, New Jersey: Prentice Hall.

Xie, Jinhong, Michael Song, Marvin Sirbu, and Qiong Wang (1997), "Kalman Filter Estimation of New-Product Diffusion Models," *Journal of Marketing Research*, 34 (August), 378-93.