Institute of Transportation Studies
University of California, Davis

Year 2006 UCD—ITS—RR—06-13

Relationships between U.S. Consumer Expenditures on Communications and Travel: 1984-2002

Sangho Choo

Taihyeong Lee

Patricia L. Mokhtarian

Institute of Transportation Studies ◇ University of California, Davis

One Shields Avenue ◇ Davis, California 95616

PHONE: (530) 752-6548 ◇ FAX: (530) 752-6572

WEB: http://its.ucdavis.edu/

RELATIONSHIPS BETWEEN

U. S. CONSUMER EXPENDITURES

ON COMMUNICATIONS AND TRAVEL: 1984-2002

Sangho Choo
The Korea Transport Institute
2311 Daewha-dong Ilsanseo-gu
Goyang-si, Gyeonggi-do 411-701, Korea
voice: +82-31-910-3169
fax: +82-31-910-3233
e-mail: shchoo@koti.re.kr

Taihyeong Lee
Department of Civil and Environmental Engineering
One Shields Avenue
University of California, Davis
Davis, CA 95616
voice: (530) 754-5450
fax: (530) 752-6572
e-mail: thlee@ucdavis.edu

and

Patricia L. Mokhtarian
Department of Civil and Environmental Engineering
and
Institute of Transportation Studies
One Shields Avenue
University of California, Davis
Davis, CA 95616
voice: (530) 752-7062
fax: (530) 752-7872
e-mail: plmokhtarian@ucdavis.edu

July 2006

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1. Introduction

The relationship between telecommunications and travel has been a fertile area of research for several decades. Early speculation (e.g., Owen, 1962) focused on the potential of telecommunications to replace travel. That hope eventually led to the establishment of several telecommuting programs, and empirical evaluations of those programs (e.g., Hamer, *et al.*, 1991; Mokhtarian, *et al*., 1995) seemed to support the substitution expectation. While empirical evidence for other telecommunications applications was far more scarce, it was similarly expected that teleconferencing, teleshopping, distance learning, and other such services would also replace travel. In the meantime, however, some scholars (e.g. Albertson, 1977; Salomon, 1985; Mokhtarian, 1990, 2003; Niles, 1994) began to point out that substitution was not the only possible impact of telecommunications on transportation. In particular, it was argued that a very likely impact would be the generation of more travel, or complementarity. In the short term, this effect could arise in two kinds of ways, which the literature (Salomon, 1986) labels *enhancement* and *efficiency*.

- *Enhancement* refers to a direct impact of one mode of communications (e.g. telecommunications) on the *demand* for another mode (e.g. travel). For example, the increasing ease of electronically obtaining information about interesting locations, activities, and people could stimulate the demand for travel to visit those locations or people and engage in those activities (Gottman, 1983; Couclelis, 1999).

- *Efficiency* refers to the use of one mode (e.g. telecommunications) to improve the operation of another mode (e.g. the transportation network). The effect on demand is indirect in this case, by increasing the effective *supply* of transportation and hence, by lowering its (generalized) cost, making travel more attractive and thus increasing the demand for it.

Based partly on the favorable empirical results mentioned above, and partly on the optimism and opportunism endemic to public sector decision-making, a number of public policies have been promulgated on the assumption that telecommunications will be a useful trip reduction instrument (e.g., Gordon, 1992, 1996; Castaneda, 1999; Joice, 2000). However, Mokhtarian and Meenakshisundaram (1999) suggest that the empirical findings in support of substitution may be a consequence of the short-term, disaggregate, narrow focus of the typical telecommuting (or other application) evaluation, and that when the focus is broadened to examine all communications across the entire population over a period of time, it is more likely that a complementarity effect will emerge. Certainly, any plot of the aggregate amounts of communications and travel over time, at practically any geographic level (e.g. Grubler, 1989), illustrates that overall, they continue to rise together, although the extent to which that pattern is due to a true causal relationship between the two types of activity is still debatable (Höjer and Mattsson, 2000; Mokhtarian, 2003).

Given the favor with which telecommunications is viewed as a transportation demand management tool, it is important to better understand the nature of its relationship with travel, in order to determine whether the optimism about its substitution potential is misplaced. In particular, it seems vital to move beyond the small-scale evaluations of single applications such as telecommuting, to a more complete view of telecommunications activity in general. Such studies could be conducted at either the disaggregate or the aggregate level, and each approach has its advantages (Mokhtarian and Salomon, 2002): disaggregate studies have the potential to offer more insight into behavior-based causal relationships, whereas aggregate studies can offer a more comprehensive scope and the potential for more readily developing aggregate forecasts of the impacts of telecommunications on travel (and conversely). This report focuses on the aggregate level.

The few aggregate studies that have been conducted to date on this question appear to offer contradictory results. An input-output (I-O) analysis of relationships between transportation and communication input intensities across 44 *industry* classes in Europe in 1980 found strong evidence of *complementarity* (Plaut, 1997), while a simultaneous equation (Rotterdam) demand model of aggregate *consumer* expenditures in Australia and the UK in 1960-1986 found that private transportation, public transportation, and communication are pairwise *substitutes* (Selvanathan and Selvanathan, 1994). The latter study further found exponential growth in communication, at the expense of the two types of transportation. Similar results have also been put forward by NOASR (1989), suggesting relatively low elasticities and a reduction of travel by only 8% over the next 35 years. On the other hand, Choo and Mokhtarian (2005; 2007) found that the aggregate relationship between actual amounts of travel (including vehicle-miles traveled, transit passengers carried, and domestic airline passenger-miles traveled) and telecommunications (including telephone calls and mobile phone subscribers) is complementarity, using structural equation modeling for national time series data (1950-2000) in the U.S. (reflecting both business and personal activity).

In fact, all these results are plausible. The consumer-oriented finding of net substitution is consistent with the nearly unanimous empirical results of numerous micro-scale studies, whereas the findings of complementarity are consistent with the historically-observed simultaneous increases in both transportation and communication in the aggregate. The divergent findings are not only empirically substantiated by these other studies, but are also conceptually reasonable (Plaut, 1997). As indicated earlier, complementarity can arise both through an enhancement effect (in which use of one mode of communication directly stimulates use of other modes) and through an efficiency effect (in which use of one mode in conjunction with another improves the efficiency of the latter). It is quite possible that both effects are obtained more strongly in an industrial context than in a consumer one. For example, the expansion of personal contacts through electronic means is more likely to lead to increased travel (enhancement) in a business context than in a social one. The use of electronic data interchange and global positioning systems (efficiency) have so far benefited goods movement more than, say, automobile drivers.

On the other hand, that balance may begin to shift as enhancing and efficiency-improving technologies such as mobile phones, the Internet, and in-vehicle navigation systems permeate the consumer sector more deeply. Hence, it is possible that, over time, the net substitution effect previously seen for consumer demand may weaken and even reverse into a complementarity effect. The latest year in the time-series data used by Selvanathan and Selvanathan was 1986; a shift may already be detectable in the intervening two decades. Thus, it is highly desirable to update and refine the Selvanathan and Selvanathan work.

The purpose of this study is to do precisely that. First of all, we examine trends with respect to consumers' expenditure patterns in transportation and communications categories from 1984 to

2002. The trends are presented for several classifications (at various levels of category aggregation), and illustrated using raw expenditures (dollar values) as well as expenditure shares (%s). Then, we analyze aggregate consumer expenditure data from the U.S. for the 19 years 1984−2002, using aggregate demand system modeling (in particular, a linear approximate almost ideal demand system, or LA-AIDS, model), to determine the relationships between expenditures on transportation and those on communications.

The organization of the report is as follows. The next chapter describes the types of relationships between transportation and communications, and reviews some empirical studies of the relationships from three different perspectives (activity, industrial expenditure, and consumer expenditure perspectives). Chapter 3 explains the data assembly and our various categorizations of the items captured by the US Consumer Expenditure Survey and the Consumer Price Index (CPI). In Chapter 4, we describe expenditure trends in current dollars as well as 1984 constant dollars, and discuss conceptually the decomposition of those trends according to sources of changes in expenditure. In Chapter 5, we analyze aggregate consumer expenditure data using aggregate demand system modeling (in particular, a linear approximate almost ideal demand system model), and present the model results (six alternatives) for the demand system. Finally, summary and conclusions are discussed in Chapter 6.

Chapter 2. Aggregate Relationships between Transportation and Communications

In this chapter, key literature is reviewed related to the empirical relationships between telecommunications and travel at the aggregate level. Section 2.1 describes the conceptual types of relationships between the two, and Section 2.2 discusses some aggregate empirical studies of the relationships from three different perspectives: activity, industrial expenditure, and consumer expenditure.

2.1 Types of Relationships between Transportation and Communications

In general economic theory, two commodities can exhibit substitution, complementarity, or independence relationships. For example, suppose that as the price of one commodity decreases, the demand for that commodity increases, but the demand for a second one decreases. Then, the commodities have a substitutive relationship. However, if the demand for the second one also increases, then the commodities are complementary. On the other hand, if the demand for the second one does not change, then the commodities are independent. Based on those facts, the relationships between telecommunications and travel have often been classified into two broad categories: substitution and complementarity.

A number of studies (Harkness, 1977; Mokhtarian, 1990, 2000; Mokhtarian and Salomon, 2002; Niles, 1994; Owen, 1962; Salomon, 1985, 1986; Salomon and Schofer, 1988) have identified the potential relationships between telecommunications and travel: substitution (reduction, elimination), complementarity (stimulation, generation), modification (change in time, mode, destination, or other characteristic), and neutrality (no impact of one medium on the other). In the discussion below, we focus primarily on the impact of telecommunications on travel as the causal direction most important to transportation and urban planning, but it should be kept in mind that travel will also affect telecommunications. In fact, recent aggregate studies (including Choo, 2004; Choo and Mokhtarian, 2005, 2007; as well as the present study) suggest that the influence of travel on telecommunications is stronger than the converse, meaning that if only the impact of telecommunications on travel is modeled, a misleading picture of the strength of the relationship is likely to result.

- In a substitutive relationship, telecommunications reduces travel demand and/or vice versa. In fact, various types of telecommunications-related activities such as on-line (telephone) shopping and teleservices for banking and transactions can reduce or eliminate travel. For example, you can order a music CD via the Internet or telephone without traveling to a music store downtown, or even download your favorite songs directly through the Internet without a delivery trip at all. In addition, telecommunications can make people's travel more efficient by eliminating unnecessary trips. If you obtain information via phone or on a website about the cancellation of a baseball game due to rain, you can save the unnecessary round trip to watch the game on that day. In the aggregate, perhaps thousands of trips can be saved by the prospective spectators. Conversely, an active in-person social life may reduce the time one spends socializing (or in solitary pursuits) on the phone or Internet.

- In a complementary relationship, telecommunications generate physical travel and/or vice versa. Information gained through telecommunications can stimulate personal travel such as visiting attractive places or making impulsive shopping trips. On the other hand, travel also creates a demand for telecommunications, before the trip (to plan it), during the trip (e.g. to pass the time, or change plans on the fly), and afterwards (to maintain communication with new contacts or follow up on action items).

- In a modification relationship, telecommunications is able to change the time, mode, destination, number of people, and so on with respect to a trip. Conversely, travel has transformed many communications from fixed to mobile modes, altered the destinations as well as origins of a communication, and so on.

- In a neutrality relationship, telecommunications has no impact on travel or vice versa. For example, many e-mail messages have no impact on travel and conversely. It should be noted that sometimes, since both substitution and complementarity effects are plausible, both types of effects may cancel each other, resulting in net effects of zero. This is conceptually different from a neutrality relationship, although empirically the two could be difficult to distinguish.

2.2 Review of Aggregate Empirical Studies

Although numerous scholars have described the overall relationships between telecommunications and travel, to date there have been only a few aggregate empirical analyses. Among them, four studies (Choo, 2004; Choo and Mokhtarian, 2005, 2007; Lee and Mokhtarian, 2004, 2005a, b, 2006; Plaut, 1997; Selvanathan and Selvanathan, 1994) are especially worthy of detailed discussion. The first one focuses on the actual activities of traveling and telecommunicating, while the other three take economic perspectives, but focus on different aspects of the subject.

2.2.1 Activity-Based Measures

Choo (2004) explored the aggregate relationships (substitution, complementarity, or neutrality) between telecommunications and travel and compared those relationships across transportation modes. This study first presents a conceptual model, considering causal relationships among travel, telecommunications, land use, economic activity, and socio-demographics. Then, based on the conceptual model, the aggregate relationships between telecommunications (local telephone calls, toll calls, and mobile phone subscribers) and travel (VMT, transit passengers, and airline PMT) are explored in a comprehensive framework, using structural equation modeling of U.S. national time series data spanning 1950-2000. At the most detailed level, individual and joint structural equation models for telecommunications and ground travel or airline travel are developed, using selected subsets of the endogenous variables, and then the causal relationships between the two are compared by mode.

The model results suggest that most significant causal relationships between telecommunications and travel are mutually complementary. That is, as telecommunications demand increases, travel demand increases, and vice versa. The only exceptions are the two causal relationships between transit passengers and mobile phone subscribers, which are substitutive. Furthermore, there are a number of neutral (zero net) effects of telecommunications on travel or vice versa. Overall, causal effects between telecommunications and travel differ depending on the particular modes involved. However, most of them are complementary regardless of the causal direction. At a less detailed level, composite indices for eight endogenous variable categories were constructed by combining the multiple variables representing a given category into a single composite indicator for that category through confirmatory factor analysis. Then, structural equation models for travel and wired (telephone calls) or mobile (mobile phone subscribers) telecommunications were estimated, using the composite indices and socio-demographic variables (Choo and Mokhtarian, 2005). The estimated models also support the hypothesis that the aggregate relationship between actual amounts of telecommunications and travel is complementarity, albeit asymmetric in directional weight. That is, as travel demand increases, telecommunications demand increases, and (to a lesser extent) vice versa. Consequently, the empirical results from both levels of structural equation modeling strongly suggest that the aggregate relationship (or system-wide net effect) between actual amounts of travel and telecommunications is complementarity, not substitution.

2.2.2 Monetary-Based Measures: Industrial Perspective

In the previous section, we discussed an empirical study that investigated aggregate relationships between transportation and communications using activity-based measures. The relationships observed using a monetary basis, however, might differ significantly from those based on the activities themselves (e.g. vehicle-miles traveled, or quantity of information communicated). This section and the next present a few aggregate empirical studies examining those relationships using monetary-based measures. In the next section we take the consumer perspective, while here we take the industrial perspective.

The first study was conducted by Plaut (1997), who pointed out that industry accounts for about 2/3 of total monetary expenditures on transportation and communications in the European Community. Utilizing input-output (I-O) analysis, she examined the relationships between transportation and communications as inputs to 44 industry groups (containing transportation and communications themselves) for nine countries of the European Community in 1980. She found generally positive correlations between transportation and communications across industries. That is, for the 44 industry groups overall, when expenditures on communications inputs were high, spending on transportation inputs also tended to be high, and conversely. She concluded that there was a complementary[1] relationship between communication and travel, at least for the industrial context.

Later, Plaut (1999) investigated the relationship between communications and transportation in the countries of Israel (in 1988), Canada (in 1991) and the United States (year not clearly specified). Her findings include complementary relationships for all the countries analyzed in the paper, although the format of the I-O accounts is different since each country uses a different set of industry categories.

[1] As Plaut points out, this is a use of the term that technically differs from its conventional definition in microeconomics, but one that is similar in concept: an increase in the demand for one good is associated with an increase in the demand for the complementary good.

Building and expanding on Plaut's work, Lee and Mokhtarian (2004, 2005a) explored the aggregate relationships between transportation and communications as industrial inputs in the U.S., using benchmark input-output accounts provided by the Bureau of Economic Analysis (BEA) of the U.S. Department of Commerce. The study analyzed Spearman correlations between transportation and communications for each of 10 benchmark years, 1947 to 1997. They investigated not only the utilities (U) sectors (i.e. services) of transportation and communications, but also the manufacturing (M) sectors (i.e. goods) for those inputs, whereas previous studies only analyzed utilities. They compared results over time based on five sets of correlations between transportation and communications (M-M, M-U, U-M, U-U, and (M+U)-(M+U)) using direct I-O accounts[2], and found a pattern of predominant complementarity for the manufacturing pair (M-M) and substitution for the utilities pair (U-U). For the other pairs, there is complementarity between transportation manufacturing and communications utilities and substitution between transportation utilities and communications manufacturing as well as between transportation and communications overall, although the first and last of those results are somewhat weakly based on only four significant correlations out of 10. Interestingly, there are intriguing indications of a possible structural change from substitution to complementarity for the three pairs showing mainly substitution effects (the utilities pair, transportation utilities – communications manufacturing pair, and "all" pair), beginning around 1987.

Subsequently, Lee and Mokhtarian (2005b, 2006) analyzed the relationship between transportation and communications using total I-O accounts[3], and found two different patterns: the first pattern exhibits uniform complementarity for the manufacturing pair (M-M); and the second pattern shows a run of substitution effects followed by a run of complementarity effects, and is exhibited by the remaining four pairs (M-U, U-M, U-U, and (M+U)-(M+U)).

As mentioned, relationships that are based on monetary values can substantially differ from those based on measures of actual activity. Further, just knowing that the amounts of communications and transportation inputs demanded tend to be high or low together, might not say anything about whether one actually causes the need for the other, or whether there is some third variable operating more or less separately on both. Although these are important limitations of the study, it offers a more informed view of the extent to which it is realistic to expect telecommunications to substitute for travel, at least in the industrial context, which constitutes a sizable proportion of the total demand for communications and transportation.

2.2.3 Monetary-Based Measures: Consumer Perspective

Selvanathan and Selvanathan (1994) estimated a simultaneous equation system (a Rotterdam demand system) of consumer demand calibrated with annual, per capita consumption expenditures and population time series data (1960-1986) for the United Kingdom and Australia. They examined

---

[2] "Direct I-O accounts" refers to the input coefficient matrices, which are commodity-by-industry direct requirements. That is, the *i-j*th input coefficient represents the monetary value of inputs of commodity *i* that are required to produce a dollar of gross output in industry *j*.

[3] "Total I-O accounts" refers to industry-by-commodity total requirements. The *i-j*th total requirement coefficient represents the dollar-valued change in output in industry sector *i* resulting from a unit (one dollar) change in the final demand for commodity *j*.

four sectors of consumer demand: private transportation, public transportation, communications, and all others, and found that private transportation, public transportation, and communications have pairwise relationships of substitution, showing all positive cross-price elasticities among those three (meaning that an increase in the price of one kind of good increases the consumption of the other kinds).

The Plaut and Selvanathan and Selvanathan studies show opposite relationships between transportation and communications. This is not necessarily surprising since they involve different sectors (industry v. consumer), methodological approaches (I-O analysis v. consumer demand modeling), treatment of time (cross-section v. time series), study period (1980 v. 1960-1986), and geographic locations (Europe v. Australia and the U.K.). To eliminate some of those potential sources of differences between the two, it would be desirable to replicate their approaches for the same geographical area during the same time period. The Lee and Mokhtarian (2004, 2005a, b, 2006) studies discussed in the previous section replicate (and extend) the Plaut approach on the U.S. for 1947-1997, while the present study essentially replicates the Selvanathan and Selvanathan methodology on the U.S. for 1984-2002. Thus, it will be of interest to compare the findings of the present study with those of Selvanathan and Selvanathan (similar methodology; different countries and earlier time frame) and Lee and Mokhtarian (same country, heavily overlapping time frame; industrial v. consumer perspective).

Chapter 3. Assembling the Consumer Expenditure and Consumer Price Index Data

This chapter describes the available consumer expenditure (CEX) data and consumer price index (CPI) data, with particular attention to the transportation and communications categories analyzed in this study. Section 3.1 provides general overviews of the consumer expenditure data and consumer price index data. Then, Section 3.2 identifies the consumer expenditure items and consumer price index items relating to transportation and communications. Nine categories are classified as transportation and five categories as communications. Finally, Section 3.3 shows how the consumer expenditure and price index categories are reconciled, because the published categories of the CEX and CPI data do not perfectly match each other. Trends in the CEX data are presented and analyzed in Chapter 4.

3.1 General Description of the Consumer Expenditure and Price Index Survey Data

3.1.1 Consumer Expenditure Surveys

Consumer expenditure surveys (CES) are conducted to collect data on expenditures for goods and services which are used in consumers' daily lives. The Bureau of Labor Statistics (BLS) performs consumer expenditure surveys, and also collects some information such as the amount and sources of family income, changes in savings and debt, and demographic and economic characteristics of the consumer unit[4]. The first nationwide expenditure survey was conducted in 1888-1891 to study workers' expenditure patterns. Later, the surveys were administered to analyze the expenditures of households or workers although they were not conducted at regular intervals. Table 3.1 presents a brief history of the consumer expenditure survey from 1888 to 1979. Since the 1972-73 administration, the survey actually comprises two individual sets of instruments: the interview survey and the diary survey. For the interview survey, approximately 15,000 addresses are contacted in each quarter of the calendar year. The interview survey uses a rotating panel sample, so that one-fifth of the addresses contacted each quarter is newly recruited to the survey (although the initial interview is conducted only for bounding purposes[5]). Among the 15,000 addresses, usable interviews are obtained from approximately 7,600 households each quarter, so that the total number of interviews for the year is about 30,400. For the diary survey, a sample of about 12,500 addresses is selected each year, which nets usable diaries from approximately 7,700 households. Each consumer unit completes two separate questionnaires (i.e. a Household Characteristics Questionnaire and a Record of Daily Expenses diary[6]) per sample, so the total number of surveys per year is approximately 15,400.

---

[4] A consumer unit (CU) comprises all members of a particular housing unit who are "related by blood, marriage, adoption, or some other legal arrangements", or who are unrelated but financially dependent on each other for major living costs (U.S. DOL, 2004). Although the government's definition of a CU technically differs from that of a household (the US Census Bureau says "a household consists of all people who occupy a housing unit regardless of relationship [and financial dependence]"), the meaning of the two terms is similar enough that we will use them interchangeably in this report.

[5] This is "to classify the unit for analysis and to prevent duplicate reporting of expenditures in subsequent interviews" (U.S. DOL, 1997).

[6] In the Household Characteristics Questionnaire, the interviewer records socioeconomic information such as the age, gender, race, marital status, family composition, work experience, and incomes of each member of the consumer

Table 3. 1: A Brief History of the Consumer Expenditure Survey Conducted by the Bureau of Labor Statistics (BLS)

Years	Characteristics of the Survey
1888-1891	- The first nationwide expenditure survey - Purpose: to study workers' spending patterns
1901	- The second survey - Reason: prices were changing rapidly - The data provided the weights for an index of the price of food purchased by workers. - The data were used as a deflator for workers' incomes and expenditures.
1917-1919	- The third survey - The data provided weights for computing a cost-of-living index (previous version of the Consumer Price Index (CPI)).
1934-1936	- Purpose: to update weights - The survey covered urban wage earners and clerical workers.
1935-1936	- Concurrent with the 1934-1936 survey - The survey was improved to allow more general economic analysis. - The Bureau of Labor Statistics (BLS) cooperated with four other federal agencies. - Consumption was estimated for urban and rural areas.
1950	- Abbreviated version of the previous survey (only for urban consumers)
1960-1961	- For both urban and rural consumers - Basis of revising the CPI weights - The survey provided data for many different economic analyses.
1972-1973	- The Bureau of the Census (under contract with BLS) conducted all sample selection and related work. - Expenditures of households in the U.S. were collected. - Two independent surveys were conducted (diary survey and interview panel survey). - Changed from an annual period to a quarterly period (interview survey) and daily expenditures (diary survey).
1979	- From this point in time, survey is conducted continuously rather than every 10 years or so. - The Bureau of the Census (under contract with BLS) collected the data. - Purposes: 1) to update the "weights and associated pricing samples" (representative samples for determining price) for the CPI; 2) to provide detailed data collected from "different types of families" - Both the interview survey and diary survey are conducted.

Note: This summary table is based on "Chapter 16. Consumer Expenditures and Income" (U.S. DOL, 1997).

---

unit. In the Daily Expenses Record, respondents record detailed information on all expenses for two consecutive weeks.

Table 3.2 presents the major characteristics of the interview and diary surveys. Since several expenditure items are assembled only from either the diary or the interview survey, the integrated data from both surveys supply a comprehensive accounting of consumer expenditures.

Table 3. 2: Characteristics of Current Consumer Expenditure Surveys

Interview Survey	Diary Survey
- Respondents recall for a period of 3 months or longer to collect data on the types of expenditures - Interviewed once per quarter (for five consecutive quarters) - Takes about 90 to 120 minutes to complete - Each quarter's data are treated independently in computing annual expenditures - Includes property, automobiles, or major appliances, or regular expenses (rent, utility bills, or insurance premiums) 1) Initial interview: demographic and family characteristics 2) From the second to the fifth interviews: major expenditure (housing, transportation, medical, education) and income information (wage, salary, and other income information) - Two major sections: 1) Monthly expenditures (about 65% of the data) 2) Quarterly expenditures (about 35% of the data)	- Completed at home for two consecutive weeks - For small or frequently purchased items that are difficult to recall - Takes about 15 minutes per visit to collect the demographic data and to provide instructions for the respondent - Includes: 1) Food and beverages 2) Eating both in and outside the home 3) Housekeeping supplies and services 4) Nonprescription drugs 5) Personal care products and services 6) Other expenses during the survey week - Excludes: 1) Expenses of people while away from home 2) Installment payments - Two major sections: 1) Household characteristics (age, sex, race, marital status, family composition, work experience and earnings) 2) Record of daily expenses (detailed description of all expenses for two consecutive weeks)

Note: This summary table for interview and diary surveys is based on "Chapter 16. Consumer Expenditures and Income" (U.S. DOL, 1997).

From 1984 onward, detailed consumer expenditure data are available on the BLS website (www.bls.gov). Accordingly, we assembled the consumer expenditure data for the 19 years from 1984 to 2002, with special attention to the categories of transportation and communications. The nine transportation and five communications categories used in our analyses are presented in Table 3.4 in Section 3.3.

3.1.2 Consumer Price Index Surveys

3.1.2.1 General

The consumer price index (CPI) is defined as a measure of the average change in the prices of a "market basket" (i.e. a representative sample) of consumer goods and services. The CPI is most often used as a measure of inflation and a deflator of other economic series (to produce inflation-adjusted series). The Bureau of Labor Statistics (BLS) publishes CPI data for all urban consumers (CPI-U) and for urban wage earners and clerical workers (CPI-W) every month. The CPI-U measures the price changes obtained from samples representing nearly all residents of urban or metropolitan areas, consisting of about 87% of the U.S. population in 1990. Not included in the population of this CPI are people living in non-metropolitan areas and in the Armed Forces, and farm families. On the other hand, the CPI-W is calculated based on a subset of the CPI-U population, consisting of about 32% of the U.S. population in 1990. The CPI-W's population consists of households for which most (50% or more) of their income comprises wages and clerical workers' earnings. Each CPI-W household must have at least one worker employed for at least 37 weeks during the previous 12 months.

The market basket for the CPI has been developed from detailed information about expenditures of families and individuals, collected from the Consumer Expenditure Surveys over time. For creating the CPI, urban areas are divided into 38 geographical regions (metropolitan areas) and all goods and services purchased by consumers are classified into 211 categories. This creates 8018 item-area combinations. Basic CPIs are first calculated for each of the 8018 combinations, and then aggregate CPIs are calculated by weight-averaging subsets of the total combinations. The weights for the aggregate CPIs are based on reported expenditures from the surveys.

Generally, CPIs are relative measures, so they require a base year (e.g. 2000) or a base period (e.g. 1982-84), whose CPIs are fixed to 100 (on average for the period). For example, when the CPI-U for transportation for 2002 is 147.4 with a base year of 1984, this can be interpreted that a bundle of transportation expenses costing $100 in 1984 would have cost $147.4 in 2002. Or, the percent change in the price of transportation between the two years is 47.4% [= (147.4-100)/100*100)], indicating the inflation rate for the period[7].

Table 3.3 shows a brief history of changes in the CPI. There are six major changes in the samples and weights for calculating CPIs. Among them, the item classification system for reporting CPIs was substantially revised in 1998, resulting in discontinuity of CPIs for some items. In this national study, we use annual CPI-U data for the U.S. city average with a base year of 1984.

3.1.2.2 Sampling and Data Structure

Primary sampling units (PSUs) are geographic unit areas for CPI sampling. Most of the PSUs within metropolitan areas are the metropolitan areas themselves, while those in non-metropolitan areas are county-based. There are three types of PSUs, based on size: type A is a PSU with population larger than 1.5 million; type B/C is a PSU in a metropolitan area with population less than type A; and type D is a PSU in a non-metropolitan area with population less than type A. After the entire nation is divided into PSUs, BLS employs stratified sampling to obtain a CPI in each region-size class (e.g. South B PSU), based on Census regions (Northeast, Midwest, South, and West).

[7] Actually, the effects of inflation are confounded with those of technological advancements (e.g. one gallon of gasoline can take an automobile farther today than it could in 1984), changes in consumer tastes (despite the availability of more fuel-efficient cars, consumer preferences for larger truck and sport utility vehicles mean that a gallon of gasoline actually produces fewer miles traveled today than in 1984), and occasional changes in the market basket to reflect new (e.g. computers) and obsolescent (e.g. record albums) goods and services. For further discussion of this point, see Section 4.3.

Table 3. 3: Historical Changes in the CPI

Period	Changes in the CPI
Prior to 1940	Published separate indexes for 32-33 cities, beginning in 1919. Developed weights (relative importance) of goods and services purchased by consumers, based on 1917-19 family expenditures in 92 industrial centers. Published a national index and the U.S. city average beginning in 1921. Included families of two or more persons.
1940-1952	Developed weights for 1940 CPIs based on 1934-36 survey of consumer expenditures. Adjusted the weights for 1950 CPIs based on 1947-1949 Consumer Expenditure Survey. Collected prices from the 34 largest cities. Added new items.
1953-1963	Adjusted weights using 1950 Consumer Expenditure Survey (in central cities and attached urbanized areas, including medium and small cities). Focused on urban wage earner and clerical worker families (CPI-W). Added new items.
1964-1977	Adjusted weights using 1960-61 Consumer Expenditure Survey in metropolitan areas. Added single-person households to the sample. Added new items. Sampled 50 areas. Included families of two or more persons and single workers.
1978-1986	Added a new CPI for all urban consumers. Adjusted weights using 1972-73 Consumer Expenditure Survey. Sampled 85 areas. Retail outlet and item sample rotation conducted every five years, beginning in 1981. Added and updated items, outlets and areas in the sample.
1987-1997	Adjusted weights using 1982-84 Consumer Expenditure Survey. Added and updated items, outlets and areas in the sample. Sampled 91 areas. Redesigned the CPI Housing Survey.
1998 – present	Adjusted weights for 1998 and 2002 CPIs using 1993-1995 and 1999-2000 Consumer Expenditure Surveys, respectively. Updated weights every two years, beginning in 2002. Updated geographic and housing sample. Revised item classification system in 1998.

Note: This table is adapted from Table 1 in "Chapter 17. The Consumer Price Index" (U.S. DOL, 1997).

The structure of consumer price index (CPI) data has four levels. At the top level, there are eight major groups:

- Food and beverage (e.g. cereals, bread, meats, poultry, and fish)
- Housing (e.g. rent of primary residence, fuels, and furniture)
- Apparel (e.g. men's shirts and sweaters, women's dresses, footwear, and jewelry)
- Transportation (e.g. new vehicles, motor fuel, airline fares, and parking fees)
- Medical care (e.g. prescription drugs, physicians' services, and hospital services)
- Recreation (e.g. televisions, pets and pet products, sports equipment, newspapers)

- Education and communication (e.g. college tuition, postage, telephone services, computer software and accessories, and Internet services)
- Other goods and services (e.g. tobacco and smoking products, haircuts and other personal services, funeral expenses, and stationery).

The major groups comprise 70 expenditure classes, which are further subdivided into 211 items. At the lowest level, there are 305 entry level items for sampling. Additionally, the CPI includes sales and excise taxes that are related to the purchase of consumer goods and services (but not income and Social Security taxes). However, the CPI does not include investment-related items, such as stocks, bonds, and real estate.

Generally, BLS collects price data monthly for all items in all PSUs, through outlet surveys (including retail stores and service establishments) obtained through personal visits or telephone calls by trained representatives. The U.S. Census Bureau conducts the Telephone Point-of-Purchase Survey (TPOPS) to acquire data on retail outlet prices, and demographic and socio-economic information from consumer units. Prices are collected in 87 urban areas from about 50,000 housing units and nearly 23,000 retail outlets such as department stores, supermarkets, and hospitals. Additionally, prices of fuels and a few other items are collected every month from all locations. Prices of most other commodities and services are obtained every month in the three largest areas (New York, Los Angeles, and Chicago) and every two months in other areas.

3.2 Categorization of Consumer Expenditure Items and Consumer Price Index Items

3.2.1 Selection Process for Transportation and Communications Items

This section describes how we selected the consumer expenditure items related to transportation and communications. As discussed in the previous sections, there are many specific items in the consumer expenditure data set. We tried to find the transportation- and communications-related items for which the data are available from 1984 to 2002. To identify the items, we started with the two broadest conceptual categories of transportation and communications, and then split them into smaller groups following the categorization structure available in the data. Finally, each group was examined with respect to specific items in the data set, and the particular items to be analyzed were determined. Figure 3.1 shows our process of selecting transportation and communications items.

Most categories are logically classified as transportation or communications. The “out-of-town lodging” category is identified as a transportation item in our context, because lodging away from home is likely to be associated with transportation (as noted below, although this category contains vacation home, hotel, and motel expenditures, which is what we wanted to analyze, unfortunately it also includes expenditures on college dormitories). The “other entertainment equipment” category is also included under transportation since it contains bicycles and a number of other recreational travel vehicles (as well as other less relevant items). Each category will be discussed in detail in the next section.

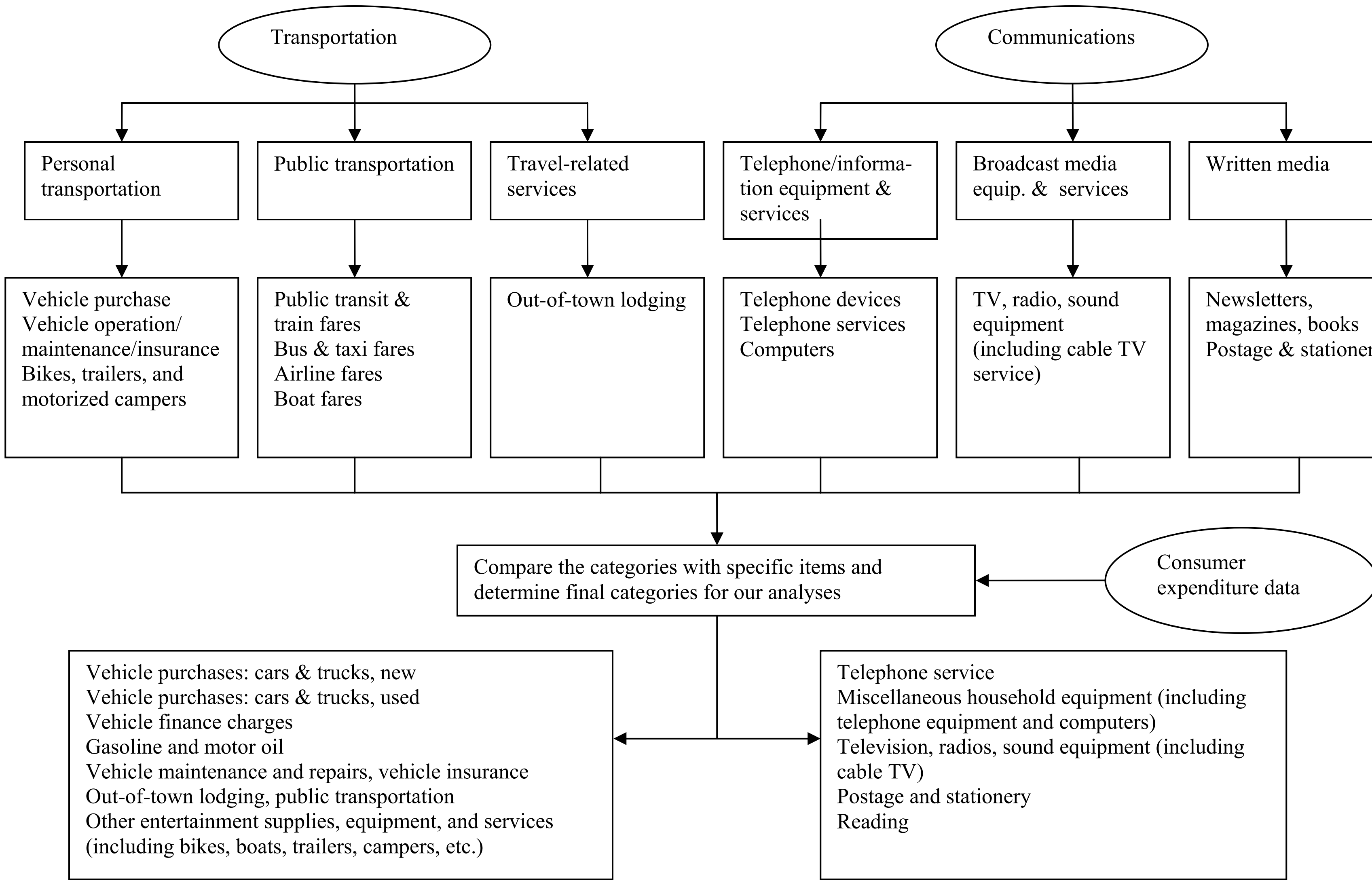


Figure 3. 1: Selection Procedure for Transportation and Communications Items

3.2.2 Consumer Expenditure Categories

Through the procedure above, we identified nine items closely related to transportation, and five items associated with communications. Table 3.4 presents the items and their ID numbers for simplicity.

Table 3. 4: Transportation and Communications Item Categories

General category	Item ID[1]	Title of item category
Transportation	T1	Out-of-town lodging
	T2	Gasoline and motor oil
	T3	Vehicle finance charges
	T4	Vehicle maintenance and repairs
	T5	Vehicle insurance
	T6	Public transportation (including air and boat fares)
	T7	Vehicle purchases: cars and trucks, new
	T8	Vehicle purchases: cars and trucks, used
	T9	Other entertainment supplies, equipment, and services (including bikes and recreational vehicles)
Communications	C1	Telephone service
	C2	Postage and stationery
	C3	Miscellaneous household equipment (including telephone and computer equipment)
	C4	Television, radios, sound equipment
	C5	Reading

Note: [1] "Item ID" is created to conveniently label the nine transportation and five communications categories.

Brief explanations[8] of each item category are presented below. Goods that are closely related to transportation and communications are not always classified into individual categories, and so several categories include other goods. However, they are included because many of their constituent items relate to transportation and communications.

Transportation

Out-of-Town Lodging (T1): All expenses for homes, school, college, hotels, motels, and other lodging while people are out of town. (Primary residence expenses are included elsewhere and not analyzed here).

Gasoline and Motor Oil (T2): Gasoline, diesel fuel, and motor oil.

Vehicle Finance Charges (T3): The dollar amount of interest paid for a loan contracted for the purchase of vehicles (new or used, domestic or imported, cars and trucks and other vehicles, including motorcycles and private planes).

[8] The explanations of the 14 categories are excerpted from the "Glossary" that is available on the BLS website (www.bls.gov/cex/csxgloss.htm).

Vehicle Maintenance and Repairs (T4): Tires, batteries, tubes, lubrication, filters, coolant, additives, brake and transmission fluids, oil change, brake work including adjustment, front-end alignment, wheel balancing, steering repair, shock absorber replacement, clutch and transmission repair, electrical system repair, exhaust system repair, body work and painting, motor repair, repair to cooling system, drive train repair, drive shaft and rear-end repair, tire repair, audio equipment, other maintenance and services, and auto repair policies.

Vehicle Insurance (T5): The premium paid for insuring cars, trucks, and other vehicles.

Public Transportation (T6): Fares for mass transit, buses, trains, airlines, taxis, school buses for which a fee is charged, and boats.

Vehicle Purchases: Cars and Trucks, New (T7): The purchase of new domestic and imported cars and trucks and other vehicles, including motorcycles and private planes.

Vehicle Purchases: Cars and Trucks, Used (T8): The purchase of used domestic and imported cars and trucks and other vehicles, including motorcycles and private planes.

Other Entertainment Supplies, Equipment, and Services (T9): Indoor exercise equipment, athletic shoes, bicycles, trailers, purchase and rental of motorized campers and other recreational vehicles, camping equipment, hunting and fishing equipment, sports equipment (winter, water, and other), boats, boat motors and boat trailers, rental of boats, landing and docking fees, rental and repair of sports equipment, photographic equipment and supplies (film and film processing), photographer fees, repair and rental of photo equipment, fireworks, and pinball and electronic video games.

Communications

Telephone Service (C1): All charges related to telephone calls (telephone equipment falls under C3, unfortunately).

Postage and Stationery (C2): All kinds of postage and stationery supplies.

Miscellaneous Household Equipment (C3): Typewriters, luggage, lamps and light fixtures, window coverings, clocks, lawnmowers and gardening equipment, other hand and power tools, telephone answering devices, telephone equipment and accessories, computers and computer hardware for home use, computer software and accessories for home use, calculators, business equipment for home use, floral arrangements and house plants, rental of furniture, closet and storage items, other household decorative items, infants' equipment, outdoor equipment, smoke alarms, other household appliances, and other small miscellaneous furnishings.

Television, Radios, Sound Equipment (C4): Television sets, video recorders, video cassettes, video tapes, discs, disc players, video game hardware, video game cartridges, cable TV, radios, phonographs, tape recorders and players, sound components, records, compact discs, and tapes, musical instruments, and rental and repair of TV and sound equipment.

Reading (C5): Subscriptions for newspapers and magazines; books through book clubs; and the purchase of single-copy newspapers, magazines, newsletters, books, and encyclopedias and other reference books.

3.2.3 Consumer Price Index Categories

We selected CPI categories associated with transportation and communications, considering the consumer expenditure categories discussed above. Table 3.5 shows the selected CPI categories together with their data availability. BLS provides all published CPI data on its website (www.bls.gov). CPIs for most categories are available for the study period (1984-2002). However, some categories were added or reclassified into new or other categories in 1998, so their data are not completely available. Further, the CPI for automobile finance charges is not published after 1997.

We used the relative importance[9] (hereafter "weight") of each category in the CPIs to extrapolate CPIs for the years missing from the "automobile finance charges" and "information technology, hardware, and services" series, and to create combined CPI categories to match the consumer expenditure categories (as well as the other categories introduced later). However, weight data for 1984 and 1985 are not available, so they first had to be extrapolated by using local or global regression analyses (with year as the explanatory variable), or by taking average values of slopes after examining their scatter plots.

Table 3.6 summarizes the weight extrapolation methods used for each category (except for the newly-added ones of 1998), together with the range of years on which the calibration was based. Many of the regression models are based on data from 1986-1997 (since the BLS revised CPI category classifications in 1998, so some of the data categories are not consistent with those before 1998), in two cases (motor fuel and motor vehicle maintenance and repair) excluding outliers. R^2 values for 13 out of the 19 regression models are higher than 0.8. Since the weight values for the postage category showed considerable fluctuation over time, missing data in that category were extrapolated by using average slope values in the positive and negative directions for 1984 and 1985, respectively. Using the extrapolated weights, CPIs for automobile finance charges were predicted for missing years. On the other hand, we excluded from the CPI calculation the five items shown in Table 3.5 as being newly added in 1998, since data were not available over the entire study period. That is, although the more aggregate *expenditure* categories used in the models include these items, the *CPIs* associated with the more aggregate categories do not use any price information for those newly-added items.

3.3 Reconciling Expenditure and Price Categories

Since the published categories for consumer expenditures and the consumer price index are not exactly the same, we need to reconcile them. In this study, we focus more on consumer expenditures (as measures of consumer demand) than on the consumer price index, so CPI categories should be combined based on the consumer expenditure categories (nine transportation and five communications) as mentioned in Section 3.2.1.

---

[9] For example, the weight of CPI for food is 16.19. That is, the price of all food items constitutes 16.19% of the price of all items. The sum of all weights will be 100%.

Table 3. 5: CPI Categories for Transportation and Communications

Category	Data availability	Notes
Transportation		
Out-of-town lodging		
Housing at school, excluding board	1984 – present	
Other lodging away from home including hotels and motels	1984 – present	
New vehicles	1984 – present	
Used cars and trucks	1984 – present	
Motor fuel	1984 – present	
Automobile finance charges	1986 – 1997	missing, discontinued
Motor vehicle maintenance and repair	1984 – present	
Motor vehicle parts and equipment	1984 – present	
Motor vehicle insurance	1984 – present	
Public transportation	1984 – present	
Sporting goods (including sport equipment and vehicles (bicycles))	1984 – present	
Communications		
Telephone services		
Land-line telephone services, local charges	1984 – present	
Land-line telephone services, long distance charges	1998 – present	
Land-line interstate toll calls	1984 – present	
Land-line intrastate toll calls	1984 – present	
Wireless telephone services	1998 – present	newly added
Postage and delivery services		
Postage	1984 – present	
Delivery services	1998 – present	newly added
Information technology, hardware, and services (including personal computers, computer software, and Internet services)	1998 – present	used the predecessor CPI, for information processing equipment, before 1998
Video and audio		
Televisions	1984 – present	
Cable and satellite television and radio service	1984 – present	
Other video equipment	1998 – present	newly added
Video cassettes, discs, and other media including rental	1998 – present	newly added
Audio equipment	1984 – present	
Audio discs, tapes, and other media	1998 – present	newly added
Recreational reading materials (including newspapers, magazines, and recreational books)	1984 – present	

Table 3. 6: Extrapolation Methods for Relative Weights of CPI Categories

Category	Calibration data range	Method	Missing years to which method was applied
Transportation			
Housing at school, excluding board	1986-2002	Regression model, $R^2 = 0.984$	1984-1985
Other lodging away from home including hotels and motels	1986-2002	Regression model, $R^2 = 0.899$	1984-1985
New vehicles	1986-1997	Regression model, $R^2 = 0.794$	1984-1985
Used cars and trucks	1986-2002	Regression model, $R^2 = 0.617$	1984-1985
Motor fuel	1986, 88, 89, 91-92	Regression model, $R^2 = 0.924$	1984-1985
Automobile finance charges	1986-89 1994-97	Regression model, $R^2 = 0.924$ Regression model, $R^2 = 0.927$	1984-1985 1998-2002
Motor vehicle maintenance and repair	1986-1990	Regression model, $R^2 = 0.880$	1984-1985
Motor vehicle parts and equipment	1986-2002	Regression model, $R^2 = 0.904$	1984-1985
Motor vehicle insurance	1986-1997	Regression model, $R^2 = 0.966$	1984-1985
Public transportation	1986-1997	Regression model, $R^2 = 0.427$	1984-1985
Sporting goods	1986-1997	Regression model, $R^2 = 0.973$	1984-1985
Communications			
Land-line telephone services, local charges	1986-2002	Regression model, $R^2 = 0.369$	1984-1985
Land-line interstate toll calls	1986-1997	Regression model, $R^2 = 0.645$	1984-1985
Land-line intrastate toll calls	1986-1997	Regression model, $R^2 = 0.889$	1984-1985
Televisions	1986-1997	Regression model, $R^2 = 0.976$	1984-1985
Cable and satellite television and radio service	1986-1997	Regression model, $R^2 = 0.892$	1984-1985
Audio equipment	1986-1997	Regression model, $R^2 = 0.991$	1984-1985
Postage	1986-1997	Average values of positive slopes (for 1984) and negative slopes (for 1985)	1984-1985
Information technology, hardware, and services	1986-1997	Regression model, $R^2 = 0.993$	1984-1985
Recreational reading materials	1986-1997	Regression model, $R^2 = 0.770$	1984-1985

Note: Categories whose regression models used data for 1986-1997 are reclassified to or combined with another category after 1997.

Table 3.7 presents the CPI categories most closely corresponding to those for consumer expenditures. For eight out of the 14 CEX categories, there is a close match to a CPI category. For another four categories, CPIs for subcategories could be combined into a composite index that matched the CEX category reasonably well. The remaining two CEX categories are the heterogeneous "other entertainment" and "miscellaneous household equipment" discussed in the previous section. In those two cases, we chose the CPI categories most closely corresponding to the items within the CEX categories that we are most interested in, namely "sporting goods" and "information technology", respectively. It should be noted that even when a CPI category is very similar to that for consumer expenditures, the detailed items in both categories may not be the same. However, since CPI data indicate average (relative) prices of the category, they can reasonably capture the effect on consumer expenditures, especially in aggregate demand studies.

Table 3. 7: Correspondence between Consumer Expenditure and Consumer Price Index Categories

Consumer Expenditure	Consumer Price Index
Transportation	
Out-of-town lodging	Combined CPI of housing at school, excluding board, and other lodging away from home including hotels and motels
Vehicle purchases: cars and trucks, new	New vehicles
Vehicle purchases: cars and trucks, used	Used cars and trucks
Gasoline and motor oil	Motor fuel
Vehicle finance charges	Automobile finance charges
Vehicle maintenance and repairs	Combined CPI of motor vehicle maintenance and repair and motor vehicle parts and equipment
Vehicle insurance	Motor vehicle insurance
Public transportation	Public transportation
Other entertainment supplies, equipment, and services	Sporting goods
Communications	
Telephone	Combined CPI of land-line telephone services, local charges, intrastate toll calls, and interstate toll calls (but not wireless services)
Postage and stationery	Postage (but not delivery services)
Miscellaneous household equipment	Information technology, hardware and services (information processing equipment before 1998)
Television, radios, and sound equipment	Combined CPI of televisions, cable and satellite television and radio service, and audio equipment
Reading	Recreational reading materials

Composite CPIs are required not only for the four categories noted in Table 3.7 (and in fact, the 14 categories of that table are not modeled directly, due to the small sample size of our data set), but also when groups of the 14 categories are combined, as described in Section 5.2. The weights of items comprising a CPI are used for creating composite CPIs. Let w_{ik} be defined as the weight of the i^{th} item in combined category k, and CPI_{ik} as the CPI for item i in category k.

There are at least two logical ways that a composite CPI for a combined category k, CPI_k, can be defined:

(i) $CPI_k = \sum_i w_{ik} CPI_{ik} / \sum_i w_{ik}$, using the corresponding CPIs, or

(ii) $relative\ CPI_k = \sum_i w_{ik} CPI_{all} / \sum_k \sum_i w_{ik} = \sum_i w_{ik} CPI_{all} / 100$, using the CPI for all items.

The first definition can be viewed as a "bottom-up" approach that builds a composite CPI from the CPIs for the constituent items in the category, while the second definition reflects a "top-down" approach that partitions the overall CPI based on the combined importance weights of the items in each composite category. For example, suppose there are two items, new vehicle purchase and used vehicle purchase, in the category of personal vehicle capital costs. The w_i's for new vehicle purchase and used vehicle purchase are hypothetically 20 and 10, and their CPIs are 110 and 100, respectively, in a certain year. The CPI for all items of that year is 105. Then, the two price measures for the category are

(i) CPI_k: (20/30) * 110 + (10/30) * 100 = 106.7,

(ii) *relative* CPI_k: {20/100 + 10/100} * 105 = 31.5.

Thus, the first measure is simply a weighted average of the individual CPIs for the items comprising the category, where the weights are the relative importance of each item to the overall market basket. The second measure simply calculates the portion of the overall CPI that is attributable to the category, based on the relative importance of all items in the category. We then have to rescale the relative CPI_k by setting the relative CPI_k of the base year to 100 (and thus the two CPI formulations cannot be directly compared until that rescaling has been accomplished). These two types of composite CPIs will be used and compared in the demand system models presented in Chapter 5; time-series plots of both formulations are found in Appendix A. It should be noted that even when we use the first way of computing CPIs in a demand system model, the CPI for the "other" category is created using the second approach. This is to avoid the difficulty in building up a CPI_{other} from the CPIs for every item in the sizable "other" category, requiring a match (not always exactly available) between item-specific CPIs and expenditure categories.

Chapter 4. Trends in Transportation and Communications Expenditures

4.1 Introduction

This chapter describes trends with respect to consumers' expenditure patterns in transportation and communications categories from 1984 to 2002. The trends are presented for several different classifications (at various levels of category aggregation), and illustrated using raw expenditures (dollar values) as well as expenditure shares (%s). Section 4.2 presents and discusses visual representations of the trends. Section 4.2.1 presents the trends using the most aggregate classification (two categories: transportation and communications). Sections 4.2.2 to 4.2.4 describe the trends using three different disaggregate classifications, containing six, five, and 14 (the most disaggregate) categories, respectively. Specifically, Section 4.2.2 uses four transportation and two communications categories: other entertainment equipment and services (Ent: e.g. bicycles, boats), non-private vehicle travel (TrNPV: out-of-town lodging and public transportation), private vehicle capital costs (TrPVC: vehicle purchase and finance), private vehicle operating costs (TrPVO: e.g. gasoline, maintenance), new communications (ComN: e.g. telephone, TV), and old communications (ComO: postage and reading). The categories are described more completely in Table 4.1. Since the entertainment and out-of-town lodging categories contain a number of items that are not transportation related, in Section 4.2.3 we remove those categories, and retain the "public transportation" category together with the remaining two transportation and two communications categories of Section 4.2.2. Section 4.2.4 analyzes consumer expenditure patterns using the most disaggregate classification (14 categories: nine for transportation and five for communications). In each subsection, we present results of regression analyses of expenditures against time, as well as graphs showing trends of consumer expenditures (dollar value) and expenditure shares (%).

Table 4. 1: Description of Transportation and Communications Categories

Code	Category	Detailed Categories
Ent	Entertainment	Other entertainment equipment and services
TrNPV	Transportation (Non-Private Vehicle)	Out-of-town lodging Public transportation
TrPBT	Transportation (Public Transportation)	Public transportation
TrPVC	Transportation (Private Vehicle, Capital)	New vehicle purchase Used vehicle purchase Vehicle finance charge
TrPVO	Transportation (Private Vehicle, Operation)	Gasoline and motor oil Vehicle maintenance and repairs Vehicle insurance
ComN	Communications (New)	Telephone service Miscellaneous household equipment TV, radios, and sound equipment
ComO	Communications (Old)	Postage and stationery Reading

Section 4.2 analyzes trends in current dollars, that is, taking each year on its own terms. But observed increases in expenditures over time are actually confounding several separate effects: increases in the unit prices of goods due to inflation, changes in the effectiveness of a good due to technological advances or quality improvements (that may raise *or* lower the unit price), changes in consumer tastes or preferences, and real changes in income. In Section 4.3, we attempt to isolate these various effects. Section 4.3.1 discusses those five potential reasons why consumer expenditures in a given category change over time. Section 4.3.2 presents trends in the Consumer Price Index (CPI)-adjusted expenditures, which roughly represent expenditures purged of the inflation effect, for the various classification schemes (two, six, five, and 14 categories). The CPIs (adjusted to the base year of 1984) are used to calculate the constant values of consumer expenditures, that is, the values in 1984 dollars, or the amount that each year's purchases would have cost had they been purchased in 1984. Section 4.3.3 qualitatively analyzes expenditure trends with respect to the remaining sources of changes in expenditure: technological changes, quality changes, taste changes, and real income changes. Finally, Section 4.4 summarizes both nominal and real dollar-based consumer expenditure trends as well as recapitulating the major sources of expenditure change.

4.2 Expenditure Trends (Current or Nominal Dollars) by Various Classification Schemes

4.2.1 Most Aggregate Classification (Two Categories)

To begin the analysis, it is of interest to examine consumers' expenditure patterns using the most aggregate classification of just two categories (transportation and communications), for the 19 years 1984-2002. Figure 4.1 shows that both transportation and communications expenditures have increased in current dollars over the study period, with transportation expenditures rising more rapidly than those for communications.

The regression of expenditures against time shows that a straight line captures the relationship quite well (explaining 93% of the variance in transportation expenditure, and 99% for communications), with the rate of increase in expenditure on transportation about 2.3 times that of the increase for communications. Specifically, over the 19-year study period, consumers increased their spending on transportation by an average of \$177 a year, compared to \$77 a year for communications, in current dollars.

When viewed as a share of total expenditures, however, the picture is rather different, as shown in Figure 4.2. The regression indicates that the transportation expenditure share has significantly decreased over the years 1984 to 2002 – about 1/10 of a percentage point per year, on average. However, the R^2 value of the equation is only 0.305, and the expenditure share has remained roughly constant at 20% since 1994. In contrast, the share of expenditure on communications shows a significant increase over time, with an R^2 of 0.651. However, the rate of that increase is about half that of the decrease in transportation expenditure share – only 1/20 of a percentage point per year. Further, the last six years of the study period have shown a slight but perceptible decline in share.

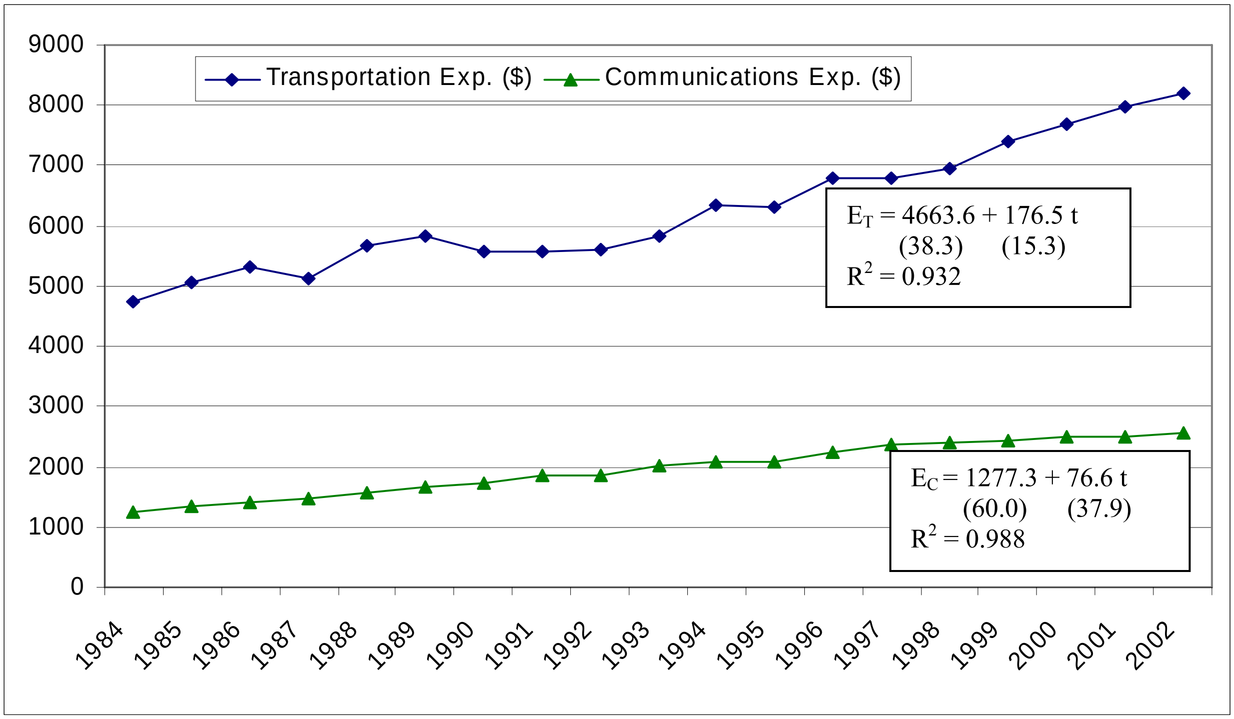


Figure 4. 1: Annual Transportation and Communications Expenditure Trends (Two-Category Classification) ($)

Notes: E_T: transportation expenditure; E_C: communications expenditure. Values in parentheses are t-statistics.

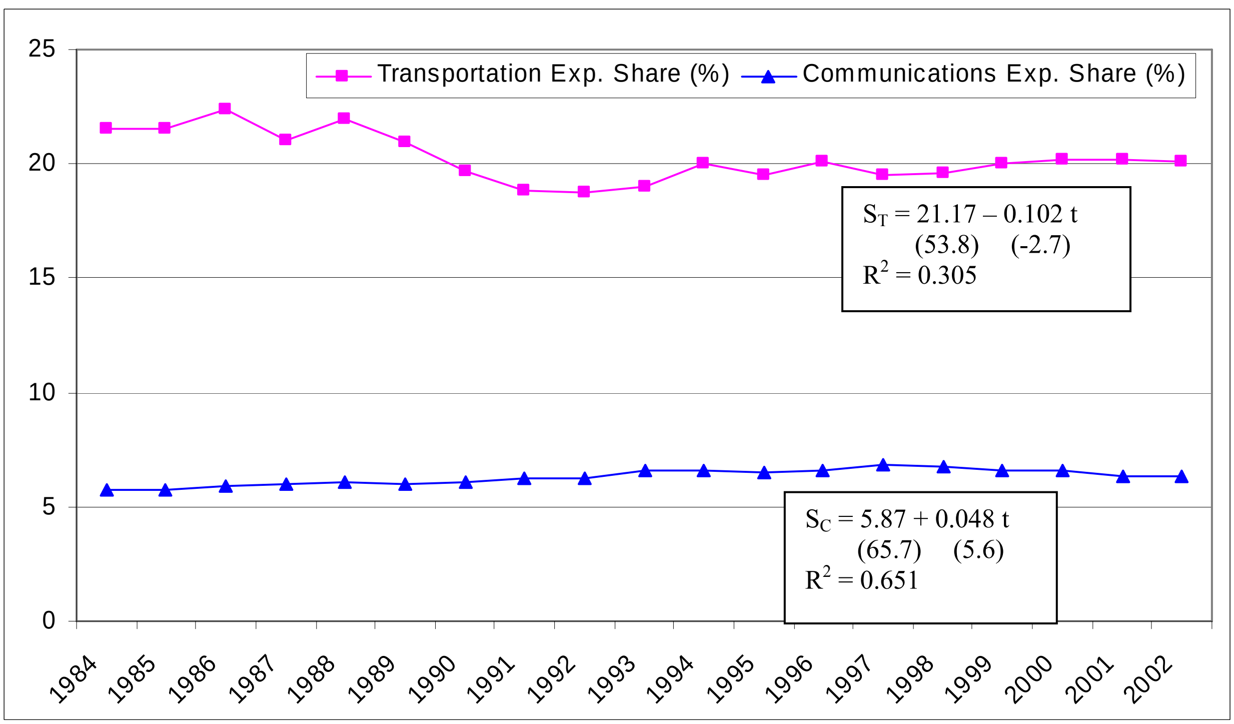


Figure 4. 2: Annual Transportation and Communications Expenditure Share Trends (Two-Category Classification) (%)

Notes: S_T: transportation expenditure share; S_C: communications expenditure share. Values in parentheses are t-statistics.

Although the trends for transportation differ depending on whether one examines raw expenditures or shares, in either case it can be seen that the expenditure on transportation is several times that of communications, although the difference is slowly narrowing over time, from a factor of about 4 in 1984, to a factor of 3 in 2002.

4.2.2 Six-Category Classification

Having reviewed the overall trends in expenditures for transportation and communications, it is of interest to examine the trends for the various subcategories that comprise each overall category. In this section, we explore the expenditure patterns for four transportation and two communications categories, namely entertainment (including bicycles and boats), non-private vehicle travel (including out-of-town lodging as well as public transportation), private vehicle capital costs (vehicle purchase and finance), private vehicle operating costs (e.g. gasoline, maintenance), new communications (e.g. telephone, TV), and old communications (postage and reading).

As explained in Section 3.2, the classification system used by the BEA is not always the most appropriate for the current analysis: some expenditures of interest, e.g. on transportation as recreation (entertainment), and on services associated with travel (lodging), fall into categories containing a number of non-travel related items as well, and similarly for communications (the miscellaneous household equipment group includes many non-communication related items, as well as computer hardware and software, and telephone equipment and accessories). We include such categories because some of their constituent items closely relate to transportation and communications.

Figure 4.3 illustrates the expenditure trends for the six categories of interest, in current dollars. Private vehicle capital and operating costs are the largest categories in every year, with other entertainment and old communications comprising the smallest categories. The figure and the regression equations in Table 4.2 show that expenditures on all categories are increasing significantly over time: TrPVC (private transportation capital) shows the largest rate of increase ($96/year on average), ComN (new communications) exhibits the second-largest rate of increase ($74/year), and the category that has the smallest increase rate (only $2.44/year) is ComO (old communications).

Again, the results for shares, shown in Figure 4.4, are different, in that the expenditure share for some categories is decreasing although their dollar value is increasing. As shown by the regression analyses presented in Table 4.2, three categories – TrNPV (non-private vehicle travel), TrPVO (private vehicle operating costs), and ComO (old communications) – are significantly (even if only modestly) decreasing over time. The expenditure share on ComN (new communications) is significantly increasing over time, while shares for other entertainment and private vehicle capital costs show no significant trend.

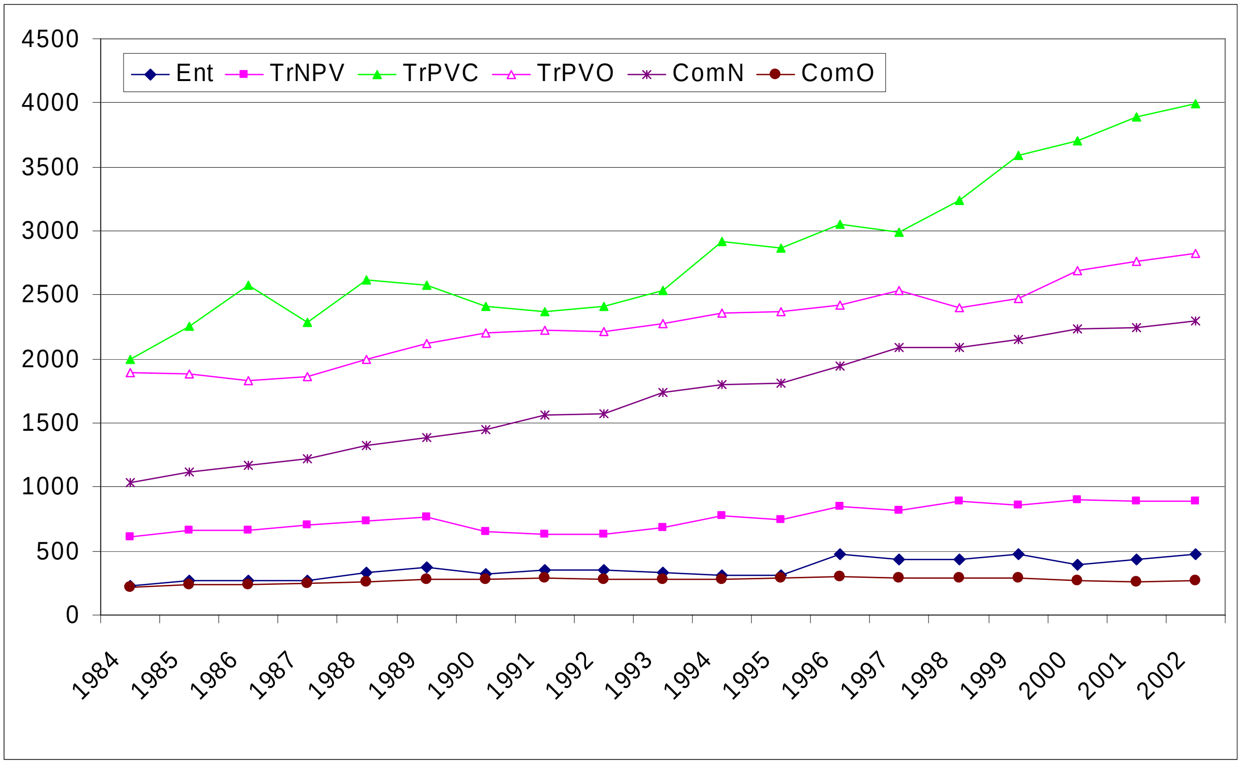


Figure 4. 3: Annual Transportation and Communications Expenditure Trends In Current Dollars (Six-Category Classification) ($)

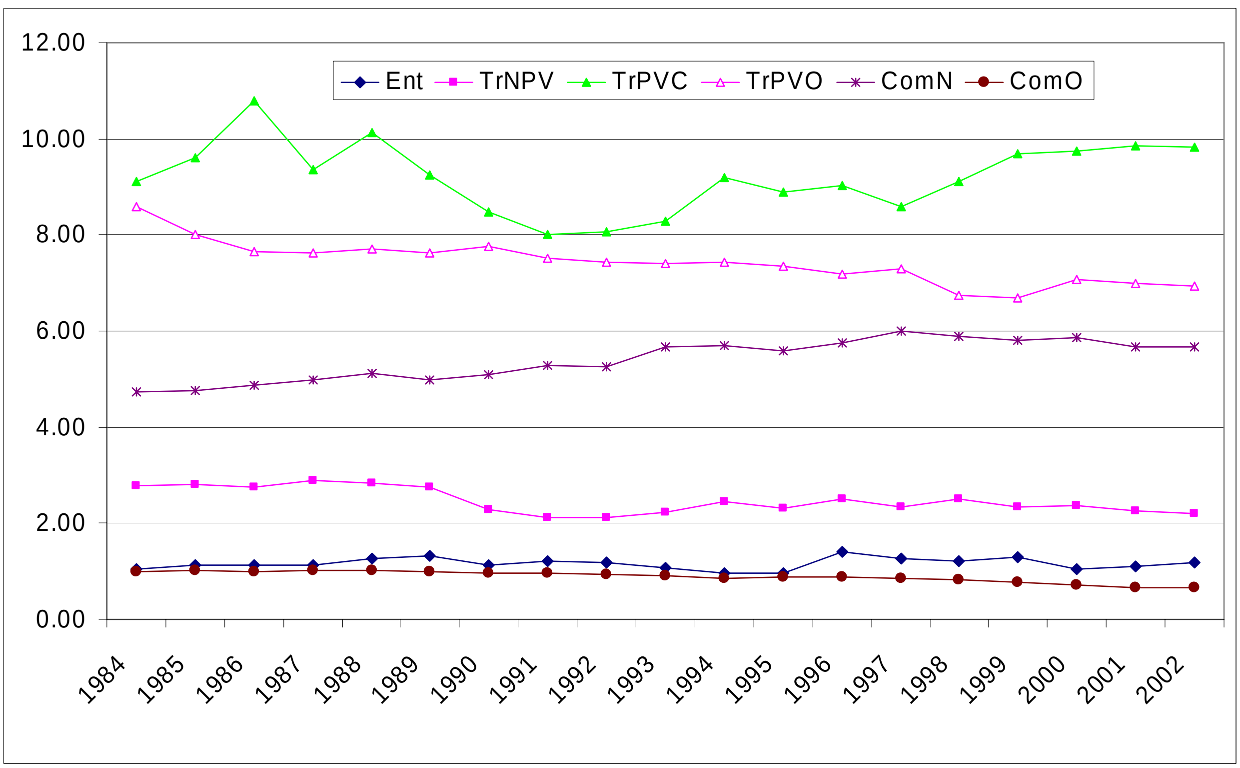


Figure 4. 4: Annual Transportation and Communications Expenditure Share Trends In Current Dollars (Six-Category Classification) (%)

Table 4. 2: Regression Equations for Expenditure and Share Based on Six Categories

	Dependent Var.	Constant	Time	R^2
Expenditure ($)	Ent	253.384 (13.904)	11.875 (6.866)	0.735
	TrNPV	614.505 (25.602)	15.681 (6.883)	0.736
	TrPVC	1989.174 (19.525)	96.314 (9.960)	0.854
	TrPVO	1806.568 (57.706)	52.621 (17.709)	0.949
	ComN	1028.437 (57.907)	74.191 (44.012)	0.991
	ComO	248.842 (33.449)	2.439 (3.454)	0.412
Expenditure Share (%)	Ent	1.147 (21.056)	0.001 (0.275)	0.004
	TrNPV	2.749 (31.189)	-0.031 (-3.753)	0.453
	TrPVC	9.210 (27.884)	0.000 (-0.011)	0.000
	TrPVO	8.065 (88.378)	-0.072 (-8.277)	0.801
	ComN	4.796 (61.074)	0.068 (9.071)	0.829
	ComO	1.071 (61.301)	-0.020 (-11.983)	0.894

Note: Values in parentheses are t-statistics.

4.2.3 Five-Category Classification

This section presents consumer expenditure patterns using the five-category classification indicated by the final five rows of Table 4.1. It differs from the six-category classification in that the “other entertainment” category has been dropped, and the “out-of-town lodging” item has been removed from the “non-private vehicle travel” category, leaving just “public transportation” in that category. The other two transportation (private vehicle capital and private vehicle operation) and communications (old and new) categories remain the same as before, but are included here again for ease of comparison.

Figure 4.5 shows the expenditure trends using this classification, in current dollars, and Figure 4.6 illustrates the expenditure share trends. Every category except TrPBT (public transportation) presents exactly the same information as in the previous section. Expenditures on public transportation (including airfares) are slightly increasing whereas the expenditure share of public transportation is very slightly decreasing over time.

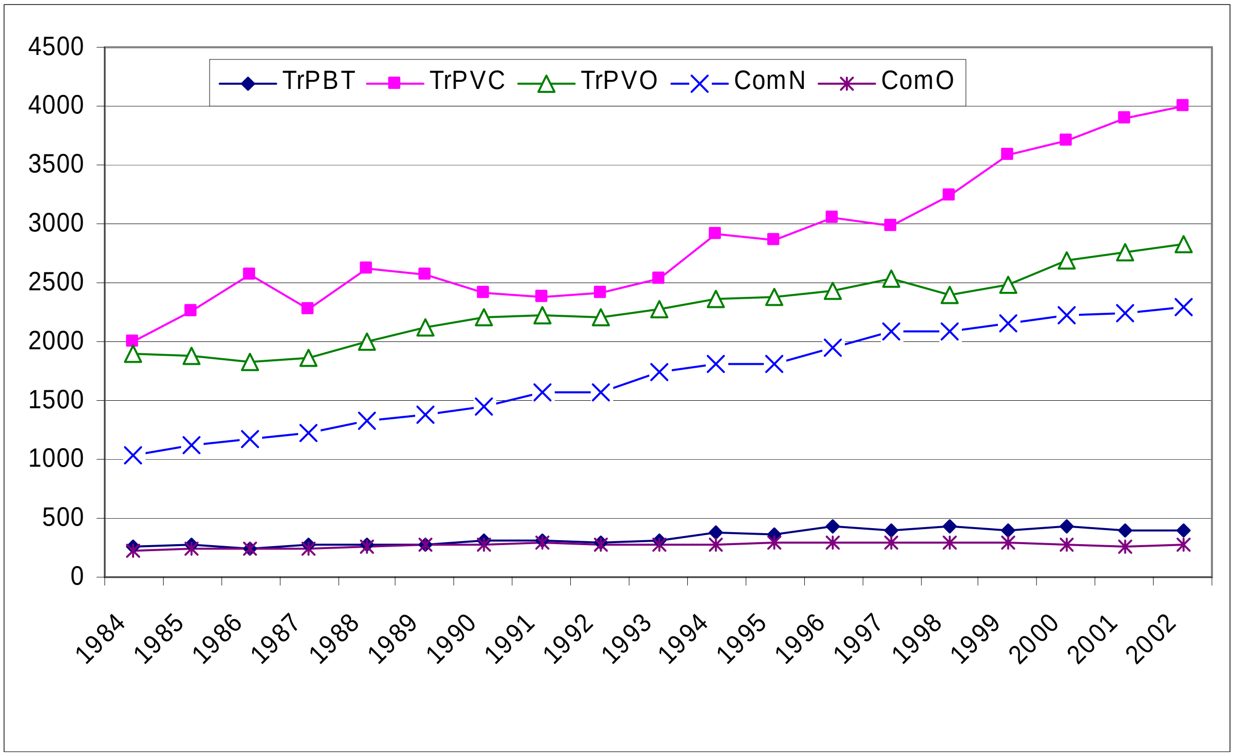


Figure 4. 5: Annual Transportation and Communications Expenditure Trends (Five-Category Classification) ($)

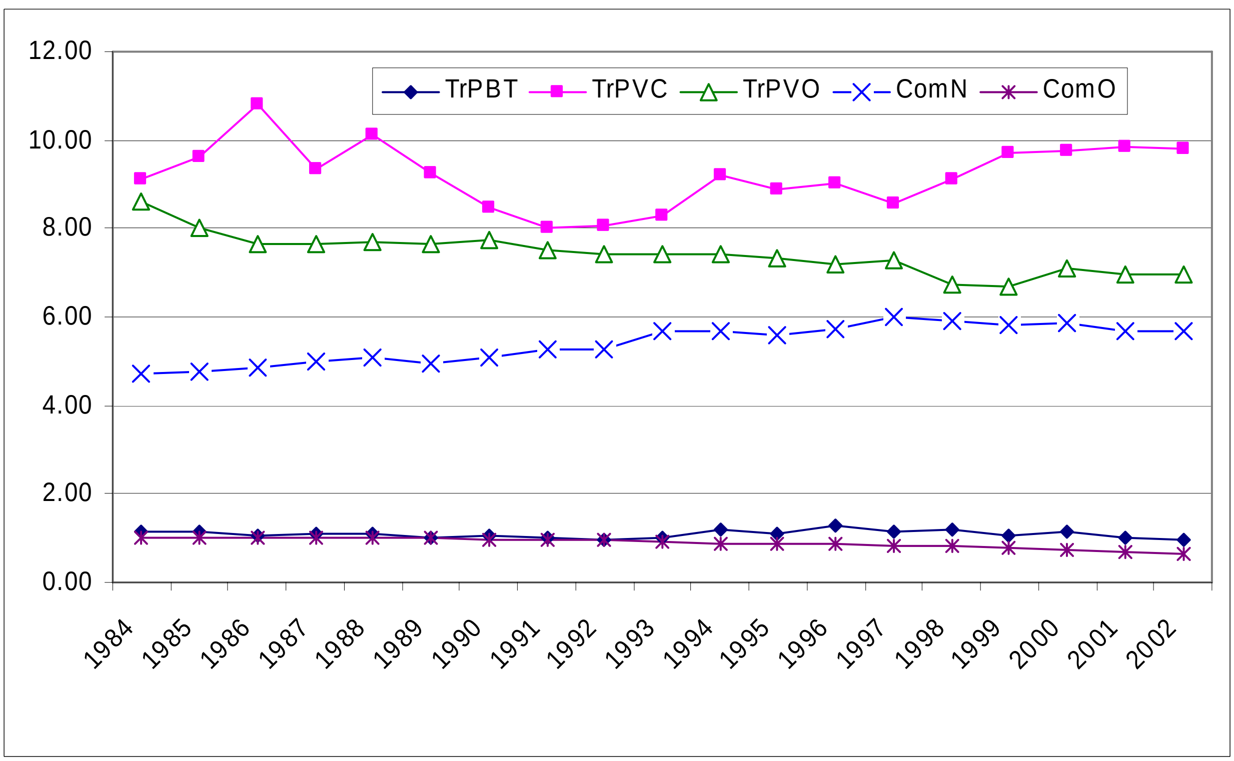


Figure 4. 6: Annual Transportation and Communications Expenditure Share Trends (Five-Category Classification) (%)

Table 4.3 provides the results of the regression analysis for the category of public transportation, as well as for the other four categories (TrPVC, TrPVO, ComN, ComO) that have not changed. For raw expenditures on public transportation, the coefficients are very significant (indicating an increase in expenditures of about $11/year) and the R^2 is high at 0.845. However, for the model of the expenditure *share* for public transportation, the coefficient of time is not significant (t-statistic = -0.248), and the R^2 is quite low (0.004). This indicates (as can also be seen from Figure 4.6) that the expenditure share of TrPBT is essentially stable over a long period of time.

Table 4. 3: Regression Equations for Expenditure and Share Based on Five Categories

	Dependent Var.	Constant	Time	R^2
Expenditure ($)	TrPBT	242.689 (21.035)	10.549 (9.633)	0.845
	TrPVC	1989.174 (19.525)	96.314 (9.960)	0.854
	TrPVO	1806.568 (57.706)	52.621 (17.709)	0.949
	ComN	1028.437 (57.907)	74.191 (44.012)	0.991
	ComO	248.842 (33.449)	2.439 (3.454)	0.412
Expenditure Share (%)	TrPBT	1.098 (29.425)	-0.001 (-0.248)	0.004
	TrPVC	9.210 (27.884)	0.000 (-0.011)	0.000
	TrPVO	8.065 (88.378)	-0.072 (-8.277)	0.801
	ComN	4.796 (61.074)	0.068 (9.071)	0.829
	ComO	1.071 (61.301)	-0.020 (-11.983)	0.894

Note: Values in parentheses are t-statistics.

4.2.4 Most Disaggregate Classification (14 Categories)

This section presents consumers' expenditure patterns using the most disaggregate classification (14 categories: nine for transportation and five for communications). Thus, we can examine each category separately in this section. Figure 4.7 shows the nine transportation and five communications expenditure trends, with the corresponding regression equations provided in Table 4.4. Expenditures in all 14 categories are increasing over time although several categories (e.g. Veh_New (new vehicle purchases), Oth_Lodg (out-of-town lodging), and Reading)[10] tend to be relatively erratic, with the Reading category being the only one whose time trend is not significant at the 0.05 level (given the sample size of 19, the p-value for a t-statistic of 1.208 is

[10] Detailed descriptions of each category are provided in Section 3.3.1.

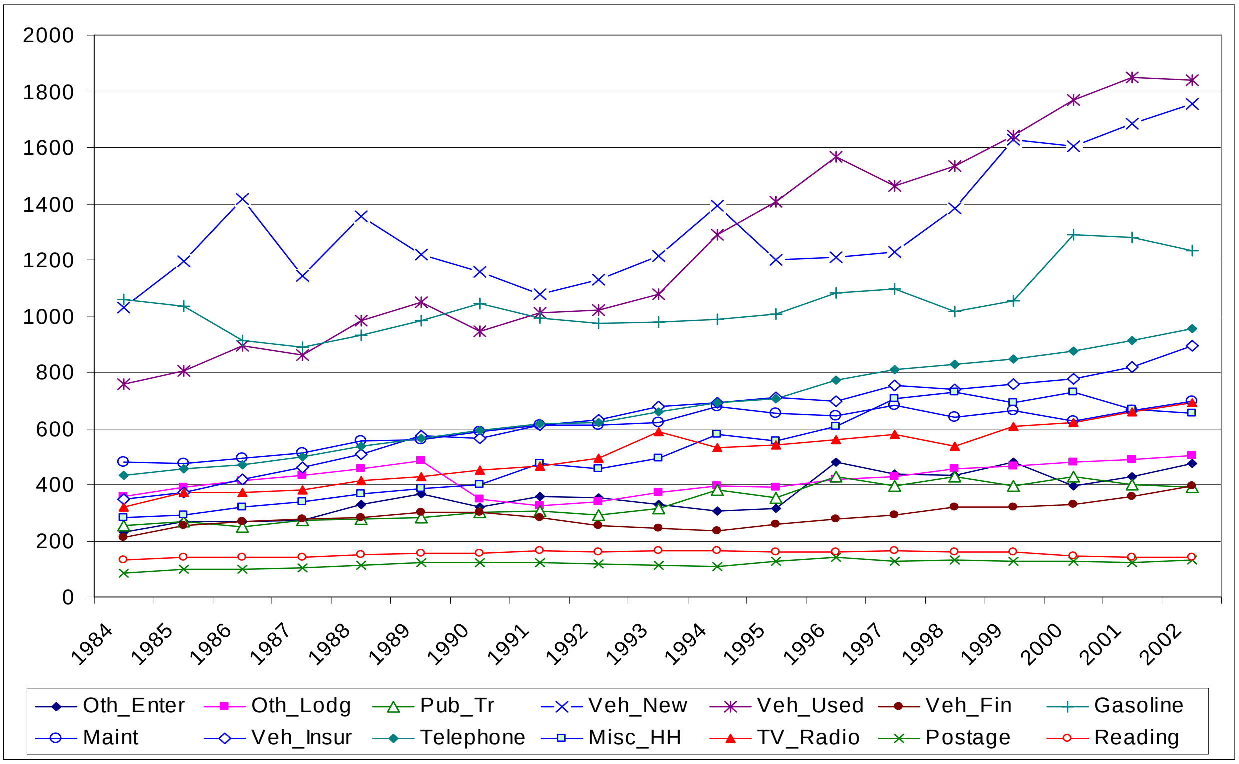


Figure 4. 7: Annual Transportation and Communications Expenditure Trends In Current Dollars (14-Category Classification) ($)

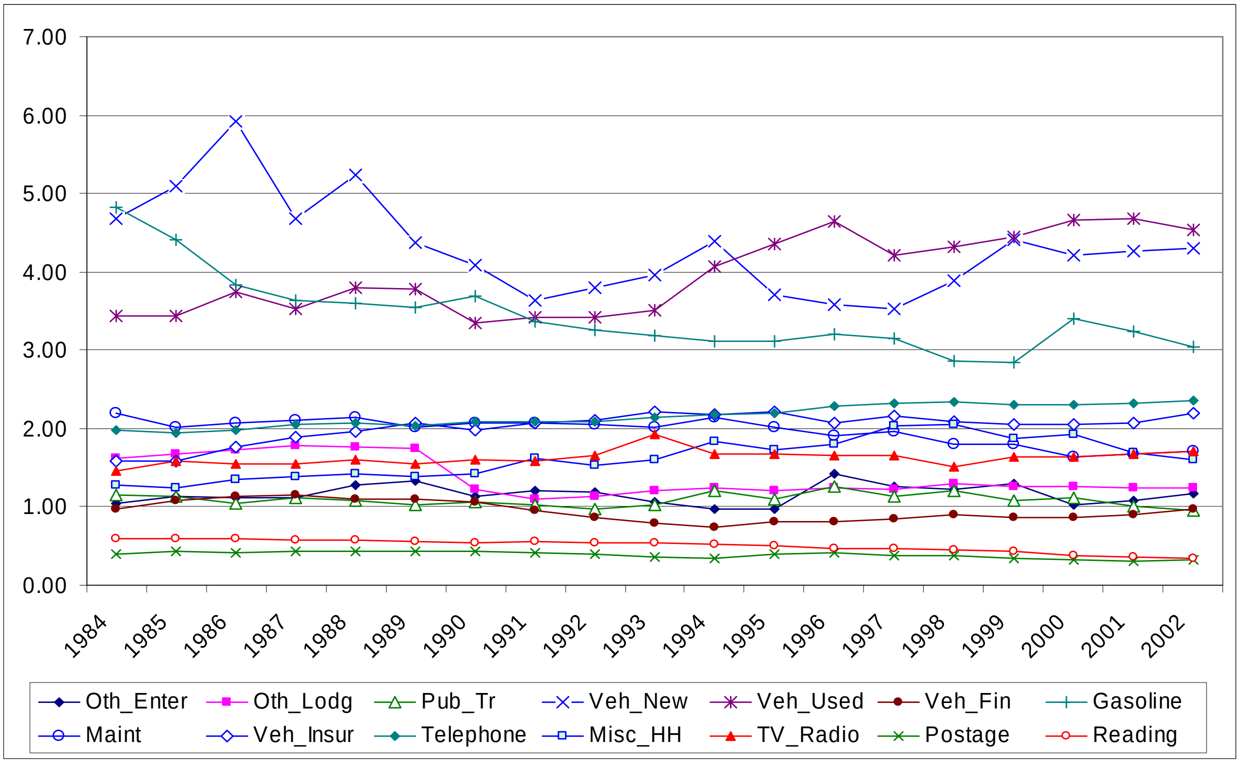


Figure 4. 8: Transportation and Communications Expenditure Share Trends In Current Dollars (14-Category Classification) (%)

Table 4. 4: Regression Equations for Expenditure and Share Based on 14 Categories

	Dependent Variable		Constant	Time	R^2
Expenditure ($)	Ent	Oth_Enter	253.384 (13.904)	11.875 (6.866)	0.735
	TrNPV	Oth_Lodg	371.816 (17.562)	5.132 (2.554)	0.277
		Pub_Tr	242.689 (21.035)	10.549 (9.633)	0.845
	TrPVC	Veh_New	1072.500 (15.791)	27.167 (4.214)	0.511
		Veh_Used	678.721 (17.012)	63.598 (16.795)	0.943
		Veh_Fin	237.953 (16.833)	5.549 (4.136)	0.502
	TrPVO	Gasoline	915.537 (25.326)	14.379 (4.191)	0.508
		Maint	500.084 (36.049)	11.435 (8.685)	0.816
		Veh_Insur	390.947 (27.046)	26.807 (19.539)	0.957
	ComN	Telephone	415.863 (67.579)	29.004 (49.656)	0.993
		Misc_HH	271.468 (13.592)	26.819 (14.148)	0.922
		TV_Radio	341.105 (28.339)	18.368 (16.078)	0.938
	ComO	Postage	100.984 (27.026)	1.896 (5.347)	0.627
		Reading	147.858 (31.267)	0.542 (1.208)	0.079
Expenditure Share (%)	Ent	Oth_Enter	1.147 (21.056)	0.001 (0.275)	0.004
	TrNPV	Oth_Lodg	1.652 (21.131)	-0.031 (-4.114)	0.499
		Pub_Tr	1.098 (29.425)	-0.001 (-0.248)	0.004
	TrPVC	Veh_New	4.850 (20.538)	-0.061 (-2.708)	0.301
		Veh_Used	3.294 (27.822)	0.074 (6.606)	0.720
		Veh_Fin	1.066 (23.926)	-0.014 (-3.286)	0.388
	TrPVO	Gasoline	4.076 (30.279)	-0.071 (-5.562)	0.645
		Maint	2.193 (54.800)	-0.025 (-6.559)	0.717
		Veh_Insur	1.797 (30.855)	0.024 (4.392)	0.532
	ComN	Telephone	1.946 (123.445)	0.024 (15.875)	0.937
		Misc_HH	1.293 (19.823)	0.036 (5.859)	0.669
		TV_Radio	1.557 (39.661)	0.008 (2.035)	0.196
	ComO	Postage	0.440 (40.538)	-0.006 (-5.773)	0.662
		Reading	0.631 (60.838)	-0.014 (-14.141)	0.922

Note: Values in parentheses are t-statistics.

0.244). Among the transportation categories, Veh_Used (used vehicle purchases) shows the largest rate of increase ($64/year, on average). The Veh_New (new vehicle purchases) and Veh_Insur (vehicle insurance) categories also show relatively high rates of increase ($27/year each), indicating that private vehicle related expenditures increased faster than those for public transportation ($11/year), out-of-town lodging ($5/year), or other recreational vehicles (Oth_Enter, $12/year). Among the communications categories, Telephone and Misc_HH (miscellaneous household equipment: computer software and hardware) show relatively high rates of increase ($29 and $27/year, respectively) and TV_Radio shows a moderate increase of $18/year, while Postage and Reading show increases of only $2/year and $0.54/year, respectively. These results are consistent with expectations, in view of the dramatic advances in telephone and computer-related technology in recent years.

Figure 4.8 illustrates the expenditure share trends for the 14 categories, which again are quite different from the dollar values of expenditure. In terms of share, eight out of the 14 categories are actually decreasing over time from 1984 to 2002: out-of-town lodging, new vehicle purchase, gasoline, vehicle finance, vehicle maintenance, public transportation (very slightly – not significantly), postage, and reading. Interestingly, in contrast to the insignificant trend for Reading in terms of raw expenditures, the trend for shares is quite strong and very linear (R^2 = 0.922), showing a loss of 1/100 of a percentage point per year. In the opposite direction, Telephone shows a similarly significant and strongly linear (R^2 = 0.937) change in share of about twice the magnitude, gaining more than 2/100 of a percentage point in share each year. R^2s for the remaining share equations are generally lower than for their raw expenditure counterparts, with the equations for Pub_Tr and Oth_Enter showing essentially no linear trend (R^2 = 0.004). Overall, however, 12 of the 14 equations for expenditure, and nine of the 14 for share explain 50% or more of the variance in their respective dependent variables.

4.3 Decomposing the Effects of Inflation, Technology, Consumer Tastes, Quality, and Income

The graphs of the previous section all show nominal (current dollar-based) expenditures rising in every category across time. To more fully understand trends in expenditure patterns, it is important to address the simple question: Why does an individual's expenditure on category *i* change over time? In Section 4.3.1, we examine that question conceptually, identifying a number of reasons for such a change. The ideal would then be to empirically decompose observed changes in expenditure into their various sources. Unfortunately, it will become clear that it is not possible to do so very exactly. However, we can at least control for some major effects on expenditures. To correct for the effect of inflation that is included in the nominal expenditures, we will analyze CPI (Consumer Price Index)-adjusted expenditure trends in Section 4.3.2. The CPI is readily available and widely used for the purpose of eliminating inflation effects, although as we will see, it actually confounds inflation and other effects that will be discussed in that section. Finally, in Section 4.3.3, we speculate on the likely remaining major sources of expenditure change, category by category.

4.3.1 Conceptual Decomposition of Expenditure Patterns

Again, the straightforward question of interest is, **"Why does a person's expenditure on category *i* change over time?"** A number of reasons present themselves, which can be labeled inflation, technology changes, quality changes, taste changes, and real income changes. We first discuss each reason in turn, and then relate them to the simple expenditure equation $E_i = p_i q_i$.

1. Identical goods are bought, but they cost more due to inflation (*p_i increases*)**.** Thus, if a given basket of goods costs more due to inflation but income has not increased to "keep up with inflation", one will spend more (not only in nominal dollars but as a proportion of income) to buy the same basket of goods in category *i* (and generally spend less in another category).

2. Identical goods are bought, but they cost less, or more, due to *real* changes in the costs of inputs, production, and/or distribution (*p_i changes*)**.** We will loosely refer to this case as **technological changes**. Examples include:

- increased production efficiencies result in lower costs;
- cheaper labor is found, which lowers the cost;
- material inputs (e.g. minerals, petroleum products) become more scarce, raising the price of the finished good;
- transportation of the finished good becomes more expensive, raising its retail price.

3. Previously-available goods are replaced or augmented by similar goods of different quality *(affecting p_i at the "group" level, meaning for the group of similar goods, and q_i at the "item" level)***.** Obviously there is some ambiguity about the words "similar" and "quality". Note that the change in quality may not be due to a change in technology – although it often is – and what constitutes "technology" can be equally ambiguous. Goods produced by technological change often have better quality compared to previously-available goods, but by no means always (e.g., where mass production from cheaper materials renders them flimsier than their previous counterparts). Even if the new good is higher in quality than the old one, its price could be either higher (to reflect the higher consumer value arising from the higher quality) or lower (if the higher quality is achieved through technological advances that also lower costs) than that of the previous one. If previously-purchased goods are completely replaced by similar ones of different quality, the consumer can no longer choose to purchase the previous goods, and we would consider this change in expenditures to be purely due to the quality change. Alternatively, if previously-purchased goods continue to coexist alongside the new goods, and the consumer chooses the new goods, then both changes in quality and changes in taste are at work.

4. Consumers' tastes or preferences have changed *(affecting q_i at the micro scale, and p_i at the macro scale)***.** At the micro level, taking availability as exogenously determined, individuals may simply prefer more or less of various items over time (e.g. they may stop smoking, or take up skiing, or reduce the frequency with which they go to movies or eat out, or have children – which alters spending patterns in many ways). These changes in preference may or may not be related to changes in quality, as mentioned above – none of the examples just offered depend on changes in quality. Similarly, they may or may not be influenced by changes in technology. At the macro level however, some goods are phased out and others are introduced in response to aggregate changes in consumer tastes over time – often enabled or driven by technology changes.

5. Real income changes over time *(affecting q_i, or shares $p_i\ q_i\ /E$)*. If an individual's income increases in real terms, she will decrease expenditures on various categories of goods (referred to as inferior goods), while increasing expenditures in other categories (referred to as normal goods). Normal goods are considered luxuries if the increase in demand is proportionally greater than the increase in income, and necessities if the increase in demand is proportionally less (see Table 5.1 of Section 5.1). The use of expenditure shares controls for changes in total expenditure overall (which constitutes "consumed income" and is generally taken as a proxy for total income[11]), but shifts among shares are still expected as a function of income (as can be seen from the fundamental demand equations, presented in Section 5.1, which model expenditure shares as a function of prices and income, or total expenditures, and from the subsequent discussion of the income elasticity of demand).

However (to the extent that tastes are viewed as synonymous with revealed preferences, as opposed to latent ones), those shifts can basically be seen as due to changes in tastes, which are correlated with changes in income. In other words, an expenditure shift is not driven purely by a change in income; rather, a rise (say) in income enables various taste changes to be realized (while a fall in income may force some less voluntary taste changes to be "revealed", e.g. from steak to ground beef). Note that while income effects can essentially be classified as a subset of taste changes, taste changes can occur even when income does not change.

The effects of these changes on expenditures can be encapsulated by recalling that expenditure on a good i, E_i, is simply the product of the unit price p_i and the number of units demanded, q_i. Thus, expenditures could change over time if:

- the unit price for an identical good changes, due to
  - inflation,
  - technological changes, i.e. changes in the real costs of inputs, production, and/or distribution, and/or
  - macro-scale changes in demand due to taste changes;
- the unit price for a "comparable" good changes, due to
  - inflation,
  - quality changes (with or without technological changes), and/or
  - macro-scale changes in demand due to taste changes;
- the unit price changes from infinite to finite or from finite to infinite (representing the introduction of a new good or phasing out an obsolete one, respectively), due to
  - technological,
  - quality, and/or
  - macro-scale taste changes; or
- the quantity demanded *at a given unit price* changes, due to
  - changes in tastes, with or without
  - changes in income.

Finally, it is worth noting in passing the obvious point that, given all these potential sources of change, which can act in different directions, it is quite possible that expenditures on a given

[11] However, people might invest their remaining income in stocks or real estate, and/or save some in bank accounts.

category may appear to remain relatively stable (even in real terms, i.e. after adjusted for inflation), while in fact the quantity, quality, and/or content of goods purchased may have changed.

4.3.2 CPI-Adjusted Expenditure Trends (1984 Constant or Real Dollars)

In the previous section, we discussed a number of potential reasons why consumer expenditures on a certain category change over time. In the process, it should have become clear that an exact decomposition of changes in consumer expenditures is unfortunately impossible, due to ambiguities in the sources of change, boundaries and overlaps between the various sources, and inadequate data on each source. It *is* possible, however, to control for the effects of inflation to some extent, using the consumer price index (CPI) which has been devised for exactly that purpose. In reality, however, CPIs are not a pure measure of inflation. One issue is that the CPI that we used in this study is the CPI-U series, that is the CPI for urban dwellers. As mentioned in Section 3.1.2, there are two separate CPI series, CPI-U and CPI-W, which are for urban consumers and for urban wage earners and clerical workers, respectively. The CPI-U series represented about 87% of the population in 1990, and the CPI-W series is created based on a subset of the CPI-U population, which represented about 32% of the population in 1990. For our study of nationwide expenditure data, the CPI-U series is clearly the more appropriate of the two. However, they do not attempt to capture the prices experienced by people living in non-metropolitan areas and in the Armed Forces, whereas the consumer expenditure data are obtained for both urban and rural areas.

A more important reason why the CPI is only an imperfect indicator of inflation is that the "market basket" of goods used to establish the CPI changes over time (see Section 3.1.2 for an introduction to how the CPI is calculated). The goods generally change somewhat each year (with about 30% of goods being replaced each year according to Moulton and Moses, 1997), reflecting availability, quality, and/or *minor* technology changes. From time to time, altogether new goods are added (either supplemental to or in replacement of older goods), reflecting *major* technology changes (e.g. cellular phone service was added in 1998, per Moulton and Moses, 1997). As argued by Deaton (1998), and demonstrated by Bils and Klenow (2001), the BLS-calculated CPI overstates the rate of inflation by failing to completely control for changes in quality in the market basket. In other words, part of an increase in prices attributed to inflation is actually due to quality improvements. As it is a matter of scholarly debate and beyond the scope of this study to correct for that bias, we must accept that our CPI-adjusted expenditures control not only for inflation, but to some unknown extent for quality changes and (as argued in footnote 4 of Chapter 3) some technology and taste changes as well. Nevertheless, for the sake of discussion we will suppose that the adjustment is mainly controlling for inflation.

Thus, this section investigates CPI-adjusted expenditure trends using our various classification schemes (two, six, five, and 14 categories). After correcting for inflation in this manner, the resulting patterns will roughly reflect the remaining major sources of expenditure change. We will informally analyze those sources for each category over time. The CPIs that are applied for this study are adjusted to the base year of 1984, to be consistent with the starting point for our consumer expenditures data.

We calculate the CPI-adjusted expenditures in a given category as follows:

$$\text{CPI-Adjusted Expenditure (\$)} = E_t^* = \frac{E_t}{CPI_t} \times 100 , \tag{4.2}$$

where E_t denotes consumer expenditures in year t using nominal dollars. For example, the CPI-adjusted average expenditure for new vehicles in 1985 is calculated as:

$$\text{CPI-Adjusted Expenditure for New Vehicles (\$)} = E_{1985}^* = \frac{E_{1985}}{CPI_{1985}} \times 100 = \frac{1197}{103.4} \times 100 = 1157.6 .$$

Thus, although the raw average expenditure for new vehicles in 1985 was $1,197, the CPI-adjusted expenditure is actually $1,157.6 (1984 dollars). The E_t^* series constitutes the inflation-adjusted expenditure pattern for the category in question.

With respect to the expenditure share, it does not make sense to use the average annual expenditure (AAE) that was applied to analyze the nominal expenditure trends, since the AAE is not inflation-adjusted. We could perform a single inflation adjustment on AAE through dividing it by the overall CPI, but to ensure that shares sum to 100%, we decompose the AAE and separately adjust each category, instead. That is, to calculate the CPI-adjusted expenditure shares, the total expenditure in year t (CPI-Adjusted Average Annual Expenditure: $AAE_{real\ t}$) is created by decomposing average annual expenditures into mutually exclusive categories, such as expenditure on transportation (E_trans_t), expenditure on communications (E_comm_t), and expenditure on other goods (E_other_t), adjusted by the corresponding CPIs as follows:

$$\begin{aligned} AAE_{real\ t} &= \left(\frac{E\_trans_t}{CPI\_trans_t} + \frac{E\_comm_t}{CPI\_comm_t} + \frac{E\_other_t}{CPI\_other_t} \right) \times 100 \\ &= E_{trans_t}^* + E_{comm_t}^* + E_{other_t}^* . \end{aligned} \tag{4.3}$$

Table 4.5 and Figure 4.9 show average annual total expenditures and CPI-adjusted total expenditures, provided as a benchmark against which to compare expenditure trends within categories. In Table 4.5, although the annual average increase rate of CPI-adjusted total expenditures is just less than 1%, it definitely affects the changes in expenditures for a certain category over time. For example, the CPI-adjusted total expenditures in 1984 and 2002 were $21,975 and $26,102, respectively. Thus, on average a consumer unit spent about $4,127 more (real dollars) in 2002 than in 1984. Given the fact that household sizes have declined somewhat (about 5%) over the same period, from averages of 2.71 in 1984 to 2.58 in 2002 (U.S. Census Bureau, 2005), it is clear that increases in per capita consumption are even more pronounced.

Figure 4.9 shows that average annual total expenditures have linearly increased in current dollars over time (R^2=0.994), at a rate of about $1,002 a year. The CPI-adjusted total expenditures in 1984 dollars have more gradually increased over time (R^2=0.838), at a rate of about $187 a year although the pattern fluctuated between 1987 and 1992. Then, it generally increased thereafter through the end of the study period. This is indicative of overall rising incomes in real terms over time. The impact of that underlying rise in income on shares of specific goods categories will depend on whether that category is a normal or inferior good, and if normal, whether it is a luxury or a necessity (see Table 5.1).

Table 4. 5: Average Annual Total Expenditures vs. CPI-Adjusted Total Expenditures

(Base Year of CPI: 1984)

Year	Average Annual Total Expenditures	CPI-Adjusted Total Expenditures
1984	21,975	21,975
1985	23,490	22,682
1986	23,866	22,639
1987	24,414	22,384
1988	25,892	22,871
1989	27,810	23,563
1990	28,381	22,994
1991	29,614	23,202
1992	29,846	22,845
1993	30,692	22,966
1994	31,731	23,297
1995	32,264	23,206
1996	33,797	23,803
1997	34,819	24,133
1998	35,535	24,366
1999	36,995	24,988
2000	38,045	25,127
2001	39,518	25,619
2002	40,677	26,102
Average Increase Rate (%)	3.48	0.96

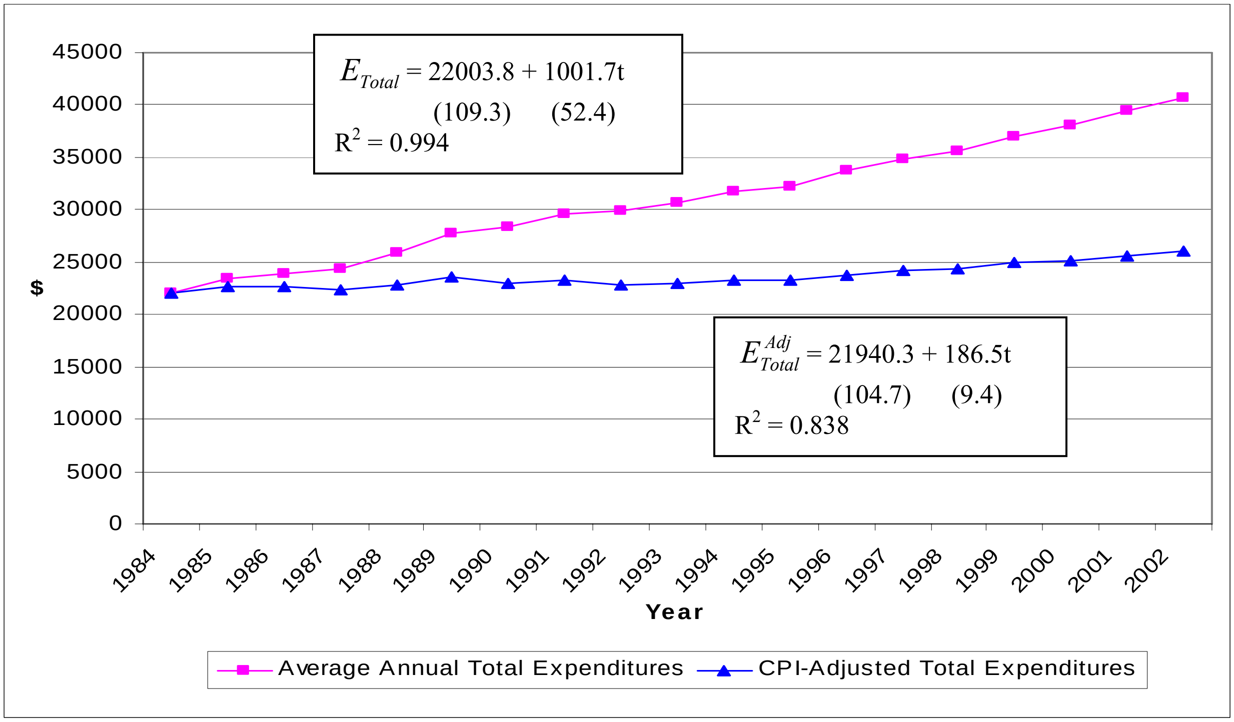


Figure 4. 9: Average Annual Total Expenditures vs. CPI-Adjusted Total Expenditures

Notes: E_{Total} : average annual total expenditures, E_{Total}^{Adj} : CPI-adjusted total expenditures. Values in parentheses are t-statistics.

In the three sub-sections below, we analyze the CPI-adjusted expenditure trends for the most aggregate classification – two categories (Section 4.3.2.1); six and five-category classifications (Section 4.3.2.2); and most disaggregate classification – 14 categories (Section 4.3.2.3).

4.3.2.1 Most Aggregate Classification (Two Categories)

This section examines the CPI-adjusted expenditure patterns using just the two highest-level categories (transportation and communications). Figure 4.10 shows that communications expenditures have steadily (R^2=0.969) increased in constant dollars over time, at a rate of about $49 a year. The pattern for transportation expenditures is not as simple: it fluctuated between 1984 and 1989, decreased until 1993, then generally increased thereafter until real expenditures in 2002 were similar to those in 1985. In reflection of these non-linearities in the data, the R^2 for the corresponding regression equation is relatively low (0.114), and the time trend is statistically insignificant (and negative, which is misleading in view of the upward trend in recent years).

As shown in Figure 4.11, the patterns of CPI-adjusted shares of total expenditure are similar to those of CPI-adjusted expenditure levels. The trend for the transportation share is more linear (R^2 = 0.485) than is the trend for the expenditure levels themselves, but shows a decline from 1984 to 1993, followed by relative stability from 1994 on (at around 19% of total expenditures). Comparing Figures 4.9, 4.10, and 4.11 shows that although real transportation expenditures increased from 1995 onward, real income kept pace with the increases so that as a share of total income, expenditures on transportation remained essentially constant. For a somewhat different view of the trends, and more detail on trends by income segment, see Bernstein, *et al.* (2005).

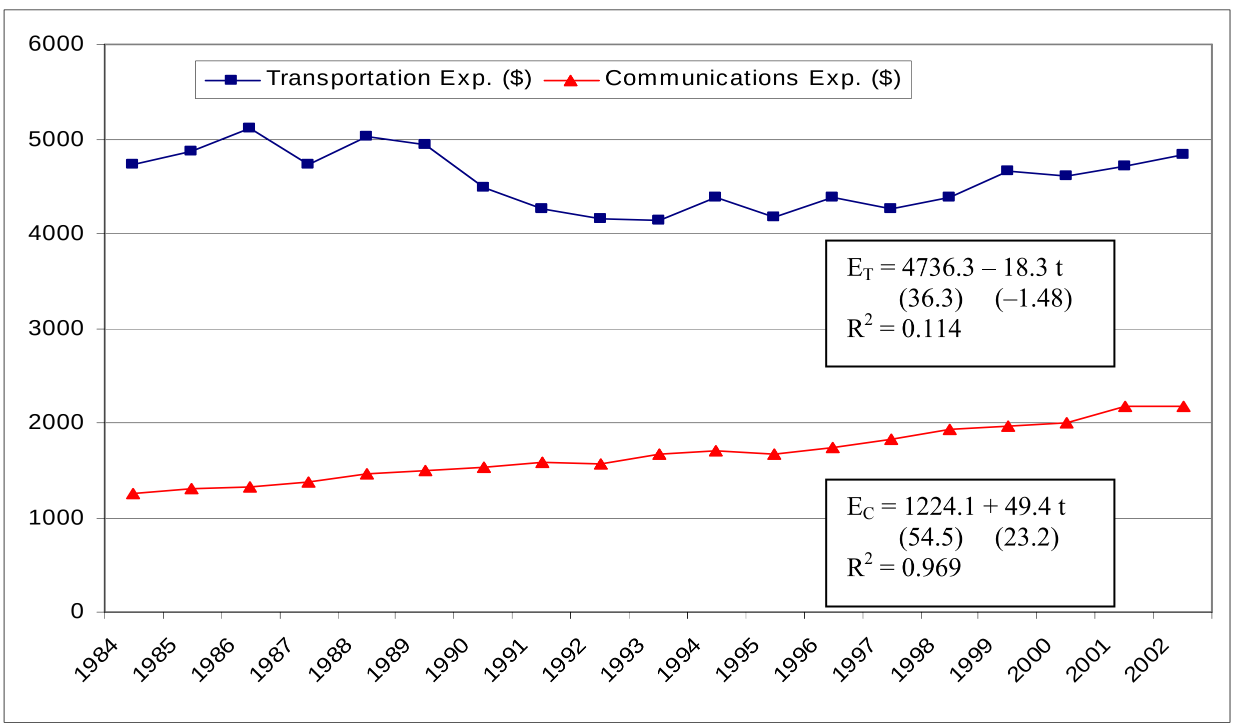


Figure 4. 10: Annual Transportation and Communications CPI-Adjusted Expenditure Trends (Two-Category Classification) (1984 $)

Notes: E_T: transportation expenditure; E_C: communications expenditure. Values in parentheses are t-statistics.

In contrast, the share of expenditure on communications shows a steady and significant increase over time with a high R^2 of 0.986. The rate of that increase is about 2/10 of a percentage point a year, constituting 8-9% of total expenditures at the end of the series. The difference in shares of expenditures on transportation and communications has been narrowing over time, from a factor of about 3.6 times higher for transportation in 1984, to about 2.2 times higher in 2002.

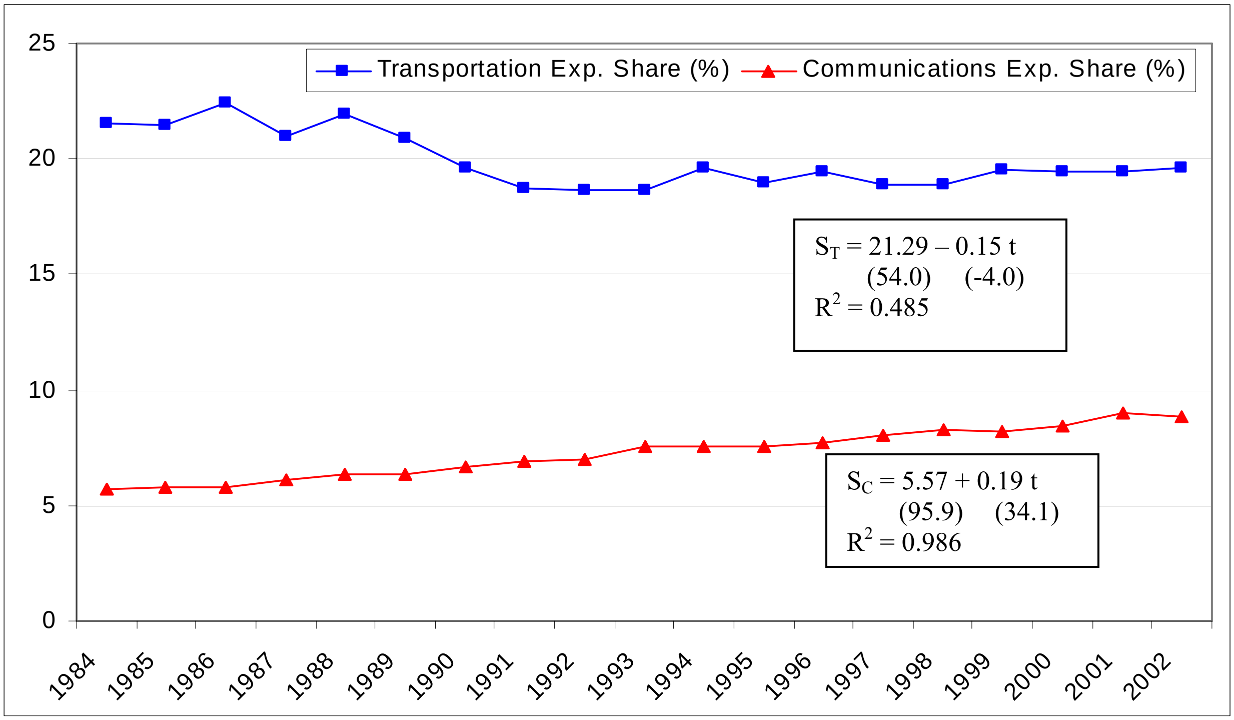


Figure 4. 11: Transportation and Communications CPI-Adjusted Expenditure Share Trends (Two-Category Classification) (%)

Notes: S_T: transportation expenditure share; S_C: communications expenditure share. Values in parentheses are t-statistics.

Comparing to the nominal expenditure and share of expenditure trends presented in Section 4.2.1 (Figures 4.1 and 4.2), the pattern of expenditures on transportation has changed into a different shape after controlling for inflation, but the CPI-adjusted share of expenditure is very similar to the share of expenditure in current dollars. For communications, the patterns between current and constant dollars and shares of expenditure are very similar, but the rate of increase in the CPI-adjusted expenditure share is about 4 times larger than that in the nominal expenditure share. That is, the share of real expenditures devoted to communications is increasing more rapidly than expressing the shares in current dollars alone would suggest.

4.3.2.2 Six- and Five-Category Classifications

Having examined the overall CPI-adjusted trends in transportation and communications, the interest of this section is to investigate the CPI-adjusted trends in expenditures and shares of expenditures for the various subcategories that compose each overall category. As mentioned in Section 4.2.2, the six-category classification comprises four transportation (entertainment, non-private vehicle travel, private vehicle capital costs, and private vehicle operating costs) and two communications (new and old communications) categories. Figure 4.12 and Table 4.6 show expenditure trends and regression equations, respectively, for the six categories of interest in CPI-adjusted constant dollars. Private vehicle capital cost is the largest category in every year, new communications and private vehicle operations costs alternate as the second-largest category

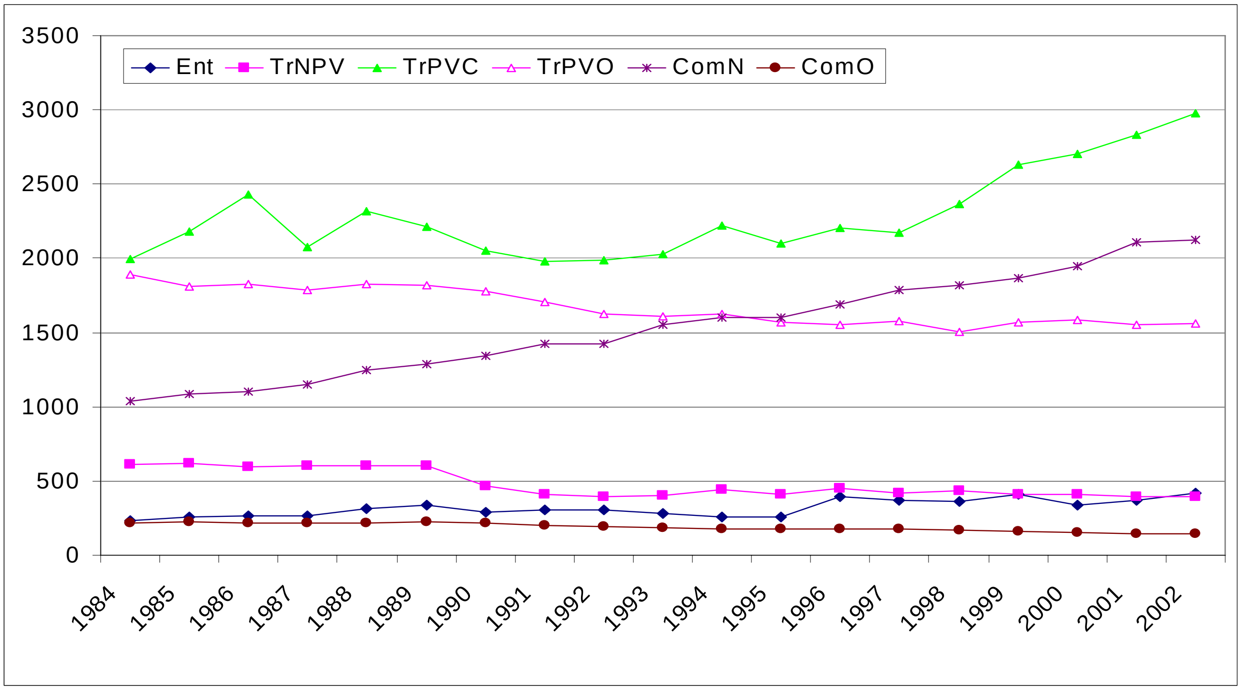


Figure 4. 12: Transportation and Communications CPI-Adjusted Expenditure Trends (Six-Category Classification) (1984 $)

Table 4. 6: Regression Analysis of CPI-Adjusted Expenditures Based on Six and Five-Category Classifications

	Dependent Var.	Constant	Time	R^2
Expenditure ($)	Ent	246.427 (15.032)	7.892 (5.072)	0.602
	TrNPV	602.690 (26.386)	-13.831 (-6.379)	0.705
	TrPBT	242.261 (36.223)	-1.956 (-3.081)	0.358
	TrPVC	1968.682 (19.660)	35.476 (3.733)	0.450
	TrPVO	1853.832 (83.966)	-20.120 (-9.601)	0.844
	ComN	992.364 (62.858)	60.606 (40.445)	0.990
	ComO	232.242 (77.890)	-4.669 (-16.499)	0.941

Notes: 1) Values in parentheses are t-statistics.
2) [grey shading]: For six-category classification only.
3) [hatched shading]: For five-category classification only.

group (ComN became the second category and TrPVO became the third one after 1995), and old communications constitutes the smallest category. Real expenditures in three categories have significantly increased over the period: ComN (new communications: telephone, TV, etc.) shows the largest rate of increase ($61/year on average), TrPVC (private vehicle capital: vehicle purchase and finance) exhibits the second-largest rate of increase ($35/year on average), and Ent (other entertainment equipment and services: including bicycles and boats) has increased only modestly ($8/year on average). Real expenditures in the remaining three categories show significant decreases over time: TrPVO (private vehicle operation: vehicle maintenance, insurance, etc.) presents the largest negative rate of change ($20/year on average), TrNPV (non-private vehicle travel: out-of-town lodging and public transportation) exhibits the second-largest rate of decrease ($14/year on average), and ComO (old communications: postage and reading) shows the smallest rate of decrease (only $5/year).

The results for shares, shown in Figure 4.13 and Table 4.7, are quite similar to those for real expenditures directly, presented in Figure 4.12 and Table 4.6. This suggests that by scaling the trends in raw expenditures against background trends in overall expenditures (serving as a proxy for income), which also increase with inflation, more robust series are obtained, which are very similar with or without controlling for inflation.

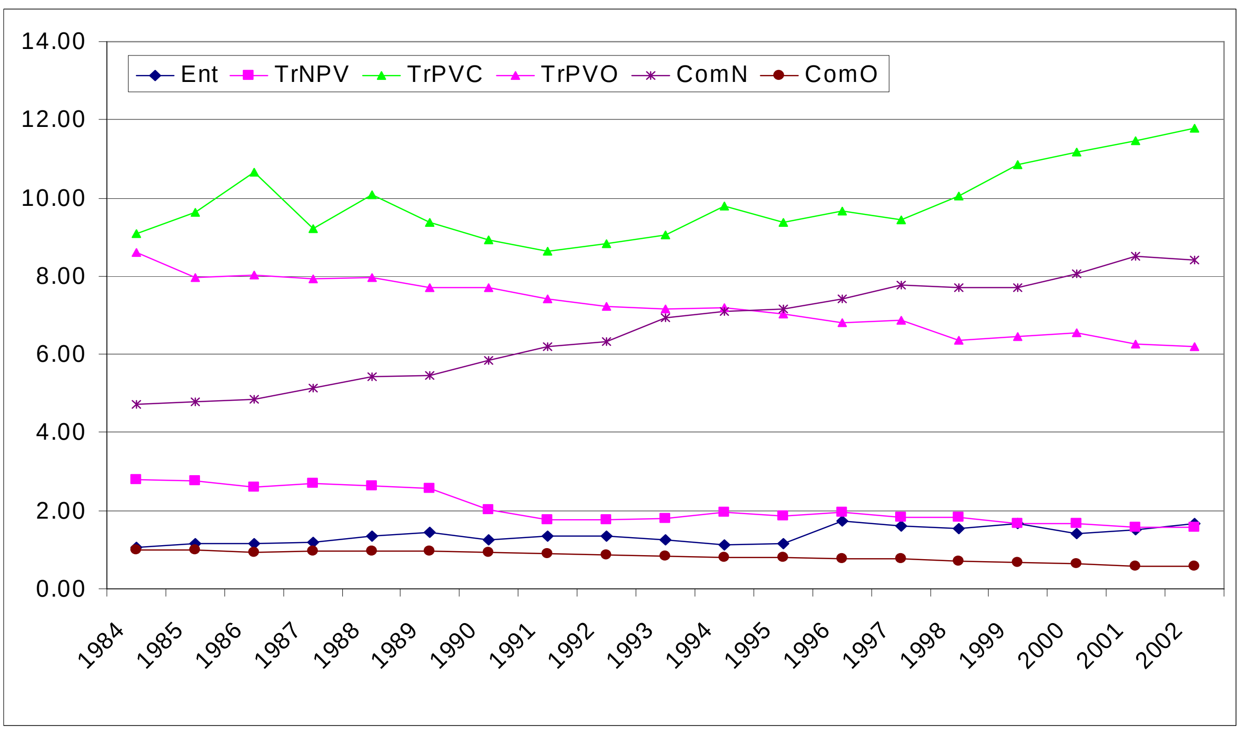


Figure 4. 13: Annual Transportation and Communications CPI-Adjusted Expenditure Share Trends (Six-Category Classification) (%)

Given that the expenditure trends in current dollars are a composite of inflation-based and real trends, and given that the inflation portion of the net effect is always positive for these categories, we would expect increases in expenditures to be smaller in constant (real) dollars than in current dollars. This is uniformly true. In particular, three categories show a sign change in rate (from positive to negative): TrPVO (e.g. vehicle maintenance and insurance) changed from an increase of $53/year to a decrease of $20/year on average; TrNPV (non-private vehicle travel) changed from an increase of $16/year to a decrease of $14/year on average; and ComO (old communications) changed from an increase of $2/year to a decrease of $5/year on average. The real change for TrPVO might be largely a result of quality changes: if the vehicle quality has improved (potentially due both to technological changes leading to more reliable cars overall, and to real increases in income permitting the purchase of higher-end vehicles within a given fleet), people might spend less for maintaining or repairing their vehicles.

Table 4. 7: Regression Analysis of Annual CPI-Adjusted Expenditure Shares Based on Six-Category Classification

	Dependent Var.	Constant	Time	R^2
Expenditure Share (%)	Ent	1.122 (17.438)	0.027 (4.430)	0.536
	TrNPV	2.696 (30.202)	-0.069 (-8.187)	0.798
	TrPVC	8.949 (26.716)	0.100 (3.140)	0.367
	TrPVO	8.326 (141.246)	-0.121 (-21.624)	0.965
	ComN	4.570 (56.824)	0.226 (29.644)	0.981
	ComO	1.038 (83.763)	-0.024 (-20.159)	0.960

As mentioned in Section 4.2.3, the five-category classification is created by dropping the entertainment category, and eliminating the “out-of-town lodging” item from the non-private vehicle travel category, leaving just “public transportation” in that category. The other four categories remain the same as before in terms of expenditure levels in CPI-adjusted constant dollars. However, with respect to the share of expenditures in CPI-adjusted constant dollars, small changes occur since annual average expenditure (AAE) for the five categories of interest is newly calculated, using the method described in equation (4.3) of Section 4.3.2. Hence, new regression equations are calibrated for all five categories with respect to expenditure share (Table 4.8, discussed below).

Table 4.6 and Figure 4.14 present the regression equations and trends for the category of public transportation in CPI-adjusted constant dollars, as well as for the other four categories (TrPVC, TrPVO, ComN, and ComO) that have not changed. The CPI-adjusted expenditures on public transportation (including airfares) have decreased significantly but only very slightly over time ($2/year), whereas nominal expenditures on public transportation have increased over time ($11/year) (see Table 4.3).

Figure 4.15 and Table 4.8 provide the trends and regression equations for expenditure shares in CPI-adjusted constant dollars, for the public transportation category and the other four categories. Again, the patterns for shares are quite similar to those for expenditures in constant dollars.

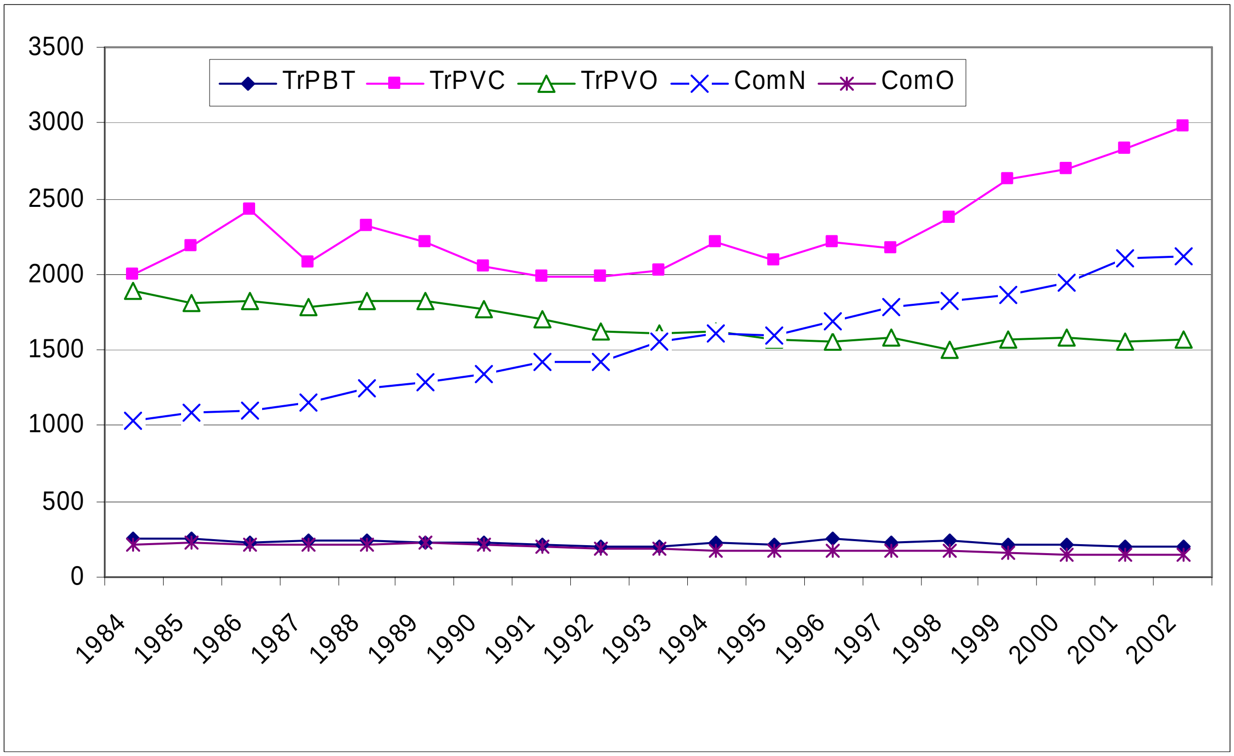


Figure 4. 14: Transportation and Communications CPI-Adjusted Expenditure Trends (Five-Category Classification) (1984 $)

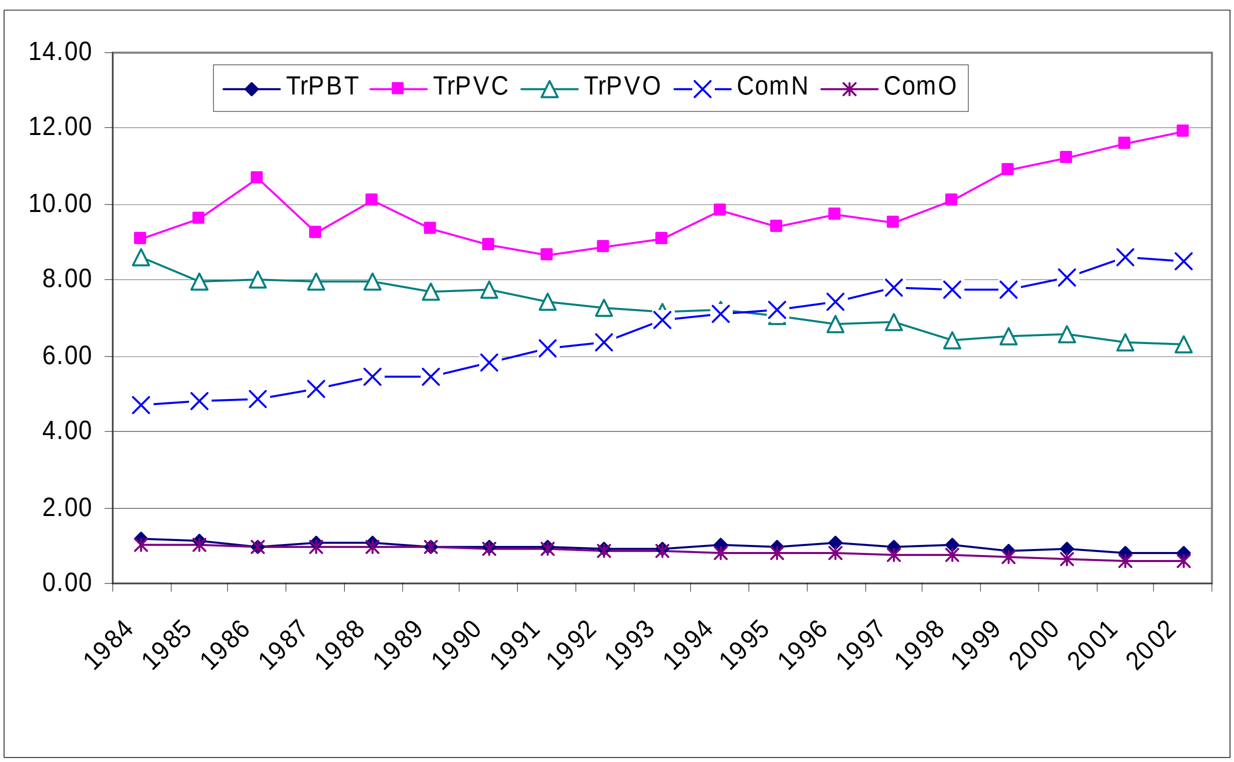


Figure 4. 15: Transportation and Communications CPI-Adjusted Expenditure Share Trends (Five-Category Classification) (%)

Table 4. 8: Regression Analysis of CPI-Adjusted Expenditure Shares Based on Five-Category Classification

	Dependent Var.	Constant	Time	R^2
Expenditure Share (%)	TrPBT	1.088 (34.794)	-0.012 (-4.209)	0.510
	TrPVC	8.932 (26.241)	0.106 (3.278)	0.387
	TrPVO	8.320 (140.584)	-0.118 (-20.941)	0.963
	ComN	4.557 (57.442)	0.231 (30.658)	0.982
	ComO	1.038 (84.565)	-0.023 (-20.081)	0.960

4.3.2.3 Most Disaggregate Classification (14 Categories)

This section presents the patterns of CPI-adjusted expenditures and shares using the most disaggregate classification (14 categories: nine for transportation and five for communications). Thus, we can investigate each category individually in this section. Figure 4.16 shows the CPI-adjusted expenditure trends, with the corresponding regression equations for both expenditures and shares provided in Table 4.9. Since the Misc_HH series takes on a much wider range of values than the other series, plotting them all on the same figure makes it difficult to analyze trends in the other 13 expenditure categories. Accordingly, in Figure 4.17 we drop the Misc_HH category and plot just the remaining ones.

Six categories out of 14 have significantly increased over time: Misc_HH (miscellaneous household equipment including computer hardware and software, and communication equipment) shows the largest rate of increase ($191/year on average), Veh_Used (used vehicle purchase) exhibits the second-largest rate of increase ($29/year), followed by Telephone and TV_Radio ($21/year and $11/year, respectively), Oth_Enter (e.g. bicycle and boats) at $8/year and Veh_Fin (vehicle finance) at $5/year. Real expenditures on new vehicles remained relatively stable over time, with an insignificant net increase of only $1 a year, but with the last five years showing larger increases. Five of the corresponding regression equations explain more than 80% of the variance in expenditures, with Oth_Enter capturing 60% and Veh_Fin only 44%.

The most dramatic trend is that of Misc_HH (including computer hardware and software). It is to be expected that the more disaggregate the categories are, potentially the more unreliable the CPI adjustment becomes (e.g. the corresponding CPI of Misc_HH is only 16.2 in 2002). This is especially true for a category showing considerable technological change over time, which is notably the case here for the Misc_HH category. This category shows an almost exponential growth in expenditures from less than $300/year in 1984 to $4,000/year (in 1984 dollars) in 2002. Recalling that this category contains computer hardware and software as well as telephone equipment (such as answering devices and accessories), substantial real growth in expenditures

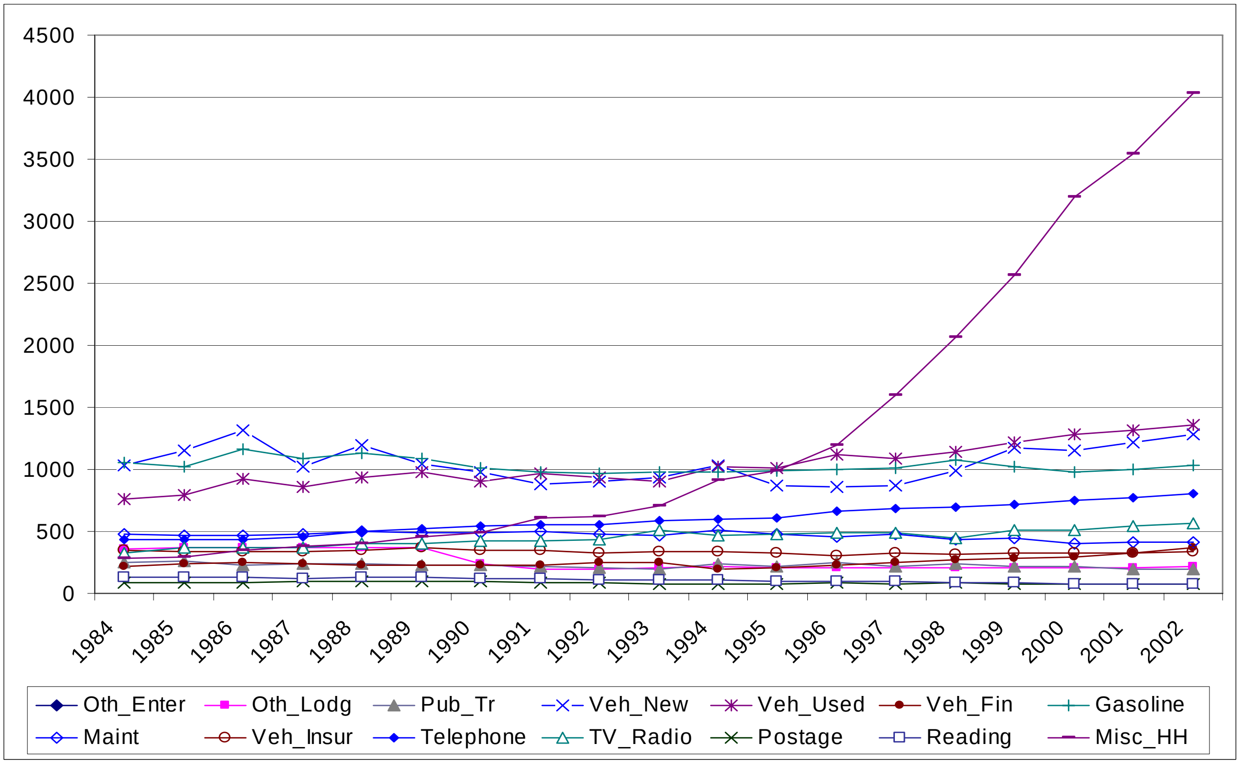


Figure 4. 16: Annual Transportation and Communications CPI-Adjusted Expenditure Trends (14-Category Classification) (1984 $)

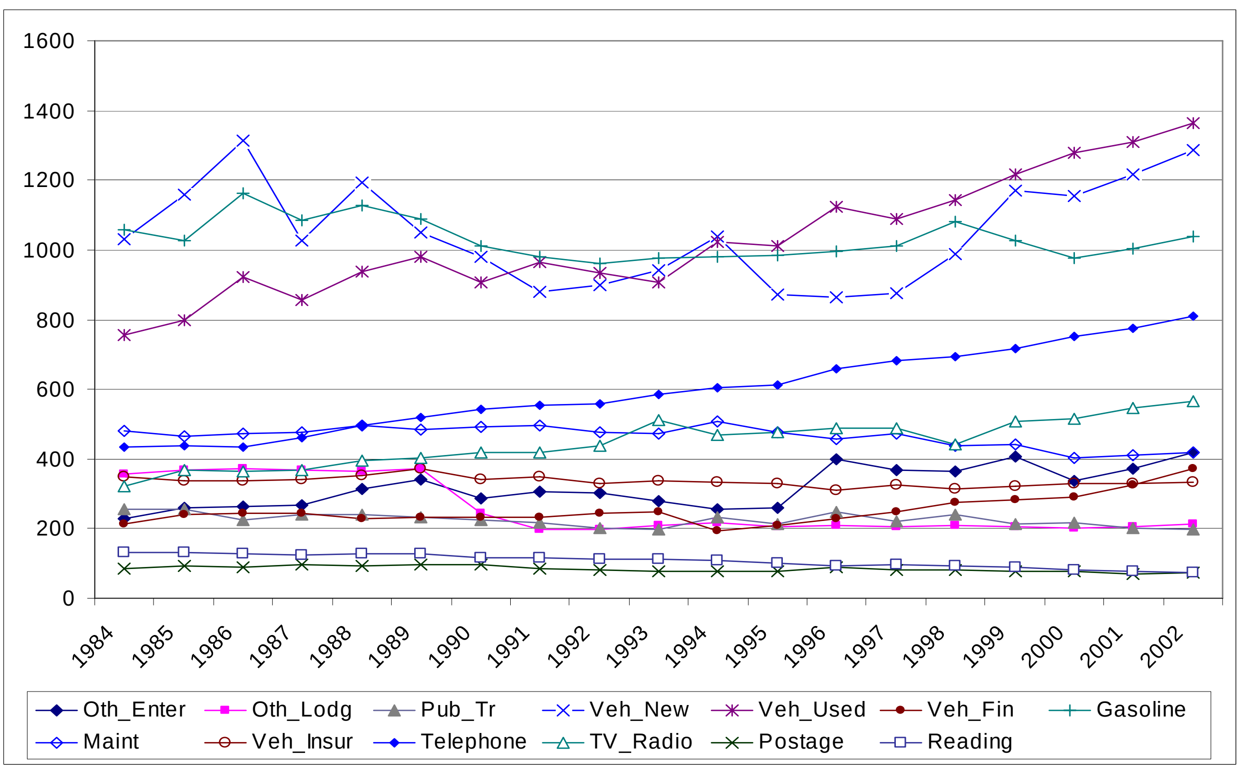


Figure 4. 17: Annual Transportation and Communications CPI-Adjusted Expenditure Trends (14-Category Classification; Misc_HH dropped) (1984 $)

Table 4. 9: Regression Analysis for CPI-Adjusted Expenditures and Shares Based on 14 Categories

	Dependent Variable		Constant	Time	R^2
Expenditure ($)	Ent	Oth_Enter	246.427 (15.032)	7.892 (5.072)	0.602
	TrNPV	Oth_Lodg	357.713 (18.006)	-10.987 (-5.827)	0.666
		Pub_Tr	242.261 (36.223)	-1.956 (-3.081)	0.358
	TrPVC	Veh_New	1039.464 (15.747)	1.004 (0.160)	0.002
		Veh_Used	766.755 (29.557)	28.963 (11.763)	0.891
		Veh_Fin	206.949 (14.582)	4.962 (3.683)	0.444
	TrPVO	Gasoline	1071.099 (47.281)	-4.528 (-2.106)	0.207
		Maint	499.189 (52.180)	-3.804 (-4.189)	0.508
		Veh_Insur	349.722 (69.304)	-1.596 (-3.333)	0.395
	ComN	Telephone	406.820 (63.460)	21.036 (34.573)	0.986
		Misc_HH	-417.772 (-1.728)	190.723 (8.314)	0.803
		TV_Radio	346.558 (33.316)	11.227 (11.371)	0.884
	ComO	Postage	94.477 (39.996)	-1.165 (-5.196)	0.614
		Reading	137.289 (94.423)	-3.340 (-24.200)	0.972
Expenditure Share (%)	Ent	Oth_Enter	1.153 (18.388)	0.017 (2.865)	0.326
	TrNPV	Oth_Lodg	1.607 (21.407)	-0.058 (-8.111)	0.795
		Pub_Tr	1.102 (34.766)	-0.018 (-6.088)	0.686
	TrPVC	Veh_New	4.791 (22.483)	-0.050 (-2.473)	0.265
		Veh_Used	3.611 (52.959)	0.068 (10.543)	0.867
		Veh_Fin	0.972 (24.211)	0.007 (1.867)	0.170
	TrPVO	Gasoline	4.888 (61.941)	-0.067 (-8.925)	0.824
		Maint	2.266 (35.481)	-0.036 (-5.958)	0.676
		Veh_Insur	1.595 (67.728)	-0.022 (-9.886)	0.852
	ComN	Telephone	1.934 (44.576)	0.057 (13.894)	0.919
		Misc_HH	-1.107 (-1.455)	0.686 (9.497)	0.841
		TV_Radio	1.622 (25.296)	0.025 (4.105)	0.498
	ComO	Postage	0.428 (42.232)	-0.009 (-8.882)	0.823
		Reading	0.616 (69.710)	-0.018 (-21.919)	0.966

Note: Values in parentheses are t-statistics.

over this period is not surprising. However, given that $4,000 in 1984 would equate to approximately $8,300 in 2002 (using the overall CPI of ComN – new communications), that calculation is not realistic as an average, per household, expenditure – especially considering that expenditures on this category in current dollars were only around $650 in 2002 (Figure 4.7). Further, there is a mismatch between CEX and CPI, that is, the category in question is Miscellaneous Household Equipment in CEX and IT Hardware and Services in CPI, although the latter category comes the closest to matching the CEX category. Moreover, since the CPIs for IT Hardware and Services are actually provided only from 1998 onward, we used the predecessor CPI category, "information processing equipment", for the period from 1984 to 1997 (see the CPI data in Table A-1 and Figure A-1 in Appendix A). For all these reasons, that series in particular must be viewed with skepticism. However, it is never modeled separately, and when combined with other communications categories in the plots earlier in this chapter and in the models of Chapter 5 (where the more aggregate series is not just the sum of the constituent series, but a new composite CPI is used to correct for inflation), no deleterious effects appear to occur.

The remaining seven categories in Table 4.9 show significant decreases in real expenditures over time. However, most changes are slight, with the rates of decrease in Postage, Veh_Insur (vehicle insurance), Reading, Maint (vehicle maintenance), and Gasoline falling between $1/year and $5/year on average, and only the category of Oth_Lodg (out-of-town lodging) decreasing more than that, at a still-low $11/year. As shown in Figures 4.18 and 4.19, the expenditure shares in CPI-adjusted constant dollars exhibit patterns quite similar to those of expenditures. Again, Misc_HH shows a suspiciously dramatic increase, to about 14% of total expenditures, gaining more than 68/100 of a percentage point in share each year.

In comparing trends between expenditures and shares, we cannot see much difference in the two sets of patterns for constant dollars, while the patterns for current dollars showed that trends in eight out of the 14 categories changed signs between direct expenditures and shares (see Table 4.4, Section 4.2.4). Here, for constant dollars, there are two noticeable changes in expenditure share: Veh_New (new vehicle purchase) exhibits a significant decrease in share of expenditures (t-statistic = -2.473) whereas it showed a negligible increase in direct expenditures, and Veh_Fin (vehicle finance) shows only a slightly significant increase in share (t-statistic = 1.867) compared to a significant increase in expenditures (t-statistic = 3.683). Perhaps most uniformly, Telephone service shows a quite linear and significant rate of increase in expenditures as well as shares (R^2 = 0.986 and 0.919, respectively), and Reading presents a significant and strongly linear (albeit small) rate of decrease in expenditures and shares (R^2 = 0.972 and 0.966, respectively).

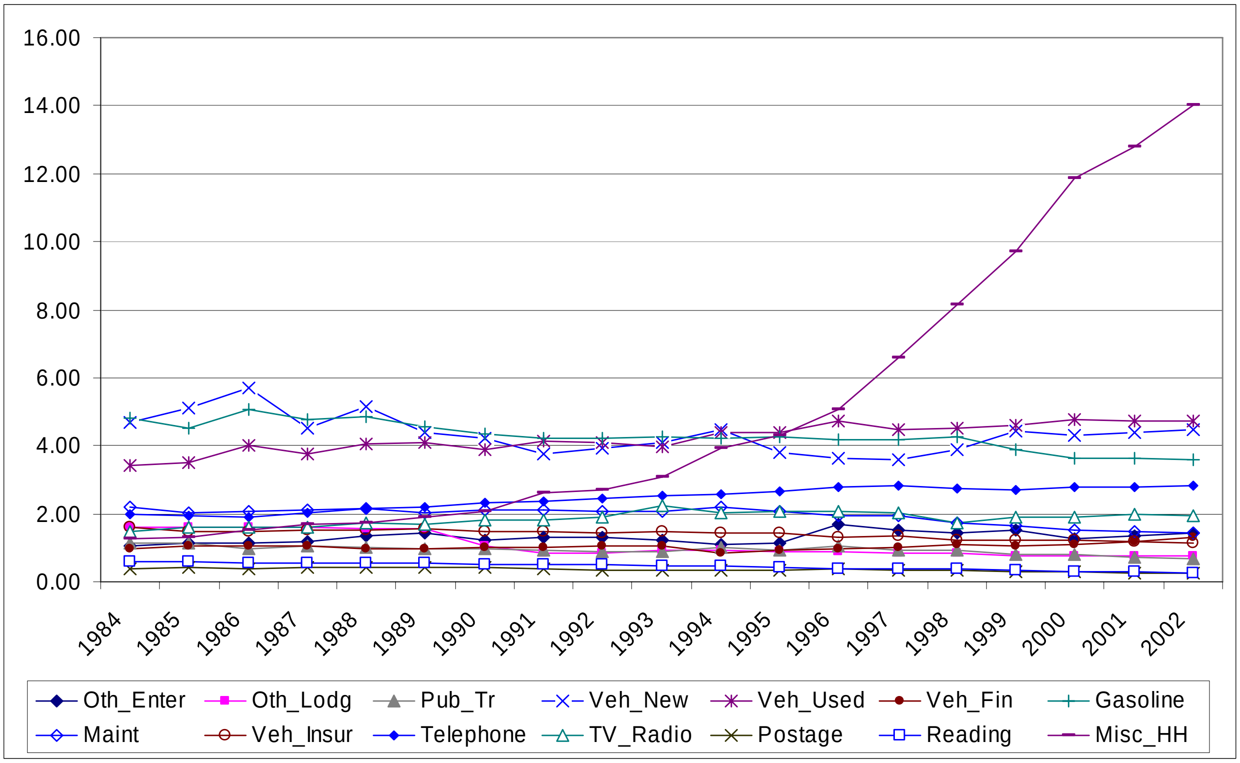


Figure 4. 18: Annual Transportation and Communications CPI-Adjusted Expenditure Share Trends (14-Category Classification) (%)

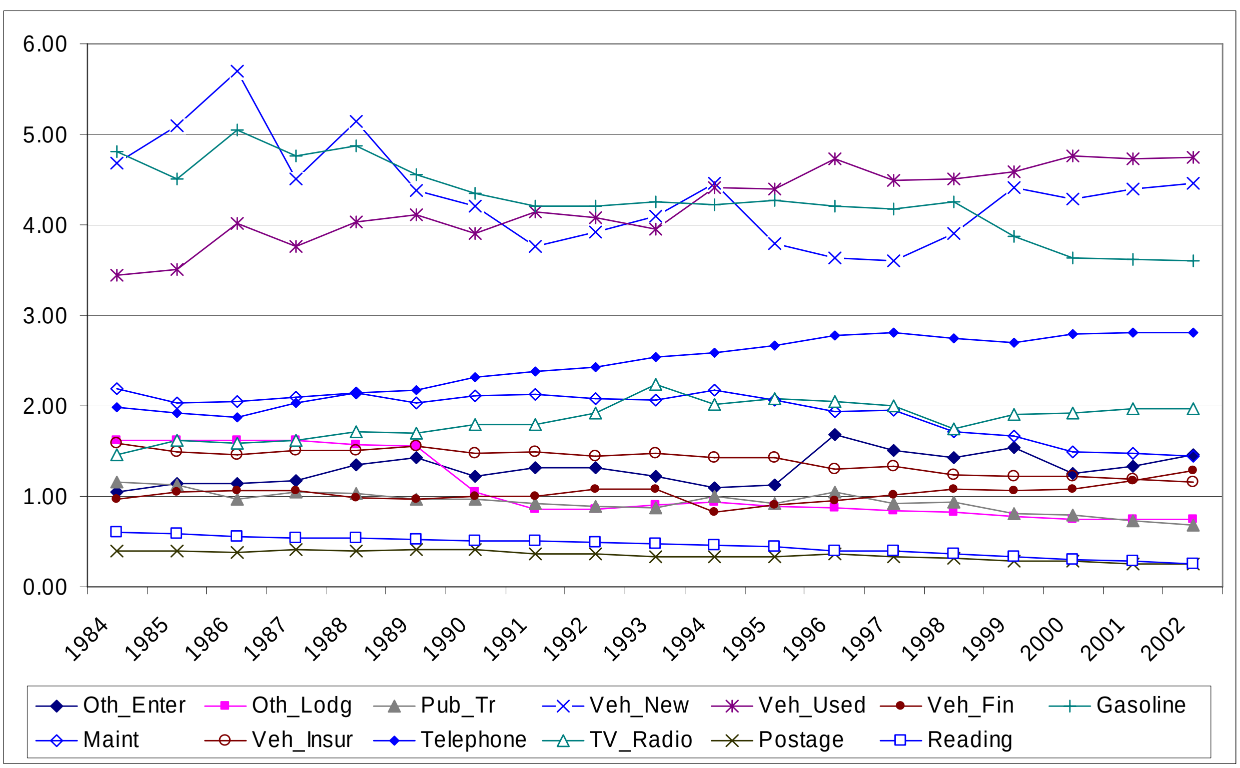


Figure 4. 19: Annual Transportation and Communications CPI-Adjusted Expenditure Share Trends (14-Category Classification; Misc_HH dropped) (%)

4.3.3 Identifying Major Effects on Expenditures in Each Category

In this section, we examine our 14 expenditure categories with respect to the major trend effects discussed in Section 4.3.1. Table 4.10 summarizes the discussion. We first assess the trends that can be determined (at least loosely) directly from the empirical data, namely the inflation and income effects. We then speculate on the remaining potential effects: technological, quality, and taste changes.

We begin by reviewing the most basic trends: the raw expenditures in each category. The second column of Table 4.10 reminds us that those increase over time for every category except Reading, which remains stable over time.

The next question is, to what extent are those increases due to inflation? To assess inflation for each category, we examine the trends in its CPI series, shown in Appendix A. CPIs that rise over time indicate categories that have been subject to inflation, while CPIs that remain relatively stable indicate categories that have escaped inflation. We ascertained the CPI trend for each category through simple regressions of the CPI series against year: the sign of the coefficient of year in the regression indicates whether the CPI basically rose, fell, or remained stable (on average) over time.

The third column of Table 4.10 summarizes those results, showing that unit prices were subject to inflation in all but two of our 14 categories. Vehicle finance charges were fairly erratic but showed no significant time trend, while the miscellaneous household goods category showed a marked decline in prices over time. The construction of the latter CPI series (actually based on information technology hardware and services from 1998 onward, and information processing equipment before 1998) and its implications are discussed at some length in Sections 3.2.3, 3.3, and 4.3.2.3. In the context of the present discussion, it is clear that, probably more than any other, this series is confounding technology, quality, and taste changes with those due to inflation.

The fourth column of Table 4.10 summarizes the trends in expenditure shares, expressed in real dollars. The use of real dollars controls for inflation, and the use of shares controls for increases in total expenditures (income). These trends, then, provide a more informative overview of expenditure patterns in each category, and will be the starting point of the remaining discussion. In dramatic contrast to the trends in raw expenditures and in unit prices due to inflation, only six of these 14 trends are positive. Thus, for the majority of categories, spending as a share of income has actually declined over time, in real terms.

We can assess one more effect based on the empirical data: the income effect. As noted in Section 4.3.1, the demand systems estimated in Chapter 5 explicitly incorporate the effect of income on expenditure shares, so we bring those later results forward here. We do not estimate a 14-equation model due to sample size limitations, so the results are presented by the more aggregate category groupings used in the models (specifically, they are based on the expenditure elasticity results from model Alternatives 3-6).

Table 4. 10: Summary of Estimated and Postulated Major Effects on Expenditures for Each Category

Category	Raw Expenditure Trend[1]	Inflation (CPI Time Trend)[2]	Expenditure Share Trend in Real $[3]	Income Change[4]			Techno-logical Change	Quality Change		Taste Change	
Affected factor	$p_i q_i$	p_i	$p_i q_i$ / E	$p_i q_i$ / E			p_i	p_i (group)	q_i (item)	p_i (macro)	q_i (micro)
Transportation											
Oth_Enter	+	+	+	+ (L)	+ (L)		–		+		+
Oth_Lodg	+	+	–		+ (L)		–	–			–
Pub_Tr	+	+	–			+ (N)	– (air)				+ (air) – (transit)
Veh_New	+	+	–	+ (L)			–		+		+
Veh_Used	+	+	+				–		+		+
Veh_Fin	+	0	+ (p=0.08)								+
Gasoline	+	+	–	+ (N)			–				+
Maint	+	+	–				–				+
Veh_Insur	+	+	–				–				+
Communications											
Telephone	+	+	+	+ (N)			–	–	+		+
Misc_HH	+	–[5]	+				–	–	+		+
TV_Radio	+	+	+				–	–	+		+
Postage	+	+	–	+ (~U)							–
Reading	0	+	–								–

Notes: Empty cells may reflect unknown or ambiguous effects, not necessarily no effect. Positive or negative signs in the q_i columns of the quality change and taste change categories do not mean that quantities of all items in the category increase or decrease, respectively. Rather, a positive sign means that the net effect of increasing the quantity of goods purchased in that category, and/or shifting purchases from lower-priced goods to higher-priced ones in the category, is to increase real expenditure share for that category (and conversely for a negative sign).

[1]Based on the time coefficient in a regression of current-dollar expenditure against year (see Table 4.4).

[2]Based on the time coefficient in a regression of CPI_i against year (see data in Appendix A).

[3]Based on the time coefficient in a regression of CPI-adjusted expenditure share against year (see Table 4.9).

[4]Obtained from the income elasticities estimated in the models of Chapter 5. L = luxury good (income elasticity > 1); N = necessity (0 < income elasticity < 1); U = unit elastic (income elasticity = 1).

[5]See Section 4.3.2.3.

Not surprisingly, all income effects are positive, indicating that these categories comprise normal goods rather than inferior goods. Some categories (entertainment, out-of-town lodging, and vehicle capital costs) are luxuries (elasticities greater than one), others (public transportation, vehicle operating costs, and new communications) are necessities (elasticities less than one), and the old communications category, roughly speaking, has unit elasticity (depending on which alternative and which version of the CPI is examined, elasticities vary between 0.2 and 1.6). In any case, the conclusion is that increases in income will increase real spending in all 14 of these categories, so none of the negative trends in expenditure share seen in the immediately preceding column are due to income effects.

Assessing the remaining effects is necessarily speculative, as it is not possible to separately identify them empirically. However, informed speculation is certainly possible, and productive. Below, we discuss groups of categories with respect to the likely impacts of technology, quality, and taste changes on their expenditure patterns.

Other Entertainment (Ent)

Real expenditure shares for other entertainment (Oth_Enter), which includes rental of motorized campers and other recreational vehicles and boats, show a positive trend, indicating that people are engaging in more (or more expensive) recreational activities across time. Clearly, as incomes rise, tastes change toward a more leisure-oriented society. Technology and quality changes also come into play, as modern recreational vehicles and equipment may differ considerably in material content and capabilities compared to a few decades ago.

Non-Private Vehicle (Tr_NPV)

In the category of non-private vehicle (Tr_NPV) expenditures, the negative trend for Oth_Lodg indicates that people are spending a smaller share of their real incomes over time for out-of-town lodging. Since leisure travel in general is increasing over time (positive income and taste change effects), two possible explanations of this declining trend for out-of-town lodging are that (1) people are substituting overnight stays in hotels/motels for those in personal recreational vehicles or RVs (a taste change), and/or (2) new entrants and competition in the lodging industry have lowered the real unit prices of lodging (quality and "technology" changes). We expect the second explanation to dominate.

For public transportation (Pub_Tr), the trend is also negative. Interpretation of this category is complicated because it contains airline travel as well as public transportation. We expect that public transit is an inferior good (with expenditures on it decreasing with income increases), and that airline travel is a luxury good (having a positive income elasticity, greater than one). Perhaps coincidentally, the only two models that isolate this category, the Alternative 6 models of Table 5.14, exhibit both of those relationships: an income elasticity of 1.301 (denoting a luxury good) results when using the bottom-up computation of composite CPIs, and one of -0.224 (denoting an inferior good, though not statistically significant) appears when using the top-down computation (see Section 3.3. for a discussion of the two approaches). Thus, in terms of taste changes we need to distinguish between the two modes. Another factor in the declining trend of expenditure shares, however, must be the ongoing changes in the airline industry, with restructuring and competition from new entrants lowering the real price of travel over time (reflected loosely as a technological change). Thus, even as the quantity of air travel demanded rises with income, expenditure shares increase at a slower rate due to lower unit prices.

Private Vehicle Capital (Tr_PVC)

From the table we can observe that the expenditure trend for new vehicles (Veh_New) is negative and for used vehicles (Veh_Used) is positive. This means that people are increasing purchases of used vehicles more than new vehicles across time, and now (as shown in Figure 4.19) the two categories have almost equal expenditures.

The trend for new vehicles is probably the net of technology changes (lowering the cost of producing “the same” car over time), quality (more amenities, even in “the same” car), and taste changes (generally migrating toward the larger, higher-quality end of the vehicle spectrum). For used vehicles, the same changes may be at work, but in differing proportions. Perhaps the increase for used vehicles is a result of lower-income people moving up the economic ladder and purchasing a first car (used), and/or even middle-income households purchasing second and third vehicles (e.g. for their teenage children) on the used car market as their incomes rise (and tastes change to make multiple cars seem more of a necessity). Another possibility is that some people want to update their cars frequently so as to enjoy technological and style innovations, but want to save money by purchasing used rather than new cars.

The final category in private vehicle capital (Tr_PVC) is vehicle financing (Veh_Fin). This trend is weakly positive, indicating that people are devoting larger shares of their incomes to this category. This is presumably due to a change in tastes toward a greater acceptability of buying on credit; it is apparently not due to rising interest rates over the study period, since this category showed no significant trend in its CPI.

Private Vehicle Operation (Tr_PVO)

All three items in the category of Tr_PVO (private vehicle operation) show decreases in real expenditure shares over time. The negative trend for Gasoline is especially interesting. Passenger-vehicle-miles traveled have steadily increased over time, and simultaneously, consumer tastes have shifted away from the compact, fuel-efficient cars made popular by the energy crises of the 1970s and 1980s, toward larger, less efficient trucks and sport utility vehicles (SUVs). Thus, the decline in the gasoline expenditure share has occurred despite countervailing income and taste change effects, and therefore represents a substantial technological improvement (since all personal vehicles, even the larger ones, are lighter and more fuel-efficient now than in the 1980s).

The negative trend for vehicle maintenance (Maint) implies that people are spending less money for repairing or maintaining their vehicles. Since they are driving more, spending more money on used vehicles, and less or the same on new ones (and hence might be expected to have higher repair bills), the implication is that technological improvements have made vehicles more reliable and less maintenance-intensive over the years. Similarly, since the expenditure shares for vehicle insurance (Veh_Insur) have declined even though vehicle-miles traveled have actually increased over time, the implication is that auto travel has gotten safer, due to a variety of factors such as better driver education, more experienced older drivers, anti-drinking-and-driving campaigns, and technological improvements in vehicles and roadways. The resulting effect on insurance rates can be interpreted as a unit price decrease.

Communications New (ComN)

All three components of the new communications category (ComN) show increasing real expenditure shares. The real cost of providing a unit of Telephone service has probably declined over time, as a result of technological advances and industry restructuring. At the same time, the increases in service quality that have come about due to technological improvements have contributed to changing tastes, reflecting increasing demand for the more advanced services that have become available over time. Similar considerations apply to miscellaneous household equipment (Misc_HH) including computer hardware and software, and to the TV and radio (TV_Radio) category. In the latter case, technological advances have improved the resolution of TV (e.g. DLP: Digital Laser Projection) and the sound quality of radio (e.g. satellite radio, high density radio). Cable television has increased consumer choice. Rapidly changing technologies (stereos, magnetic tape players, digital devices) have to some extent forced consumers to keep updating their home audio and video equipment as well as content platforms (from records to compact disks, videotapes to digital video disks).

Communications Old (ComO)

Finally, in the old communications category, the negative trends for Postage and Reading probably largely indicate taste changes away from postal service and printed materials (newspapers, magazines, books, letters), as new communication methods (e.g. e-mail, online business) have replaced many old ones. These trends appear to belie historical claims of constancy of expenditure on mass media. However, Dupagne's (1997) review of this literature criticized the theoretical deficiency of those studies, indicating that they had little connection to traditional economic or consumption theory.

4.4 Summary of Trends in Transportation and Communications Expenditures

In Sections 4.2 and 4.3.2, we investigated trends in consumer expenditures on transportation and communications, in current and constant (CPI-adjusted) dollars, respectively, using various classifications. In Sections 4.3.1 and 4.3.3, we speculated on several reasons why a consumer's expenditure on a certain category changes over time, including inflation but particularly after inflation is controlled for. This section summarizes the findings.

Table 4.11 compares the nominal (in current dollars) and real (in CPI-adjusted constant dollars) trends in transportation and communications using the most aggregate classification (only two categories: transportation and communications) and the five-category classification (three transportation categories and two communications categories). In the most aggregate classification, nominal expenditures on both transportation and communications have significantly increased over the study period (1984-2002), whereas only communications expenditures have significantly increased in CPI-adjusted constant dollars. When viewed as a share of total expenditures in current and CPI-adjusted constant dollars, the transportation expenditure share has significantly decreased over time, in contrast with the communications expenditure share which has significantly increased over time.

Table 4. 11: Nominal and Real Trends in Expenditures and Shares for Transportation and Communications (Two- and Five-Category Classifications)

Category		Nominal Trend		Real Trend	
		Sign	Significance	Sign	Significance
Transp.	Exp.	+	*	–	
	Exp. Share	–	*	–	*
Comm.	Exp.	+	*	+	*
	Exp. Share	+	*	+	*
Transportation					
TrPBT	Exp.	+	*	–	*
TrPVC		+	*	+	*
TrPVO		+	*	–	*
TrPBT	Exp. Share	–		–	*
TrPVC		+		+	*
TrPVO		–	*	–	*
Communications					
ComN	Exp.	+	*	+	*
ComO		+	*	–	*
ComN	Exp. Share	+	*	+	*
ComO		–	*	–	*

Note: *: significant at 95% confidence level.

Turning to the five-category classification, the expenditures on all three transportation categories – public transportation (TrPBT), private vehicle capital (TrPVC), and private vehicle operation (TrPVO) – show significant increases over time in current dollars; however, in CPI-adjusted constant dollars, only TrPVC (i.e. purchase of private vehicles) has significantly increased while the other two categories significantly decreased. When examined as a share of total expenditures, only private vehicle operations (TrPVO) has significantly decreased in both nominal and real terms. Expenditure shares on public transportation (TrPBT) and private vehicle capital (TrPVC) have significantly decreased and increased, respectively, only in CPI-adjusted constant dollars over time. Both expenditures and shares for communications show significant trends in current as well as CPI-adjusted constant dollars. Specifically, it is obvious that expenditures and shares for new communications (ComN, e.g. telephone, computer) have increased in current dollars as well as in CPI-adjusted constant dollars. Expenditures on old communications (ComO, including Postage and Reading) have significantly decreased in constant dollars (increased in current dollars), and expenditure shares on old communications have significantly decreased over time in both current and constant dollars.

Table 4.12 summarizes the trends in expenditure levels and shares in nominal and real dollars for the 14-category classification. Across the table as a whole, with few exceptions, trends for items in the same more aggregate category (e.g. for the three items in the TrPVO category) share the same sign. Nominal expenditure levels (top left quadrant of the table), not too surprisingly, are increasing in all 14 categories (although the trend for Reading is not significant). Trends in the remaining three quadrants of the table of the table are mixed, but similar to each other (again with a few exceptions) across the quadrants. This suggests that scaling expenditures by income gives an approximate correction for inflation (since incomes increase with inflation) as well as for income changes.

Table 4. 12: Nominal and Real Trends in Expenditures and Shares for the 14-Category Classification

Category			Nominal Trend		Real Trend	
			Sign	Significance	Sign	Significance
Expenditure ($)	Ent	Oth_Enter	+	*	+	*
	TrNPV	Oth_Lodg	+	*	–	*
		Pub_Tr	+	*	–	*
	TrPVC	Veh_New	+	*	+	
		Veh_Used	+	*	+	*
		Veh_Fin	+	*	+	*
	TrPVO	Gasoline	+	*	–	*
		Maint	+	*	–	*
		Veh_Insur	+	*	–	*
	ComN	Telephone	+	*	+	*
		Misc_HH	+	*	+	*
		TV_Radio	+	*	+	*
	ComO	Postage	+	*	–	*
		Reading	+		–	*
Expenditure Share (%)	Ent	Oth_Enter	+		+	*
	TrNPV	Oth_Lodg	–	*	–	*
		Pub_Tr	–		–	*
	TrPVC	Veh_New	–	*	–	*
		Veh_Used	+	*	+	*
		Veh_Fin	–	*	+	
	TrPVO	Gasoline	–	*	–	*
		Maint	–	*	–	*
		Veh_Insur	+	*	–	*
	ComN	Telephone	+	*	+	*
		Misc_HH	+	*	+	*
		TV_Radio	+	*	+	*
	ComO	Postage	–	*	–	*
		Reading	–	*	–	*

Note: *: significant at 95% confidence level.

For a qualitative decomposition of the net trends in raw and real expenditures, we refer the reader to Table 4.10 of Section 4.3.3, and the discussion there. Very briefly, *inflation* nearly always increases unit prices (with exceptions for vehicle finance charges and miscellaneous household equipment, including computer hardware and software). *Income* effects are positive for all categories, meaning that these are all normal goods, not inferior ones. Broadly speaking, we speculate that *taste changes* have contributed to increasing expenditures in most categories, with the exception of out-of-town lodging, the public transit component of the public transportation category, and the old communication media categories of postage and reading. We suggest that *technological changes* (including, in a loose sense, industry restructuring) have led to decreased unit prices in most categories. In the private vehicle operations categories, technological improvements dominate, so that expenditure shares are decreasing despite increasing demand. Conversely, in the new media categories, taste changes dominate, so that expenditure shares are increasing despite technological improvements which lower prices.

Chapter 5. Modeling Transportation and Communications Demand Systems

The previous chapter discussed consumers' expenditure trends over time in various transportation and communications categories, separately. In this chapter, we estimate demand system models for transportation and communications to explore their interrelated nature. Section 5.1 presents the Almost Ideal Demand System (AIDS) modeling approach that is used in this study, and how to calculate expenditure and price elasticities in the AIDS. In the following section, six alternative model systems are described, based on various classification schemes. Section 5.3 discusses the model results for each alternative at a general level, as well as the expenditure, own-, and cross-price elasticities for the transportation and communications categories in particular. In the last section, relationships between the categories are compared across the alternatives.

5.1 Methodology

A number of methods have been developed and applied for estimating aggregate consumer demand functions, including the Rotterdam (Theil, 1976), translog (Christensen, *et al.*, 1975), and Almost Ideal Demand System (AIDS, Deaton and Muellbauer, 1980) approaches. This study employs the AIDS method since it is more flexible and can reflect many desirable properties of a demand system such as homogeneity and symmetry. The general form of the AIDS model can be written as

$$w_i = \alpha_i + \sum_j \gamma_{ij} \ln p_j + \beta_i \ln(X/P),\ i = 1, 2, \ldots, k,$$

where $w_i = \dfrac{p_i q_i}{\sum_j p_j q_j}$ is the (current-dollar) expenditure share of good i, p_j is the price of good j, q_j is the quantity demanded of good j, X = $\sum_j p_j q_j$ is the total expenditure on all goods (often treated as synonymous with income), and P is the price index defined as

$$\ln P = \alpha_0 + \sum_j \alpha_j \ln p_j + \frac{1}{2}\sum_i \sum_j \gamma_{ij} \ln p_i \ln p_j,\ i, j = 1, 2, \ldots, k.$$

According to consumer (price) theory, the following adding up, homogeneity, and symmetry restrictions should hold, although they have often been found to fail in practice:

(i) $\sum_i \alpha_i = 1$, $\sum_i \gamma_{ij} = 0$, $\sum_i \beta_i = 0$ (adding up);

(ii) $\sum_j \gamma_{ij} = 0$ (homogeneity); and

(iii) $\gamma_{ij} = \gamma_{ji}$ (symmetry).

The adding up constraint ensures that the expenditure shares w_i sum to 1. Homogeneity means that an increase in income and all prices by the same factor should leave the optimum solution unchanged (e.g. the same optimum quantities would be demanded if both income and prices doubled). Symmetry means that the impact on the quantity demanded of good *i* of a unit increase in the price of good *j* should equal the impact on the quantity of *j* of a unit increase in the price of *i*.

Generally, the unconstrained system is estimated, and then statistically tested as to whether the homogeneity and symmetry restrictions are empirically justified. Alternatively, the homogeneity and symmetry conditions can simply be imposed on the model at the outset. The adding up (across equations) restrictions are generally imposed by deleting any one of the equations in estimation and imputing its coefficients from the adding up restrictions.

In empirical studies, however, it is common to use Stone's price index (P^*) instead of P since using P renders the equation system highly non-linear in its unknown parameters, hence potentially making it difficult to estimate. Stone's price index is defined as

$$\ln P^* = \sum_j w_j \ln p_j, \quad j = 1, 2, \ldots, k.$$

That is, the composite log-price of goods is the weighted average of log-prices across all goods (categories), where the weights are the shares of expenditures on each good (category). The AIDS using Stone's index is called the linear approximate AIDS (LA/AIDS) (Blanciforti and Green, 1983). The LA/AIDS is theoretically and practically reasonable, and easily interpretable (Alston and Chalfant, 1993; Lazaridis, 2003).

In the LA/AIDS, noting that $w_i = \frac{p_i q_i}{X}$ is a function of X and using the product rule of differentiation, the *income (expenditure) elasticity* of demand for good *i* can be calculated as (see also Buse, 1994; Green and Altson, 1990)

$$e_{income,i} = \frac{\partial q_i}{\partial X} * \frac{X}{q_i} = \frac{\partial (w_i X)}{\partial X} * \frac{X}{p_i q_i} = \left[\frac{\partial (w_i)}{\partial X} * X + \frac{\partial (X)}{\partial X} * w_i \right] * \frac{X}{p_i q_i}$$
$$= \left[\frac{\partial w_i}{\partial \ln(X)} + w_i \right] * \frac{1}{w_i} = (\beta_i / w_i) + 1 ,$$

where p_i and q_i are the price and quantity demanded of good *i*, respectively.

Generally, the *price elasticity* is defined as the percentage change in the *quantity* of good *i* demanded given a percentage change in the price of good *j*. There are two types of *price elasticities* of demand, Marshallian (uncompensated) and Hicksian (compensated). The Marshallian price elasticity reflects both substitution and income effects, whereas the Hicksian price elasticity accounts for the substitution effect only. More formally, we have

- Marshallian (uncompensated) elasticity

$$e_{ij}^M = \frac{\partial q_i}{\partial p_j} * \frac{p_j}{q_i} = -\delta_{ij} + \frac{\partial (w_i)}{\partial \ln(p_j)} * \frac{X}{p_i * q_i} = -\delta_{ij} + \left[\gamma_{ij} - \beta_i \frac{\partial \ln P}{\partial \ln(p_j)} \right] * \frac{1}{w_i}$$
$$= -\delta_{ij} + (\gamma_{ij} / w_i) - \beta_i (w_j / w_i)$$

- Hicksian (compensated) elasticity

$$e_{ij}^{H} = e_{ij}^{M} + w_j e_{income,i} = -\delta_{ij} + (\gamma_{ij} / w_i) - \beta_i (w_j / w_i) + w_j (\beta_i / w_i + 1)$$
$$= -\delta_{ij} + (\gamma_{ij} / w_i) + w_j \ ,$$

where δ_{ij} is the Kronecker delta ($\delta_{ij} = 1$ if i =j ; and 0 otherwise).

The Marshallian elasticity is based on maximizing utility under the budget constraint (i.e. holding total expenditure, as well as all other prices, constant), whereas the Hicksian elasticity is based on minimizing expenditures at a fixed utility level (i.e. holding real expenditures constant; Nicholson, 1998; Li, *et al*., 2004). They are identical except for the $w_j (\beta_i/w_i + 1)$ term in the Hicksian elasticity, which is w_j times the income elasticity of demand for good *i*, and which eliminates (compensates the consumer for) the income effect found in the equation for the Marshallian elasticity (note that β_i, the coefficient of the income term in the AIDS system, is thereby cancelled out so that income does not affect the Hicksian elasticity). When the income elasticity is positive (i.e. when a good is normal), the compensated elasticity is greater than or equal to the uncompensated one. When price elasticities are negative (as would generally be the case for own-price elasticities and always, by definition, true for the cross-price elasticities of complementary goods), this means that the compensated elasticity is less negative (less price elastic) than the uncompensated one, and hence that compensated demand is less sensitive to changes in price than uncompensated demand. This is again because the compensated demand considers only the substitution effect of price changes, while the uncompensated demand considers both substitution and income effects (Nicholson, 1998). On the other hand, when both income and price elasticities are positive (the latter condition would be unusual for own-price elasticities, but is true by definition for the cross-price elasticities of substitute goods), the compensated elasticity being greater than the uncompensated one means it is more positive, and hence that compensated demand is *more* sensitive to price changes than uncompensated demand. For ease of reference, a typology of income and price elasticities is provided in Table 5.1.

Since the three elasticities in the model are functions of the parameters being estimated (βs and γs), t-tests on their values can be conducted using the estimated variances and covariances of the parameter estimators (Blanciforti and Green, 1983). As usual, the null hypothesis is that an elasticity is equal to zero, meaning that demand is not related to price or income changes.

In this study, we employ the LA/AIDS approach, estimate unconstrained models, and then test the homogeneity and symmetry restrictions. Additionally, the expenditure and both types of price elasticities are calculated and compared. We estimate each set of models without and with a time trend variable "t" in each equation, in the latter case to capture average changes in taste over time (see Blanciforti and Green, 1983 for another application of this approach). For the sake of brevity, we discuss only the first set of models in the text, and provide the time trend models in Appendix B. In Section 5.4, we summarize the results of the time trend models together with the others.

Table 5. 1: A Typology of Elasticities

Condition	Name	Explanation
Expenditure (Income) Elasticities		
e > 0	normal good	As income rises, so does the quantity demanded
e > 1	luxury	As income rises, the quantity demanded increases by a greater proportion
0 < e < 1	necessity	As income falls, the quantity demanded decreases by a smaller proportion
e < 0	inferior good	As income rises, the quantity demanded falls
Price Elasticities (Uncompensated)		
Own		
e < 0	(the usual case)	As the price of a good increases, the quantity demanded of it decreases
e > 0	Veblen or Giffen good	As the price of a good increases, so does the quantity demanded of it, indicating a status effect (Veblen) or a good essential to subsistence (Giffen)
Cross		
e > 0	substitution	As the price of one good increases, the quantity demanded of another good increases
e < 0	complementarity	As the price of one good increases, the quantity demanded of another good decreases
Any Elasticity		
| e | < 1	inelastic	The demand response is proportionately smaller than the income or price change
| e | > 1	elastic	The demand response is proportionately larger than the income or price change
| e | = 1	unit-elastic; unitary elasticity	The demand response is proportional to the income or price change

5.2 Model Specifications

Generally, expenditure share (w_i) and price (p_i) variables for communications, transportation, and the other (all remaining) categories are needed to estimate LA/AIDS models. As discussed in Chapter 3, there are nine and five subcategories for transportation and communications, respectively. Our data on these variables are available only from 1984 to 2002 (19 years of observations). The expenditure share for the numeraire ("other") category is calculated by subtracting the sum of the expenditure shares of all transportation and communications categories from one. Since price and quantity data for all goods are not available, in keeping with common practice (Blanciforti, et al., 1986; Eales and Unnevehr, 1988) CPI data (specifically, two different sets of composite CPIs obtained by different weighting schemes) are used for the price variables in the LA/AIDS models. Additionally, we created a CPI for the "other" category using its relative importance among the CPIs (see Section 3.3 for details of the construction of these CPI measures).

In practical terms, 14 equations (not counting the "other" category) cannot be estimated simultaneously, because our data has only 19 years of observations and the number of parameters to be estimated in an LA/AIDS model would exceed the number of observations. Thus, based on the various conceptual groupings for the 14 communications and transportation categories (discussed in detail in Section 3.2), we developed six alternative grouping schemes for the communications and transportation categories.

As shown in Figure 5.1, the 14 categories were classified into two to six groups. The classifications are conceptually reasonable and meaningful for exploring relationships between transportation and communications by level and type of aggregation. For example, alternative 1 has the most aggregate categories (transportation and communications), while alternative 4 has the most disaggregate categories (entertainment, out-of-town lodging together with public transportation, personal-vehicle capital and operation, and new and old communications technologies). The first four groups of alternative 4 are related to transportation and the last two are related to communications. On the other hand, we exclude the "other entertainment equipment/service" category in alternative 5, and both the "other entertainment equipment/ service" category and the "out-of-town lodging" category in alternative 6 to explore relationships between pure vehicle-travel-related categories and communications (see Section 3.2 for further discussion of these two categories).

We estimate LA/AIDS models for the six alternatives and calculate expenditure, own-, and cross-price elasticities in the following section. SAS 8.0 is employed for model estimation, using the iterative seemingly unrelated regression estimation (SURE) method. This method allows users to easily test the homogeneity and symmetry of the models.

5.3 Model Results

For model estimation, the equation for the "other" category was deleted in each LA/AIDS model to achieve the adding-up restriction. Although the parameters of the deleted equations can be manually obtained through the adding-up condition, they are not presented here since we focus on relationships between communications and transportation. The parameters of the LA/AIDS model for each alternative were first estimated, and then expenditure and price elasticities were calculated at mean values of expenditure shares. All model results are presented for the two different types of composite CPIs we computed: individual and (CPI-all-based) weighted CPIs. Their parameter estimates are occasionally different with respect to signs and statistical significances because of differences in their trends (see Appendix A for plots of their trends). In view of the small sample size, we adopt the relatively liberal standard of p-value < 0.1 as the threshold for statistical significance.

We tested the utility and demand theory-based symmetry and homogeneity restrictions for all alternatives using F-tests. As shown in Table 5.2, most AIDS models rejected the restrictions, although the most aggregate alternatives (with fewest equations in their systems) did not always reject the restrictions. In fact, many empirical studies (including the foundational one of Deaton and Muellbauer, 1980) reject both conditions. This may be because the symmetry and homogeneity restrictions are only satisfied in a steady state situation (Durbarry, 2002). In view of the fact that our models are based on time series data (which are dynamic), we present the model results obtained without imposing the restrictions, as is often done (Blanciforti, et al., 1986).

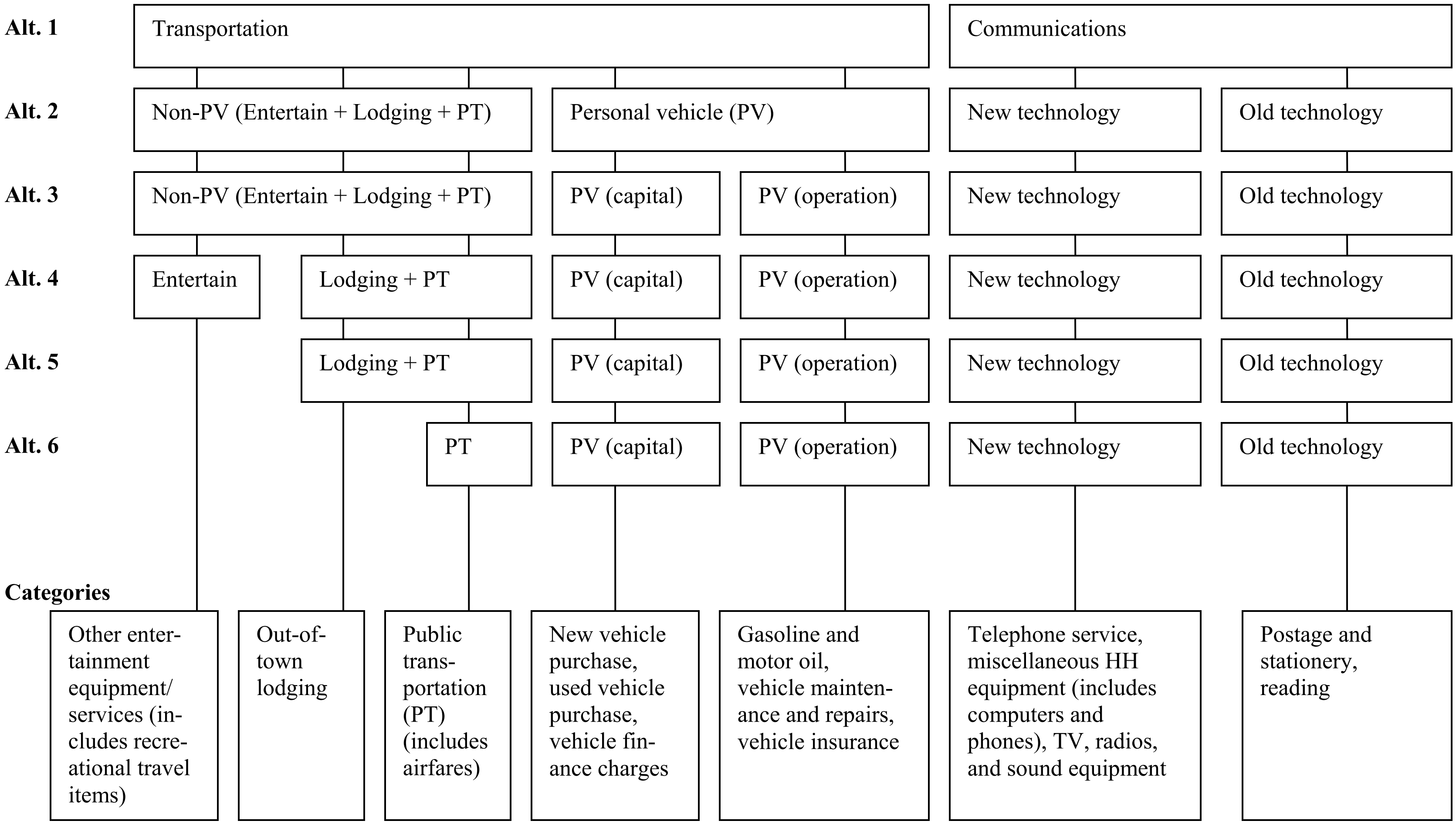


Figure 5. 1: Alternative Grouping Schemes for Transportation and Communications Categories

Table 5. 2: Test Results of Symmetry and Homogeneity Restrictions

Restriction	Alt. 1 (2 equations)	Alt. 2 (4 equations)	Alt. 3 (5 equations)	Alt. 4 (6 equations)	Alt. 5 (5 equations)	Alt. 6 (5 equations)
Without time trend "t"						
Individual CPI						
Symmetry	FTR	R	R	R	R	R
Homogeneity	R	R	R	R	R	R
Weighted CPI						
Symmetry	FTR	FTR	R	R	R	R
Homogeneity	FTR	R	R	R	R	R
With time trend "t" (see Appendix B for models)						
Individual CPI						
Symmetry	FTR	R	R	R	R	R
Homogeneity	R	R	R	R	R	R
Weighted CPI						
Symmetry	FTR	FTR	R	R	R	R
Homogeneity	R	R	R	R	R	R

Notes: FTR = fail to reject the hypothesis of the corresponding restriction at α=0.1. R = reject the hypothesis of the corresponding restriction at α=0.1.

5.3.1 Alternative 1

Table 5.3 presents the estimated parameters for the alternative 1 model. This alternative has the most aggregate categories, one each for transportation and communications. The R^2 values of the equations range from 0.65 to 0.94, showing good fits. Interestingly, the individual CPI model has more significant coefficients than the weighted CPI-all model (five versus one). Also, the transportation equation has more significant variables than the communications one in the individual model.

As shown in Table 5.4, the expenditure elasticities all have positive signs, indicating that all categories are normal goods. That is, as total expenditure (income) increases, demand for each category increases. Additionally, transportation has expenditure elasticities greater than one (indicative of a luxury good), while communication expenditure elasticities are about equal to or less than one (the latter case indicative of a necessary good). This implies that households tend to spend proportionally more money on transportation items than on communications, when their total expenditures increase. Interestingly, while previous studies (cited therein) found the combined transportation and communications category to be a luxury in Australia, Haque (1992), applying a different functional form to 1975-76 data, found it to be a necessity. In addition to the better-fitting (double semilog) functional form that he used, and the differing data sets of the earlier studies, Haque suggests that a structural change in the Australian economy (accompanied by a doubling in the share of expenditures on transportation and communications in the decade 1966-1975) could partly account for the opposing results.

As expected, all but two of the own-price elasticities (shaded cells) are negative and significant (meaning that an increase in price decreases the quantity purchased), and one of the two positive

Table 5. 3: Estimated Parameters of the AIDS Model (Alt. 1)

Category (Shares)	R^2	Parameters				
		α_i	$\gamma_{i1 \text{ (Trans.)}}$	$\gamma_{i2 \text{ (Com.)}}$	$\gamma_{i3 \text{ (Others)}}$	β_i
Individual CPI						
Transportation	0.76	-0.431**	0.497**	-0.0445	-0.734**	0.229**
Communications	0.94	-0.0974	0.0460	0.0313**	-0.0431	-0.000350
Weighted CPI for all items						
Transportation	0.65	-0.403	-0.0546	0.0130	-0.140	0.171
Communications	0.84	0.0961	-0.00871	-0.00337	0.0506*	-0.0254

Note: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05.

Table 5. 4: Elasticities among Transportation and Communications (Alt. 1)

Category (Shares)	Expenditure elasticity	Price elasticity			
		Marshallian (uncompensated)		Hicksian (compensated)	
		Transportation	Communications	Transportation	Communications
Individual CPI					
Transportation	2.133**	1.223	-0.291	1.655*	-0.157
Communications	0.994**	0.732	-0.503**	0.933*	-0.441**
Weighted CPI for all items					
Transportation	1.845**	-1.441**	0.0109	-1.0669*	0.127
Communications	0.597	-0.0567	-1.028**	0.0642	-0.991**

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities.

ones is not significant. The significant, positive compensated own-price elasticity for transport means that expenditure on the total transportation category increases, even though its price increases. This may indicate consumers' taste changes with respect to transportation items. In general, however, a positive Hicksian own-price elasticity could occur with a zero or even negative Marshallian elasticity by excluding the income effect of price changes. As discussed before, mathematically, it can be seen that this would occur if the additional $w_j\ (\beta_i/w_i + 1)$ term in the Hicksian elasticity (i.e. either the share of the *i*th = *j*th good, w_i, or its income elasticity, $(\beta_i/w_i + 1)$, or both) were large enough. Since the income elasticity of transportation is relatively high in that model (2.1), and its expenditure share is also relatively high (about 20% in 2002, according to Figure 4.4 of Chapter 4), the result is plausible.

Among the cross-price elasticities, only one is significantly different from zero. The positively significant, compensated cross-price elasticity indicates that there is a substitute relationship between transportation and communications, excluding income effects, with the magnitude (= 0.93) suggesting that the impact of transportation price on communications is unit-elastic. That is, if the transportation price increases, a consumer tends to increase her expenditure share on communications approximately proportionally. Note however that the relationship is not symmetric: an increase in the price of communications results in a small, statistically insignificant *decrease* in expenditure on transportation, or essentially has no effect on transportation. In general, even if the symmetry constraint held in the demand equations, the corresponding elasticities would not be symmetric. This is because, as we can see from the elasticity equations, elasticities depend on the expenditure shares for communications or transportation, and the share spent on communication is much smaller than that for transportation, as shown in Figure 4.2. This result is substantially consistent with Selvanathan and Selvanathan (1994). Using a classification of private transportation, public transportation, and communication, and applying the Rotterdam (Theil 1976) approach to data from Australia and the UK between 1960 and 1986, they found pairwise substitution among the three goods.

As expected, when the uncompensated price elasticity is negative, the compensated one is generally smaller in magnitude (i.e. less negative) than the uncompensated one, and when the uncompensated price elasticity is positive, the compensated one is always larger in magnitude.

5.3.2 Alternative 2

This alternative has two categories for each of transportation (personal vehicle and non-PV) and communications (old technologies and new technologies). Table 5.5 shows the estimated coefficients of the AIDS models. The R^2 values of the equations range from 0.64 to 0.97. The individual CPI-based model has a better fit than the weighted CPI-all-based model. Nearly half of the coefficients in the former model are statistically significant at $\alpha = 0.1$, while only three in the latter model are statistically significant. Table 5.6 presents the expenditure and price elasticities. All expenditure elasticities are positive, and all except two are significant. Particularly, the transportation categories have higher elasticities, all greater than one, than the communications ones do. Not surprisingly, expenditure elasticities for the non-personal vehicle category are much higher than those for the personal vehicle category. As income increases, a consumer tends to disproportionally increase expenditures on the leisure travel and activities signified by the entertainment equipment, out-of-town lodging, and public transportation (including airfares) categories.

Table 5. 5: Estimated Parameters of the AIDS Model (Alt. 2)

Category (Shares)	R^2	Parameter						
		α_i	γ_{i1} (non-PV)	γ_{i2} (PV)	γ_{i3} (new tech)	γ_{i4} (old tech)	γ_{i5} (others)	β_i
Individual CPI								
Transportation (non-PV)	0.81	-0.316*	-0.00131	0.128**	0.00637	0.0546	-0.251**	0.0760**
Transportation (PV)	0.70	0.230	0.105	0.280*	-0.139*	0.0469	-0.590**	0.155**
Communications (new tech)	0.96	-0.0949	0.0275*	0.0325	0.0267*	-0.0107	-0.0349	-0.00566
Communications (old tech)	0.96	-0.00601	-0.0148**	-0.00849	0.0144**	0.00699	0.0185	-0.00715*
Weighted CPI for all items								
Transportation (non-PV)	0.64	-0.287	-0.0189	-0.0171	0.00635	0.0149	-0.0431	0.0699
Transportation (PV)	0.64	-0.171	-0.0987	-0.00582	-0.0128	-0.0464	0.0790	0.0872
Communications (new tech)	0.94	0.0412	0.00265	-0.00452	0.00679	0.0132*	0.0289	-0.0248
Communications (old tech)	0.97	0.0119	0.00512	-0.00004	0.000269	0.00538**	-0.0208**	0.00528

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. PV = personal vehicle. Heavily-bordered blocks denote relationships among goods in the same aggregate category of transportation or communications.

Table 5. 6: Elasticities among Transportation and Communications (Alt. 2)

Category (Shares)	Expenditure elasticity	Price elasticity							
		Marshallian (uncompensated)				Hicksian (compensated)			
		Non-PV	PV	New tech	Old tech	Non-PV	PV	New tech	Old tech
Individual CPI									
Transportation (non-PV)	3.096**	-1.112	3.188**	0.063	1.487	-1.000	3.702**	0.230	1.514
Transportation (PV)	1.932**	0.596	0.530	-0.885*	0.273	0.666	0.851	-0.781	0.291
Communications (new tech)	0.895**	0.513*	0.620	-0.500*	-0.197	0.546*	0.768	-0.451*	-0.189
Communications (old tech)	0.199	-1.629**	-0.818	1.662**	-0.209	-1.622**	-0.785	1.673**	-0.207
Weighted CPI for all items									
Transportation (non-PV)	2.928**	-1.591*	-0.793	0.071	0.393	-1.485	-0.306	0.229	0.419
Transportation (PV)	1.525*	-0.613	-1.122*	-0.105	-0.284	-0.557	-0.869*	-0.023	-0.270
Communications (new tech)	0.541	0.066	-0.007	-0.850**	0.248*	0.085	0.083	-0.820**	0.253*
Communications (old tech)	1.591**	0.553	-0.103	-0.002	-0.403**	0.610	0.162	0.084	-0.389**

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities. Heavily-bordered blocks denote relationships among goods in the same aggregate category of transportation or communications.

Many of the own-price elasticities are not significantly different from zero, but all significant ones are negative and (except for two in the weighted CPI model) inelastic (between –1 and 0). This suggests that the counter-intuitive positive sign for own-price elasticities found in the alternative 1 model may be due to mixed effects of aggregation. For cross-price elasticities, many of them are significant in the individual CPI-based model, whereas only one is significant in the weighted CPI-all-based model. (This is in contrast to the case for own-price elasticities, where seven out of eight were significant in the weighted CPI-all-based model, compared to only two out of eight for the individual CPI-based model). Focusing on the individual CPI model, then: within transportation, as expected, the non-personal vehicle and personal vehicle categories are substitutes. Increases in the price of personal vehicles encourage people to use other modes more. Similarly, within communications, the relationship between new and old technology categories is substitution. As the prices of telephone and the Internet decline relative to those for postage and print media (based on the individual CPI trends), consumers are likely to replace some mail and print purchases with electronic counterparts. Again, however, these relationships are not symmetric (or even significant) in both directions.

For cross-price elasticities between transportation and communications, complementary relationships were identified of price changes in new communications technology on personal vehicle expenditures, and of price changes for non-PV items on old communications technology expenditures. The latter relationship is more elastic (showing Marshallian and Hicksian elasticities of -1.63 and -1.62, respectively). The interpretations are: consumers tend to increase their expenditures on PVs when new communications technology costs decrease (although disproportionately less than the cost decrease); and, consumers tend to increase their expenditures on old communications technology when non-PV costs decrease (disproportionately greater than the cost decrease). Thus, consumption of communications can positively affect that of transportation and conversely, probably due to a synergistic effect on generation of additional activities. On the other hand, the non-personal-vehicle and the new communications technology categories are inelastic substitutes (0.51 and 0.55). That is, an increase in the price of non-PV goods/services leads to a disproportionately smaller increase in expenditures on new communications technologies.

5.3.3 Alternative 3

In alternative 3, the personal vehicle transportation category was split into capital and operation categories, resulting in four categories for transportation and two for communications. Estimated parameters of the AIDS models appear in Table 5.7. R^2 values of the equations range from 0.63 to 0.98. More significant coefficients at $\alpha = 0.1$ are found in the individual CPI-based model (14, aside from constants) than in the weighted CPI-all-based model (10). Among them, only five are significant in both models. Similar to alternatives 1 and 2, the transportation-related equations have more significant variables than do the communications-related ones. As shown in Table 5.8, all expenditure elasticities are positive, and all except one are significant in each model (with the three transportation ones being significant in both models). The elasticities of the non-personal vehicle and personal vehicle capital categories are greater than 2 (which means very elastic). The personal vehicle capital elasticities are higher than are typically found in the literature; for example Goodwin *et al.* (2004) report a range of 0.28 to 1.62 (mean 0.81) for long-term income elasticities of vehicle ownership based on 15 estimates from dynamic models, and a value of 1.22 for the single study

Table 5. 7: Estimated Parameters of the AIDS Model (Alt. 3)

Category	R^2	Parameter							
		α_i	γ_{i1} (non-PV)	γ_{i2} (PV-capital)	γ_{i3} (PV-op)	γ_{i4} (new tech)	γ_{i5} (old tech)	γ_{i6} (others)	β_i
Individual CPI									
Transportation (non-PV)	0.81	-0.359*	-0.00546	0.0601**	0.0514	0.0133	0.0430	-0.213**	0.0743**
Transportation (PV-capital)	0.63	0.0894	0.121	0.130	0.00526	-0.165*	0.0988	-0.484*	0.160*
Transportation (PV-op)	0.98	0.163	-0.02776*	0.000468	0.0394**	0.015262	-0.0916**	0.0954**	-0.0263**
Communications (new tech)	0.96	-0.110	0.0267	0.0155	0.0152	0.0292	-0.0134	-0.0291	-0.00545
Communications (old tech)	0.96	-0.00171	-0.0135**	-0.00051	-0.00472	0.0116**	0.00570	0.0165	-0.00678*
Weighted CPI for all items									
Transportation (non-PV)	0.73	-0.370*	-0.0219	0.0292	-0.0119	-0.00176	0.0194	-0.0732	0.0808*
Transportation (PV-capital)	0.74	-0.768	-0.0499	0.174**	-0.00499	-0.0300	0.00640	-0.194	0.155
Transportation (PV-op)	0.95	0.307**	-0.0581**	-0.0445**	-0.00831	-0.0116**	-0.0372**	0.165**	-0.0294
Communications (new tech)	0.94	0.0160	0.00165	0.00949	-0.00301	0.00428	0.0146*	0.0195	-0.0216
Communications (old tech)	0.97	0.0135	0.00518	-0.00073	-0.000000966	0.000424	0.00530**	-0.0202**	0.00506

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Heavily-bordered blocks denote relationships among goods in the same aggregate category of transportation or communications.

Table 5. 8: Elasticities among Transportation and Communications (Alt. 3)

Category	Expenditure elasticity	Price elasticity									
		Marshallian (uncompensated)					Hicksian (compensated)				
		Non-PV	PV-capital	PV-op	New tech	Old tech	Non-PV	PV-capital	PV-op	New tech	Old tech
Individual CPI											
Transportation (non-PV)	3.048**	-1.225*	1.468**	1.265	0.257	1.168	-1.114	1.748**	1.491	0.422	1.196
Transportation (PV-capital)	2.740**	1.247	0.251	-0.072	-1.886*	1.058	1.346	0.503	0.131	-1.738	1.082
Transportation (PV-op)	0.646**	-0.361*	0.039	-0.442*	0.225	-1.231**	-0.338*	0.098	-0.394	0.260	-1.225**
Communications (new tech)	0.899**	0.497*	0.296	0.288	-0.455	-0.247	0.530*	0.379	0.355	-0.406	-0.238
Communications (old tech)	0.240	-1.486**	0.013	-0.473	1.342**	-0.354	-1.478**	0.035	-0.455	1.355**	-0.352
Weighted CPI for all items											
Transportation (non-PV)	3.228**	-1.685*	0.600	-0.493	-0.169	0.514	-1.568*	0.898	-0.254	0.006	0.543
Transportation (PV-capital)	2.678**	-0.603	0.741	-0.179	-0.417	0.055	-0.506	0.987	0.020	-0.272	0.078
Transportation (PV-op)	0.604*	-0.769**	-0.563**	-1.083**	-0.135	-0.498**	-0.747**	-0.507**	-1.038**	-0.102	-0.493**
Communications (new tech)	0.601	0.045	0.212	-0.026	-0.899**	0.273*	0.067	0.268	0.018	-0.867**	0.278*
Communications (old tech)	1.567**	0.560	-0.134	-0.042	0.017	-0.412**	0.617	0.010	0.074	0.102	-0.398**

Notes: * p-value < 0.1. Shaded cells indicate own-price elasticities. Heavily-bordered blocks denote relationships among goods in the same aggregate category of transportation or communications.

they identified involving static models on time-series data (the case closest to ours). Our personal vehicle operations elasticities, however (0.65 and 0.60), are consistent with the ranges found in the same review (0.27 – 1.71, mean 1.08 across 50 long-term dynamic studies; 0.02 – 1.34, mean 0.44 across five static studies on time series data). Except for PV operations, the transportation categories have higher elasticities than the communications ones do. That is, as income increases, consumers tend to increase their spending on transportation-related goods and services by a higher proportion than their increase in spending on communication.

All own-price elasticities are either negatively significant or insignificant. Especially, the non-personal vehicle category has the highest elasticity, and among the significant ones, the personal vehicle operation category has the second-highest. The uncompensated own-price elasticities for personal vehicle operation expenditures here (-0.44, -1.08), and in all of the subsequent models, are consistent with the range (-1.81 to 0, mean -0.64) of long-term own-price elasticities of fuel consumption found in a review of 51 independent estimates by Goodwin, *et al*. (2004), and similar to the range (-0.77 to -0.28) of static own-price elasticities of fuel consumption found in a review of eight independent estimates based on time-series data (the case closest to our own) in the same paper.

For cross-price elasticities within the respective transportation and communications categories, the personal vehicle capital and non-PV categories have a substitution relationship (of a similar magnitude in both directions, although significant only for the impact of a change in PV capital prices on expenditures for non-PV items). Similar to the Alt. 2 model of Tables 5.4 and 5.5, this substitution relationship indicates an expected mode shift impact of price change among transportation modes. In contrast, it is also logical that the non-PV and PV operation categories, and (in the weighted CPI models) PV capital and operation categories, have complementary relationships. These two categories are directly related to auto travel. Their cross-price elasticities are less than one, indicating an inelastic relationship. The relationship between PV capital and operation found in the weighted CPI model (with a significant cross-price elasticity of -0.56) is consistent with the literature (Goodwin, *et al.,* 2004 found long-term elasticities of demand for fuel with respect to vehicle purchase price ranging from -0.88 to 0 with a mean of -0.51 across 10 studies using dynamic models, and elasticities ranging from -0.66 to -0.15 with a mean of -0.45 across four studies using static models on time series data).

Again similar to the results of alternative 2, the two communications categories have a substitution relationship. The cross-price elasticities of the new technology category on old technology are significant and greater than one in the individual CPI model, while the opposite elasticities are significant (but less than one) in the weighted CPI-all model.

Turning to cross relationships between communications and transportation, we see that the non-PV and the new communications technology categories are substitutes, while the non-PV and the old communications technology categories are complements, and so are the new technology and PV capital categories. These results are also similar to those of alternative 2. We now further find that the impact of old communications technology on PV operation is complementarity, with elasticities greater than one in the individual CPI model. This suggests that increases in the demand for old-fashioned communications such as mail and magazines (indicative of a wider range of interests, activities, and personal relationships), leads to increased personal vehicle use (i.e. that increased travel is one natural outcome of that broader range).

5.3.4 Alternative 4

Alternative 4 has the most disaggregate and largest number of categories. Here, the non-PV category was split into two categories: other entertainment equipment/service, and out-of-town lodging/public transportation. Table 5.9 shows the estimated parameters of the two AIDS models. R^2 values of the equations range from 0.49 to 0.99, with the two entertainment equations having the lowest R^2s. In contrast to the previous alternatives, here the weighted CPI-based model has more significant variables at $\alpha = 0.1$ (21, not counting constants) than does the individual CPI-based model (15). Similar to the previous alternatives, the transportation-related equations have more significant variables (3.25 to 5 variables per equation) than do the communications-related ones (2 to 3.5 variables per equation). Table 5.10 presents all expenditure and price elasticities in both compensated and uncompensated forms. All expenditure elasticities are positive and significant in both the individual and weighted CPI models. Among them, the expenditure elasticity for the entertainment category has the highest magnitude (greater than 3) in each model, which is natural in view of the discretionary nature of this category. As before, it is also observed that transportation categories tend to have higher expenditure elasticities than do the communications categories. That is, expenditures on transportation-related goods and services are more sensitive to income than are those on communications, suggesting that the latter are more essential than the former.

For own-price elasticities, only the elasticity of the PV operation category is significant in the individual CPI model. On the other hand, elasticities of all categories except one are significant in the weighted CPI model, but two of them (for PV capital and old communications technology) are positive. This may be a consequence of the failure of the model to meet the homogeneity and symmetry conditions, which may in turn be a consequence of changing tastes.

For within-category (transportation and communications, respectively) cross-price elasticities, the entertainment category has a complementary effect on the lodging/PT and PV capital categories, with elasticities greater than one. This indicates that entertainment-related activities are accompanied by a greater demand for lodging/PT (e.g. air travel) and PV capital (e.g. buying a new car) goods and services. The other cross-relationships within transportation or communications categories (e.g., complementarity between PV capital and PV operations, substitution of PV capital for lodging/PT, and substitution between new technology and old technology) are similar to those in the previous alternatives. Additionally, there are some significant relationships between the transportation and communications categories. Interestingly, the entertainment category has a positive effect on the old communications technology category and a negative one on the new communications technology category. That is, expenditures on old communications services such as mail and magazines can substitute for those on entertainment activities if the price of the latter rises, but such a price increase would reduce expenditures on new communications services such as telephone calls (indicating a complementary relationship). The other relationships are similar to those in alternative 3.

Table 5. 9: Estimated Parameters of the AIDS Model (Alt. 4)

Category	R^2	Parameters								
		α_i	γ_{i1} (enter)	γ_{i2} (lodg-ing + PT)	γ_{i3} (PV-capital)	γ_{i4} (PV-op)	γ_{i5} (new tech)	γ_{i6} (old-tech)	γ_{i7} (others)	β_i
Individual CPI										
Transportation (entertainment)	0.56	-0.225	0.00372	-0.0290*	-0.00747	0.00221	0.0168	0.0418	-0.0273	0.0273
Transportation (lodging + PT)	0.95	0.0108	-0.0493**	0.00598	0.0676**	0.0405**	0.0162	0.00211	-0.113**	0.0183
Transportation (PV-capital)	0.77	0.592	-0.169**	0.0442	0.132*	-0.0135	-0.0607	0.0912	-0.213	0.0441
Transportation (PV-op)	0.98	0.194*	-0.00997	-0.0324**	-0.00095	0.0343*	0.0140	-0.0876**	0.115**	-0.0307**
Communications (new tech)	0.97	-0.0305	-0.0261*	0.0163	0.0165	0.0136	0.0469**	-0.0161	0.00970	-0.0239
Communications (old tech)	0.99	-0.0335	0.0112**	-0.00807**	-0.00074	-0.00404	0.00345	0.00670	-0.00137	0.00125
Weighted CPI for all items										
Transportation (entertainment)	0.49	-0.230*	0.00465	0.0128	-0.0123	-0.00635	0.00362	0.0149	-0.0609	0.0520*
Transportation (lodging + PT)	0.91	-0.184	-0.0317**	-0.0306**	0.0488**	-0.0161*	-0.0107*	-0.0209	0.0196	0.0476*
Transportation (PV-capital)	0.84	-0.931**	-0.106**	-0.0304	0.203**	-0.0488	-0.0508**	-0.0966*	-0.0736	0.231**
Transportation (PV-op)	0.96	0.292**	-0.0178	-0.0495**	-0.0407**	-0.0124	-0.0136**	-0.0482**	0.177**	-0.0215
Communications (new tech)	0.96	-0.0313	-0.0279**	0.00538	0.0173	-0.0156*	-0.00163	-0.0144	0.0536	0.000157
Communications (old tech)	0.99	0.0254	0.00797**	0.00351	-0.00284	0.00320**	0.00193**	0.0128**	-0.0290**	-0.00055

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Heavily-bordered blocks denote relationships among goods in the same aggregate category of transportation or communications.

Table 5. 10: Elasticities among Transportation and Communications (Alt. 4)

Category	Expenditure elasticity	Price elasticity											
		Marshallian (uncompensated)						Hicksian (compensated)					
		Entertain	Lodging + PT	PV-cap	PV-op	New tech	Old tech	Entertain	Lodging + PT	PV-cap	PV-op	New tech	Old tech
Individual CPI													
Trans (entertainment)	3.350**	-0.707	-2.557*	-0.860	0.016	1.323	3.582	-0.668	-2.474*	-0.552	0.265	1.504	3.612
Transportation (lodging + PT)	1.740**	-2.007**	-0.776	2.671**	1.588**	0.618	0.079	-1.987**	-0.733	2.831**	1.717**	0.712	0.095
Transportation (PV-capital)	1.479*	-1.845**	0.468	0.388	-0.182	-0.685	0.986	-1.828**	0.505	0.524	-0.072	-0.605	0.999
Transportation (PV-op)	0.586**	-0.130	-0.427**	0.025	-0.507**	0.212	-1.177**	-0.123	-0.413**	0.079	-0.464*	0.243	-1.172**
Communications (new tech)	0.558*	-0.479*	0.312	0.346	0.285	-0.108	-0.294	-0.472*	0.326	0.398	0.326	-0.078	-0.289
Communications (old tech)	1.140**	1.259**	-0.908**	-0.096	-0.463	0.379	-0.251	1.272**	-0.880**	0.009	-0.379	0.441	-0.241
Weighted CPI for all items													
Trans (entertainment)	5.485**	-0.651	0.990	-1.477	-0.880	0.070	1.243	-0.587	1.125	-0.972	-0.473	0.366	1.292
Transportation (lodging + PT)	2.931**	-1.308**	-2.286**	1.800**	-0.796*	-0.536**	-0.866	-1.274**	-2.214**	2.070**	-0.578	-0.378*	-0.840
Transportation (PV-capital)	3.508**	-1.180**	-0.392	0.977*	-0.716*	-0.687**	-1.071*	-1.139**	-0.306	1.300**	-0.456	-0.498**	-1.040*
Transportation (PV-op)	0.710*	-0.237	-0.660**	-0.521**	-1.145**	-0.167*	-0.647**	-0.228	-0.642**	-0.456*	-1.093**	-0.129	-0.640**
Communications (new tech)	1.003**	-0.517**	0.099	0.319	-0.288	-1.030**	-0.266	-0.505**	0.124	0.412	-0.214	-0.976**	-0.257
Communications (old tech)	0.938**	0.893**	0.395	-0.313	0.363*	0.220*	0.438*	0.904**	0.418	-0.226	0.433**	0.271**	0.447*

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities. Heavily-bordered blocks denote relationships among goods in the same aggregate category of transportation or communications.

5.3.5 Alternative 5

Alternative 5 excludes the other entertainment equipment/service category from alternative 4, since (as discussed in Section 3.2) it contains a number of goods *not* related to travel, as well as many that are. The estimated parameters of the two AIDS models appear in Table 5.11. R^2 values of the equations range from 0.63 to 0.98. The individual CPI-based model has more significant variables than does the weighted CPI-based model. Table 5.12 shows all expenditure and price elasticities in both compensated and uncompensated forms.

All expenditure elasticities are positive and most are significant in the models. In particular, lodging/PT and PV capital categories have the highest expenditure elasticities in each model, indicating that as income increases, consumers tend to spend disproportionately more money on travel such as air fares and lodging, and on buying a car. On the other hand, income has a lower influence on the demand for communications categories. Turning to the own-price elasticities, just one category, PV-op, is significant in the individual CPI model (with that one plus three others significant in the weighted CPI-all model). It is inelastic, indicating the essential nature of vehicle operating costs. The lodging/PT category is price elastic in the weighted CPI model, consistent with other evidence that domestic air travel demand is price elastic (Gillen, et al., 2004). The other significant own-price elasticities (for the two communications categories) are inelastic, less than one in absolute magnitude. It is found that the PV capital category has a positive sign (and in the weighted model is relatively large at 0.74 Marshallian and 0.99 Hicksian, although not significant in either model), which is counter-intuitive. However, it may be interpreted that cars are such a necessity that even when their price increases, consumers continue to purchase them (recall that the overall transportation own-price Hicksian elasticity was positive and significant in the individual CPI model of Alt. 1, Table 5.4. PV own-price elasticities have also been positive in all the other models – though significant only in the weighted CPI-all model of Alt. 4).

Looking at within-category cross-price elasticities, it is clear that the lodging/PT and PV capital categories are substitutes, which is plausible since they represent alternative mode choices. The impact of PV-op on lodging/PT is substitution (and elastic) in the individual CPI model, while the impact of lodging/PT on PV-op is complementarity (and inelastic) in both models. Each relationship is plausible. On the one hand, an increase in the cost of operating a PV (just as for an increase in its capital costs) may shift consumers more toward non-PV modes such as transit for short-distance trips and air for long-distance trips. But at the same time, non-PV goods and services, including lodging on trips as well as transit and airlines, are often accompanied by PV travel (to access the lodging, the transit, or the airport), so that a rise in price of those items, leading to a cutback in their demand, would cut the demand for operating a PV as well. However, the significance of both effects (having opposite signs) is clearly a symmetry violation of the AIDS model. That is, the impact of a price change for good A on the demand for good B is different from the impact of a price change for good B on the demand for the good A. Comparing their magnitudes, the substitution relationship (1.54-2.55 for the effects of PV-capital and -operations on lodging/PT) is much stronger than the complementary one (0.38-0.64) for the reverse effect of lodging/PT on PV-operations. Similar to the previous alternatives, the new and old communications technology categories are substitutes.

Table 5. 11: Estimated Parameters of the AIDS Model (Alt. 5)

Category	R^2	Parameter							
		α_i	γ_{i1} (lodging + PT)	γ_{i2} (PV-capital)	γ_{i3} (PV-op)	γ_{i4} (new tech)	γ_{i5} (old tech)	γ_{i6} (others)	β_i
Individual CPI									
Transportation (lodging + PT)	0.86	-0.125	0.0268	0.0675**	0.0489*	-0.0121	0.00271	-0.195**	0.0510**
Transportation (PV-capital)	0.63	0.107	0.115	0.132	0.0179	-0.153	0.0923	-0.495*	0.156*
Transportation (PV-op)	0.98	0.154	-0.0287**	-0.00068	0.0368*	0.0124	-0.0885**	0.0994**	-0.0249*
Communications (new tech)	0.96	-0.109	0.0267*	0.0164	0.0174	0.0339*	-0.0168	-0.0304	-0.00732
Communications (old tech)	0.96	0.000031	-0.0127**	-0.00077	-0.00603	0.00913*	0.00680	0.0169	-0.00605
Weighted CPI for all items									
Transportation (lodging + PT)	0.83	-0.126	-0.0287	0.0401**	-0.00244	-0.00348	0.0123*	-0.0293	0.0243
Transportation (PV-capital)	0.73	-0.742	-0.0238	0.175**	-0.00373	-0.0272	0.0134	-0.237*	0.155
Transportation (PV-op)	0.95	0.328**	-0.0484**	-0.0458**	-0.00417	-0.00922	-0.0284**	0.149**	-0.0356
Communications (new tech)	0.94	0.0203	0.00710	0.00964	-0.00342	0.00475	0.0151**	0.0103	-0.0205
Communications (old tech)	0.96	0.0105	0.00302	-0.00063	-0.0003	0.000088	0.00433**	-0.0165*	0.00541

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Heavily-bordered blocks denote relationships among goods in the same aggregate category of transportation or communications.

Table 5. 12: Elasticities among Transportation and Communications (Alt. 5)

Category	Expen-diture elasticity	Price elasticity									
		Marshallian (uncompensated)					Hicksian (compensated)				
		lodging + PT	PV-capital	PV-op	New tech	Old tech	lodging + PT	PV-capital	PV-op	New tech	Old tech
Individual CPI											
Transportation (lodging + PT)	3.067**	0.036	2.547**	1.830*	-0.603	0.091	0.112	2.830**	2.058*	-0.437	0.119
Transportation (PV-capital)	2.695**	1.212	0.281	0.069	-1.753*	0.987	1.278	0.529	0.269	-1.607	1.011
Transportation (PV-op)	0.665**	-0.378**	0.022	-0.480*	0.185	-1.190**	-0.362**	0.083	-0.430*	0.221	-1.184**
Communications (new tech)	0.865**	0.497*	0.316	0.333	-0.365	-0.310	0.518*	0.395	0.397	-0.318	-0.302
Communications (old tech)	0.322	-1.406**	-0.024	-0.625	1.060*	-0.232	-1.398**	0.006	-0.602	1.077*	-0.230
Weighted CPI for all items											
Transportation (lodging + PT)	1.985*	-2.187**	1.536**	-0.172	-0.194	0.488*	-2.138**	1.719**	-0.025	-0.087	0.506*
Transportation (PV-capital)	2.679**	-0.300	0.743	-0.165	-0.386	0.131	-0.234	0.990	0.034	-0.241	0.155
Transportation (PV-op)	0.520	-0.640**	-0.573**	-1.021**	-0.098	-0.379**	-0.628**	-0.525**	-0.982**	-0.070	-0.374**
Communications (new tech)	0.621	0.141	0.213	-0.035	-0.892**	0.283**	0.156	0.270	0.011	-0.858**	0.288**
Communications (old tech)	1.607**	0.323	-0.126	-0.079	-0.023	-0.520**	0.363	0.021	0.041	0.064	-0.506**

Notes: *0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities. Heavily-bordered blocks denote relationships among goods in the same aggregate category of transportation or communications.

Both substitution and complementarity relationships between transportation and communications are found in the models. Similar to the results for alternatives 2 and (for the individual CPI model) 3, the impact of the lodging/PT category on the new technology category is substitution, whereas its effect on the old technology category is complementarity. Also, the latter is more elastic. In addition, the impact of old technology on PV operation is complementarity, with the impact being elastic in the individual CPI model (but inelastic in the weighted CPI model). That is, a decrease in the price of forms of communications such as mail and magazines leads to more travel by auto. This may happen due to an increase in social activities by auto travel. This relationship, taken together with the complementarity of the reverse impact of lodging/PT on old technology, suggests a synergy between object-based forms of communications about people, events, and activities, and the travel associated with those communications.

5.3.6 Alternative 6

For alternative 6, we consider only public transportation instead of the non-PV or out-of-town lodging/PT category, making it a pure transportation mode category. Table 5.13 presents the estimated parameters of the two AIDS models. R^2 values for all equations except one (for public transit in the weighted CPI system) are higher than 0.70. The individual CPI-based model again has more significant variables than does the weighted CPI-based model. Taken across all alternatives, this result may suggest that an individual-based CPI is more significantly related to the corresponding demand. Again, the transportation-related equations have more significant variables than do the communications-related ones. All expenditure and price elasticities in both compensated and uncompensated forms are shown in Table 5.14.

For expenditure elasticities, all categories are positive and all but one (the old technology category) are significant in the individual CPI model, while only two are significant in the weighted CPI model. Similar to alternative 5, the public transportation and PV capital categories are income elastic. The old technology category is also income elastic in the weighted CPI model. This may indicate that as income increases, social activities and leisure expenditures increase, and then people are likely to spend proportionately more money on mail, magazines, and books. A few own-price elasticities are significant. The only own-price elasticity that is significant for the individual CPI model is that for old technology, and it is negative and elastic as expected. Other significant own-price elasticities in the weighted CPI model, those for PV operation and new technology, are also negative. Similar to alternative 5 and others, the PV capital category has a positive sign in the weighted CPI model, though not significant.

Turning to within-category cross-price elasticities, the public transportation and PV capital category or PV operation category are substitutes (highly elastic in the individual CPI model). Similar to the previous alternatives, the PV capital and the PV operation categories are complements in the weighted CPI model, and their elasticity is less than one (inelastic). The new and the old technology categories are also seen to be substitutes in the individual CPI model.

Turning to cross-category elasticities, similar to previous alternatives, the public transportation category has a substitution and complementarity relationship to the new and the old technology categories, respectively. Also as before, old technology has a *complementary* effect on PV *operation*. Interestingly, however, in the individual CPI model, old technology has a *substitution*

Table 5. 13: Estimated Parameters of the AIDS Model (Alt. 6)

Category	R^2	Parameter							
		α_i	γ_{i1} (PT)	γ_{i2} (PV capital)	γ_{i3} (PV-operation)	γ_{i4} (new tech)	γ_{i5} (old tech)	γ_{i6} (others)	β_i
Individual CPI									
Transportation (public transit)	0.70	-0.0147	0.0135*	0.0187**	0.0328**	0.00434	0.00632	-0.0761**	0.00328
Transportation (PV-capital)	0.72	0.335	0.146**	0.0645	0.0130	-0.179**	0.198	-0.548**	0.137*
Transportation (PV-op)	0.97	0.154	-0.0198	0.0132	0.0433**	0.0146	-0.107**	0.0806*	-0.0219
Communications (new tech)	0.96	-0.103	0.0219*	0.00414	0.0142	0.0333*	0.000615	-0.0229	-0.0102
Communications (old tech)	0.97	-0.00755	-0.0119**	0.00531	-0.00524	0.00982**	-0.0025	0.0168	-0.00462
Weighted CPI for all items									
Transportation (public transit)	0.35	0.0567	0.00301	0.0131	-0.0000500	0.00111	0.00506	-0.00770	-0.0133
Transportation (PV-capital)	0.75	-0.832*	0.0253	0.178**	-0.0165	-0.0262	0.00295	-0.293**	0.179*
Transportation (PV-op)	0.91	0.398**	-0.00597	-0.0456**	-0.00478	-0.00468	-0.0203*	0.0726**	-0.0324
Communications (new tech)	0.94	-0.0205	0.0106	0.0108	-0.00701	0.00412	0.0104	0.0109	-0.0138
Communications (old tech)	0.96	0.0103	-0.00104	-0.000810	0.000253	-0.000210	0.00430**	-0.0102*	0.00419

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Heavily-bordered blocks denote relationships among goods in the same aggregate category of transportation or communications.

Table 5. 14: Elasticities among Transportation and Communications (Alt. 6)

Category	Expen-diture elasticity	Price Elasticity									
		Marshallian (uncompensated)					Hicksian (compensated)				
		Public transit	PV-capital	PV-op	New tech	Old tech	Public transit	PV-capital	PV-op	New tech	Old tech
Individual CPI											
Transportation (public transit)	1.301*	0.236	1.690**	2.983**	0.382	0.577	0.251	1.809**	3.079**	0.452	0.589
Transportation (PV-capital)	2.486**	1.574**	-0.437	0.030	-2.025**	2.136	1.601**	-0.208	0.215	-1.890**	2.158*
Transportation (PV-operation)	0.704**	-0.263	0.205	-0.395	0.212	-1.435**	-0.256	0.269	-0.342	0.250	-1.428**
Communications (new tech)	0.811**	0.407*	0.094	0.276	-0.373	0.013	0.416*	0.169	0.336	-0.329	0.020
Communications (old tech)	0.482	-1.324**	0.643	-0.549	1.129**	-1.276*	-1.319**	0.687	-0.513	1.155**	-1.271*
Weighted CPI for all items											
Transportation (public transit)	-0.224	-0.711	1.316	0.086	0.168	0.475	-0.713	1.295	0.070	0.156	0.473
Transportation (PV-capital)	2.942**	0.253	0.757	-0.323	-0.389	0.015	0.285	1.028	-0.105	-0.230	0.041
Transportation (PV-operation)	0.564	-0.076	-0.575*	-1.032**	-0.040	-0.270*	-0.070	-0.523*	-0.990**	-0.009	-0.265*
Communications (new tech)	0.746	0.200	0.223	-0.111	-0.910**	0.196	0.208	0.292	-0.056	-0.870**	0.202*
Communications (old tech)	1.470*	-0.122	-0.134	-0.007	-0.049	-0.523**	-0.106	0.001	0.103	0.031	-0.509**

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities. Heavily-bordered blocks denote relationships among goods in the same aggregate category of transportation or communications.

effect on PV capital, while new technology has a *complementarity* effect on the same category. The complementary effect of new communications technologies on travel is not surprising, although it would have been more expected with respect to PV operation than PV capital. The differential effects of old technologies on PV operation compared to PV capital, however, are more difficult to explain. The complementarity effect on PV operation was discussed in connection with alternative 5; the substitution effect on PV capital is unique to this alternative, and applies only to the individual CPI model.

5.4 Summary of Significant Relationships

This section reviews the significant expenditure and price elasticities estimated from the AIDS models. In particular, the relationships between transportation and communications are compared among the models. These relationships are identified by examining the cross-price elasticities between the various elements in each of the two categories.

Table 5.15 shows a summary of expenditure and (own and cross) price elasticities for all alternatives. All ***expenditure (income) elasticities*** are positive, indicating that all transportation and communications categories studied here are normal goods. Most transportation categories (entertainment, out-of-town lodging, public transportation, and personal vehicle (PV) capital) are highly income-elastic (luxuries) except for the PV operation category, which is income-inelastic (a necessity). This indicates that once a consumer acquires a vehicle, there is a demand for the goods/services needed to operate it, regardless of income change. Communications categories are sometimes income-inelastic, but generally less elastic than transportation ones, indicating that communications is more essential than travel. The old communications technology category (printed media and postage) is more income-elastic than the new technology one (electronic communication goods and services), especially in the weighted CPI models.

As expected, ***own-price elasticities*** are generally negative where they are significant. Also, they are often insignificant, indicating insensitivity to price. On the other hand, a couple of positive, significant results (PV capital in Alt. 4 or transportation overall in Alt. 1) could reflect changing tastes. Similar to expenditure elasticities, transportation categories are generally more price-elastic than communications ones.

With respect to ***within-category cross-price elasticities***, transportation categories have both substitution and complementarity relationships, while the two communications categories have a substitution relationship. Substitution relationships are identified in the pairwise transportation categories below:

- personal vehicle (PV) and non-PV categories (Alt. 2),
- PV capital and non-PV categories (Alt. 3),
- PV capital and lodging/PT categories (Alt. 4),
- lodging/PT categories and PV capital or PV operation (Alt. 5),
- public transportation and PV capital or PV operation (Alt. 6).

Table 5. 15: Summary of Expenditure and Price Elasticities

Effects	Model Alternatives					
	1	*2*	*3*	*4*	*5*	*6*
Expenditure (income) elasticities						
Transportation						
Elastic (e > 1; luxury)	√	√	√	√	√	√
Inelastic (0 < e < 1; necessity)			√	√	√	√
Communications						
Elastic (e > 1; luxury)		√	√	√	√	√
Inelastic (0 < e < 1; necessity)	√	√	√	√	√	√
Own-price elasticities						
Transportation						
Elastic (e < -1)*	√	√	√	√	√	√
Inelastic (-1 < e < 0)		√	√	√	√	√
Communications						
Elastic (e < -1)	√			√		√
Inelastic (-1 < e < 0)	√	√	√	√	√	√
Cross-price elasticities (within category)						
Transportation						
Substitution (e > 0)	n/a	√	√	√	√	√
Complementarity (e < 0)	n/a		√	√	√	√
Communications						
Substitution (e > 0)	n/a	√	√	√	√	√
Complementarity (e < 0)	n/a					
Cross-price elasticities (between categories)						
Transportation-communications						
Substitution (e > 0)	√	√	√	√	√	√
Complementarity (e < 0)		√	√	√	√	√

Notes: Only significant elasticities are considered. * The Hicksian transportation own-price elasticity in the individual CPI-based model for Alt. 1 is positive, significant, and greater than 1; however, both Marshallian and Hicksian own-price elasticities in the weighted CPI-based model for Alt. 1 are negative, significant, and less than -1. Both Marshallian and Hicksian own-price elasticities for PV-cap in the weighted CPI-based model for Alt. 4 are positive and significant. Own-price elasticities for PV-cap in all other models are sometimes positive and sometimes negative, but not significant. All other significant own-price elasticities for transportation categories are negative.

Complementarity relationships are significant for several pairs of transportation categories:

- PV operation and non-PV (Alts. 3 & 4),
- PV operation and PV capital (Alts. 3, 4, 5, & 6),
- entertainment and non-PV (Alt. 4),
- entertainment and PV capital (Alt. 4),
- PV operation and lodging/PT (Alt. 5).

New and old technology communications categories have substitution relationships for all alternatives except Alt. 1 (where they are not distinguished).

With respect to ***between-category cross-price elasticities*** (the main focus of this study), transportation and communications categories have both substitution and complementarity relationships. Table 5.16 provides a detailed summary of the significant relationships between transportation and communications categories for all alternatives, including the results for a parallel set of equations containing a time trend (found in Appendix B). Both sets of results are similar, but more significant relationships are found in the models without a time trend.

In the model without the time trend, substitution in the impact of transportation on communications (i.e. the substitution of communications as the price of travel increases) is found at the most aggregate level (two categories). This illuminates not only our own results, but the comparable one (substitution between transportation and communications at an aggregate level of classification) of Selvanathan and Selvanathan (1994). However, the two-category model *with* the time trend shows complementarity in the impact of communications on transportation (i.e. the generation of travel as the price of communication decreases). Both results are plausible: communication media *do* have the ability to obviate the need to travel (and thus can replace travel as travel becomes more expensive), but they can also stimulate the desire to travel (and thus when their prices fall, more communication occurs, which leads to more travel).

Both types of relationships continue to surface for finer disaggregations of the two main categories, but the dominant relationship is complementarity, with or without the time trend. Table 5.17 shows that 72 of the relationships summarized in Table 5.16 are complementarity, compared to only 30 demonstrating substitution. Interestingly, the predominant nature of the relationship differs depending on the direction. With respect to the influence of communications on transportation, complementarity overwhelmingly dominates, accounting for 56 out of 66 significant relationships across all models. With respect to the influence of transportation on communications, however, the two types of relationships are more evenly distributed: substitution dominates, with 20 significant relationships, but complementarity is also strongly present with 16 significant relationships. The fact that there are far fewer significant relationships in this direction (36 in all) compared to the communications → transportation direction (66) may indicate that both complementarity and substitution effects are present and counteracting each other more often in the transportation → communications direction. From the standpoint of promoting communications as a replacement for travel, however, it is unfortunate that the larger number of significant relationships in the communications → transportation direction are of the "wrong" kind: complementarity, leading to more travel rather than less.

Table 5. 16: Summary of Significant Relationships between Transportation and Communications

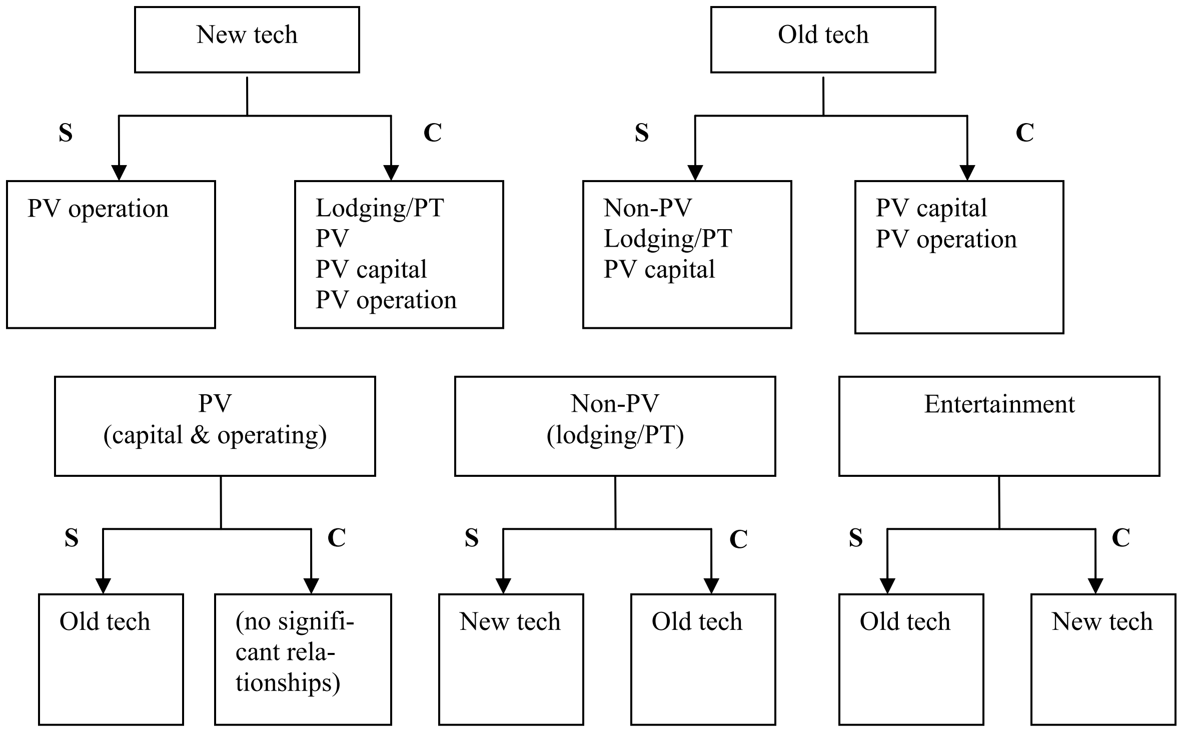
	Alt. 1		Alt. 2		Alt. 3		Alt. 4		Alt. 5		Alt. 6	
price → demand	*w/out t*	*with t*	*w/out t*	*with t*	*without t*	*with t*	*without t*	*with t*	*without t*	*with t*	*without t*	*with t*
Transportation → communications	S^{IH}											
PV cap → old tech												$S^{IM,IH}$
PV op → old tech							$S^{WM,WH}$	S^{WH}				
Non-PV → old tech			$C^{IM,IH}$		$C^{IM,IH}$							
Lodging/PT → old tech							$C^{IM,IH}$		$C^{IM,IH}$			
Public trans. → old tech											$C^{IM,IH}$	$C^{IM,IH}$
Entertainment → old tech							$S^{IM,IH,WM,WH}$	$S^{WM,WH}$				
Non-PV → new tech			$S^{IM,IH}$		$S^{IM,IH}$							
Lodging/PT → new tech									$S^{IM,IH}$			
Public trans. → new tech											$S^{IM,IH}$	
Entertainment → new tech							$C^{IM,IH,WM,WH}$					
Communications → transportation		$C^{WM,WH}$										
Old tech → PV cap							$C^{WM,WH}$				S^{IH}	
Old tech → PV op					$C^{IM,IH,WM,WH}$	$C^{IM,IH,WM,WH}$	$C^{IM,IH,WM,WH}$	$C^{IM,WM,WH}$	$C^{IM,IH,WM,WH}$	$C^{IM,IH,WM,WH}$	$C^{IM,IH,WM,WH}$	$C^{IM,IH,WM,WH}$
Old tech → non-PV				$S^{WM,WH}$		$S^{WM,WH}$						
Old tech → lodging/PT									$S^{WM,WH}$	$S^{WM,WH}$		
New tech → PV			C^{IM}	C^{WM}								
New tech → PV cap					C^{IM}	$C^{WM,WH}$	$C^{WM,WH}$	$C^{WM,WH}$	C^{IM}	$C^{WM,WH}$	$C^{IM,IH}$	$C^{WM,WH}$
New tech → PV op							C^{WM}	S^{IH}, $C^{WM,WH}$				
New tech → lodging/PT							$C^{WM,WH}$					

Notes:
S = substitution, C = complementarity,
IM = Marshallian (uncompensated) elasticity in the individual CPI model,
IH = Hicksian (compensated) elasticity in the individual CPI model,
WM = Marshallian (uncompensated) elasticity in the weighted CPI model,
WH = Hicksian (compensated) elasticity in the weighted CPI model.

Table 5. 17: Categorization of the Relationships Shown in Table 5.16

		Substitution	Complementarity	Total
Transportation → communications	Without t	15	14	**29**
	With t	5	2	7
	Total T → C	**20**	**16**	**36**
Communications → transportation	Without t	3	27	**30**
	With t	**7**	29	**36**
	Total C → T	**10**	**56**	**66**
Total	**Without t**	**18**	**41**	**59**
	With t	**12**	**31**	**43**
	Total	***30***	***72***	***102***

Specifically, as shown in Figure 5.2, we found that the effects of new communications technology on personal vehicle travel, out-of-town lodging, and public transportation (which includes airline travel) are complementarity (with the single exception noted for the "Alt. 4 with t" individual CPI model of Table 5.16). This suggests that telephone services and in-home electronic entertainment may generate both personal vehicle and non-personal vehicle travel. On the other hand, the effect of old communications technology on non-PV travel is substitution, whereas its effect on personal vehicle operation is complementarity. The former result seems to indicate a role of letters, books, and print media in reducing the demand for long-distance travel (airlines and out-of-town lodging), while the latter result indicates that the same media tend to stimulate personal vehicle travel. The effect of old communications on personal vehicle capital expenditures is substitution in Alt. 6 but complementarity in Alt. 4.



S = substitution, C = complementarity

Figure 5. 2: Relationships between Transportation and Communications Subcategories

Chapter 6. Summary

Using aggregate data from the U.S. Consumer Expenditure survey for the 19 years 1984-2002, this report analyzes relationships between expenditures on transportation and communications. The central question of interest is, with respect to consumer expenditures, do transportation and communications tend to be substitutes, complements, or neither? While this question has been explored in a number of disaggregate studies focusing on a single application such as telecommuting, there are relatively few studies addressing it at the aggregate level, using comprehensive measures comprising all aspects of transportation and communications.

We employed several classification schemes for expenditure categories, from the most aggregate (two categories: transportation and communications), to the most disaggregate (nine transportation categories: new vehicle purchases, used vehicle purchases, vehicle finance charges, gasoline/motor oil, vehicle maintenance/repairs, vehicle insurance, public transportation including air and boat as well as mass transit, out-of-town lodging, and "other entertainment" including bikes and recreational vehicles; and five communications categories: telephone service, miscellaneous household equipment including phones and computers, television/radio/ sound equipment, postage/stationery, and reading).

First, we examined trend plots, presented for several classifications (i.e. at various levels of category aggregation), and for raw expenditures (dollar values) as well as expenditure shares (percents), based both on current dollars and on constant or real (CPI-adjusted, approximately controlling for inflation) dollars. At the most aggregate level, communications expenditures have steadily increased over time, both in terms of CPI-adjusted dollars (at a rate of about $49 a year, from $1,257 in 1984 to $2,177 in 2002, with 1984 as the base year) and as a share of total expenditures (at a rate of about 2/10 of a percentage point a year, from 5.7% in 1984 to 8.9% in 2002). The pattern for real transportation expenditures is not as simple: it fluctuated and dipped until 1993, then generally increased thereafter until real expenditures in 2002 ($4,830) were similar to those in 1985. As a share of the total, however, real transportation expenditures have remained relatively stable at around 19% since 1994. The difference in shares of expenditures on transportation and communications has been narrowing over time, from a factor of about 3.6 times higher for transportation in 1984, to about 2.2 times higher in 2002.

For a qualitative decomposition of the net trends in raw and real expenditures, we refer the reader to Table 4.10 of Section 4.3.3, and the discussion there. Very briefly, *inflation* nearly always increases unit prices (with exceptions for vehicle finance charges and miscellaneous household equipment, including computer hardware and software). *Income* effects are positive for all categories, meaning that these are all normal goods, not inferior ones. Broadly speaking, we speculate that *taste changes* have contributed to increasing expenditures in most categories, with the exception of out-of-town lodging, the public transit component of the public transportation category, and the old communication media categories of postage and reading. We suggest that *technological changes* (including, in a loose sense, industry restructuring) have led to decreased unit prices in most categories. In the private vehicle operations categories, technological improvements dominate, so that expenditure shares are decreasing despite increasing demand. Conversely, in the new media categories, taste changes dominate, so that expenditure shares are increasing despite technological improvements which lower prices.

We next used aggregate demand system modeling (in particular, the linear approximate almost ideal demand system, or LA-AIDS, model) to determine the relationships between expenditures on transportation and those on communications, again for several different classifications. We found that all ***expenditure (income) elasticities*** are positive, indicating that all transportation and communications categories studied here are normal goods. Most transportation categories are highly income-elastic (luxuries) except for the personal vehicle (PV) operation category, which is income-inelastic (a necessity). Communications categories are sometimes income-inelastic, but generally less elastic than transportation ones, indicating that communications is more essential than travel.

As expected, ***own-price elasticities*** are generally negative where they are significant. Also, they are often insignificant, indicating insensitivity to price. Similar to expenditure elasticities, transportation categories are generally more price-elastic than communications ones. With respect to ***within-category cross-price elasticities***, transportation categories have both substitution and complementarity relationships, while the two communications categories have a substitution relationship.

With respect to ***between-category cross-price elasticities*** (the main focus of this study), transportation and communications categories have both substitution and complementarity relationships, often not symmetric. For example, at the most aggregate (two-category) classification level, we found substitution in the impact of transportation on communications (i.e. the substitution of communications as the price of travel increases) in the model without a time trend, but complementarity in the impact of communications on transportation (i.e. the generation of travel as the price of communication decreases) in the model with a time trend. Both results are plausible: communication media *do* have the ability to obviate the need to travel (and thus can replace travel as travel becomes more expensive), but they can also stimulate the desire to travel (and thus when their prices fall, more communication occurs, which leads to more travel).

Both types of relationships continue to surface for finer disaggregations of the two main categories, but the dominant relationship is complementarity. Overall, 72 of the significant between-category relationships identified across all models are complementarity, compared to only 30 demonstrating substitution. Interestingly, the predominant nature of the relationship differs depending on the direction. With respect to the influence of communications on transportation, complementarity overwhelmingly dominates, accounting for 56 out of 66 significant relationships across all models. With respect to the influence of transportation on communications, however, the two types of relationships are more evenly distributed: substitution dominates, with 20 significant relationships, but complementarity is also strongly present with 16 significant relationships. The fact that there are far fewer significant relationships in this direction (36 in all) compared to the communications → transportation direction (66) may indicate that both complementarity and substitution effects are present and counteracting each other more often in the transportation → communications direction. From the standpoint of promoting communications as a replacement for travel, however, it is unfortunate that the larger number of significant relationships in the communications → transportation direction are of the “wrong” kind: complementarity, leading to more travel rather than less.

In Chapter 2, we reviewed several other aggregate studies of transportation – communications relationships, and suggested that it would be particularly interesting to compare the results of this study to those of (1) Selvanathan and Selvanathan (henceforth S&S, 1994), who used a similar consumer demand modeling methodology, but applied to different countries (Australia and the United Kingdom) and an earlier time frame (1960-1986), and (2) Lee and Mokhtarian (2004, 2005a, b, 2006), who studied the same country (the United States) in a highly overlapping time frame (1947-1997), but used input-output analysis to study the industrial demand for transportation and communications. We are now in a position to make that comparison.

Turning first to the two consumer demand studies on the right-hand side of Table 6.1, we see some similarities. Both studies found public and private transportation to be substitutes, and, consistent with the result for S&S's more aggregated categories, the present study found the influence of transportation on communications to be a substitution effect more often than not (although often insignificant, hinting at both substitution and complementarity effects often nearly canceling out). In contrast to S&S, however, the present study found strong evidence of a complementary influence of communications on transportation. It is interesting that price elasticities in the C $\rightarrow$ T direction (while still positive, indicating substitution) are far weaker for S&S than the elasticities in the T $\rightarrow$ C direction. This would be true if a substantial complementarity influence of C on T, though outweighed by a substitutionary influence, did exist. Thus, although we cannot be sure, this is suggestive that perhaps similar complex processes are at work in both cases – weighted differently for the earlier study, but perhaps more similar if S&S were to be replicated in Australia and the UK in a time frame similar to that of the present study.

Turning now to the two US studies along the bottom of Table 6.1, the comparison is not as straightforward since different categorizations and approaches were used. What is interesting, however, is that although some substitution effects appear for the US industrial demand studies of Lee and Mokhtarian, those effects disappear completely after 1982: for the 1987, 1992, and 1997 benchmark years, every single correlation between a measure of transportation and one of communications is positive (although several are not statistically significant), indicating complementarity. Since 1986 is the last year covered by S&S, there is again a hint that earlier relationships were undergoing a qualitative shift in that general time frame – clearly switching from substitution to complementarity in the case of industrial demands in the US, and perhaps doing something similar in the case of consumer expenditures in all three countries studied.

In sum, this study has added to our understanding of the nature of the association between communications and travel, with respect to their roles in the consumer sector of the economy. The existence of effects in both directions (substitution and complementarity) is testimony to the complexity of the relationships involved, with both generation and replacement possible and happening simultaneously. Despite this complexity, however, one result is quite clear: there is very little empirical support for the expectation that new communications technologies will substitute for personal vehicle travel (although there is evidence of substitution for non-personal-vehicle travel, specifically the public transportation category which includes airline travel as well as urban mass transit). To the contrary, there is considerable support for a complementary impact of new technologies on both PV and non-PV travel. Thus, the outcome of this study will be of interest to policymakers and planners who are considering, or may consider, telecommunications in the broad sense as a transportation demand management policy tool.

Table 6. 1: Comparison of the Present Study to Related Aggregate Analyses

Key: *authors (publication dates)*	**Selvanathan & Selvanathan (1994)**
methodology	Consumer demand model (Rotterdam)
study period	1960-1986
study area	Australia, United Kingdom
key findings	♦ Public transportation (PuT), private transportation (PrT), and communication (C) are pairwise substitutes. ♦ Influence of PrT on C is much stronger (price elasticities of 0.57 for UK and 0.31 for Australia) than influence of C on PrT (0.08 and 0.04, respectively). ♦ True to a lesser degree for the influence of PuT on C (0.09 and 0.18) compared to the converse (0.03 and 0.07).
Lee & Mokhtarian (2004, 2005a, b, 2006)	**Choo et al. (the present study)**
Input-output analysis of industrial demand	Consumer demand model (LA-AIDS)
1947-1997	1984-2002
United States	United States
For 10 benchmark years in the study period, analyzed correlations of total industrial demand for transportation manufacturing (TM) and utilities (TU), and communication manufacturing (CM) and utilities (CU), as well as transportation (T) and communications (C) overall. ♦ TM and CM are complements. ♦ TU and CM are substitutes through 1967 and complements thereafter. ♦ TM and CU; TU and CU; and T and C are substitutes through 1982 and complements thereafter.	♦ Personal vehicle (PV) and public transportation (PT) are substitutes where relationship is significant. ♦ Influence of T on C is most often (20 out of 36 significant relationships) substitution. ♦ Influence of C on T is significant more often (66 times) than the converse, and is most often (56 times) complementarity.

← United States, study period overlap (1984-1997), industry v. consumer perspective →

↑ consumer perspective, Australia/UK v. US, nearly disjoint study periods ↓

References

Albertson, L. A. (1977) Telecommunications as a travel substitute: Some psychological, organizational, and social aspects. *Journal of Communication* **27(2),** 32-43.

Bernstein, Scott, Carrie Makarewicz, and Kevin McCarty (2005) *Driven to Spend: Pumping Dollars out of Our Households and Communities*. Produced by the Surface Transportation Policy Project and the Center for Neighborhood Technology, June. Available at http://www.transact.org/library/reports_pdfs/driven_to_spend/Driven_to_Spend_Report.pdf, accessed July 20, 2006.

Bils, Mark and Peter J. Klenow (2001) Quantifying quality growth. *The American Economic Review* **91(4)**, 1006-1030.

Blanciforti, Laura A., Richard D. Green, and Gordon A. King (1986) *U.S. Consumer Behavior Over the Postwar Period: An Almost Ideal Demand System Analysis*. Giannini Foundation Monograph No. 40, Department of Agricultural and Resource Economics, University of California, Davis.

Castaneda, R. (1999) Glendening signs measure to promote teleworking. *Washington Post* (May 26), M10.

Choo, Sangho (2004) *Aggregate Relationships between Telecommunications and Travel: Structural Equation Modeling of Time Series Data.* Ph.D. Dissertation, Department of Civil and Environmental Engineering, University of California, Davis.

Choo, Sangho and Patricia L. Mokhtarian (2005) Does telecommunications affect passenger travel or vice versa? Structural equation models of aggregate U.S. time series data using composite indices. *Transportation Research Record* **1926**, 224-232. Also presented to the 84th Annual Meeting of the Transportation Research Board, Washington DC, January, Paper no. 05-2581 on the conference CD-ROM.

Choo, Sangho and Patricia L. Mokhtarian (2007) Telecommunications and travel demand and supply: Aggregate structural equation models for the U.S. *Transportation Research A* **41(1)**, 4-18.

Couclelis, Helen (1999) From sustainable transportation to sustainable accessibility: Can we avoid a new 'tragedy of the commons'? In D. Janelle and D. Hodge, eds. *Information, Place, and Cyberspace: Issues in Accessibility*. Berlin: Springer-Verlag.

Deaton, Angus (1998) Getting prices right: What should be done? *The Journal of Economic Perspectives* **12(1)**, 37-46.

Dupagne, Michel (1997) A theoretical and methodological critique of the principle of relative constancy. *Communication Theory* **7(1)**, 53-76.

Eales, James S. and Laurian J. Unnevehr (1988) Demand for beef and chicken products: Separability and structural change. *American Journal of Agricultural Economics* **70**, 521-532.

Goodwin, Phil, Joyce Dargay, and Mark Hanly (2004) Elasticities of road traffic and fuel consumption with respect to price and income: A review. *Transport Reviews* **24(3)**, 275-292.

Gordon, Gil (1992) Trip-reduction legislation signed into law in New Jersey. *Telecommuting Review: The Gordon Report* (May), 3.

Gordon, Gil (1996) Arizona deals with pollution by mandating telecommuting in government agencies. *Telecommuting Review* **13(10)** (October), 12-13.

Gottmann, Jean (1983) Urban settlements and telecommunications. *Ekistics* **50**, 411-416.

Grubler, A. (1989) *The Rise and Fall of Infrastructures: Dynamics of Evolution and Technological Change in Transport*. Heidelberg: Physica Verlag.

Hamer, R., E. Kroes, and H. van Ooststroom (1991) Teleworking in the Netherlands: An evaluation of changes in travel behaviour. *Transportation* **18**, 365-382.

Haque, Mohammed Ohidul (1992) Aggregate expenditure elasticity for transport and communication in Australia. *Transportation* **19**, 43-57.

Harkness, Richard C. (1977) Selected results from a technology assessment of telecommunication-transportation interactions. *Habitat* **2(1/2)**, 37-48.

Höjer, Matthias and Lars-Göran Mattsson (2000) Determinism and backcasting in future studies. *Futures* **32**, 613-634.

Joice, Wendell (2000) Federal telework topics. In *Telework: The New Workplace of the 21st Century*. United States Department of Labor, Washington, DC, 155-167. Available on the Internet at www.dol.gov/dol/asp/public/telework/main.htm.

Lee, Taihyeong and Patricia L. Mokhtarian (2004) *An Input-Output Analysis of the Relationships Between Communications and Travel for Industry*. Institute of Transportation Studies, University of California, Davis, July.

Lee, Taihyeong and Patricia L. Mokhtarian (2005a) Correlations between communication and transportation inputs to U. S. industry, 1947-1997. Presented at the 84th Annual Meeting of the Transportation Research Board, Washington DC, January. Paper no. 05-2755 on the conference CD-ROM.

Lee, Taihyeong and Patricia L. Mokhtarian (2005b) Correlations between industrial demands (direct and total) for communications and transportation in the U.S. economy, 1947-1997. Unpublished manuscript, available from the authors.

Lee, Taihyeong and Patricia L. Mokhtarian (2006) Relationships between total industrial demands for communications and transportation: An I-O analysis for the U.S., 1947-1997. Presented at the 85th Annual Meeting of the Transportation Research Board, Washington DC, January. Paper no. 06-2915 on the conference CD-ROM.

Li, Gang, Haiyan Song, and Stephen F. Witt (2004) Modeling tourism demand: A dynamic linear AIDS approach. *Journal of Travel Research* **43(2),** 141-150.

Mokhtarian, Patricia L. (1990) A typology of relationships between telecommunications and transportation. *Transportation Research A* **24A(3)**, 231-242.

Mokhtarian, Patricia L. (2000) Telecommunications and travel. In: *Transportation in the New Millennium*, Transportation Research Board, National Research Council, National Academy of Science, Washington, DC.
Available at www.nationalacademies.org /trb/publications/millennium/00115.pdf.

Mokhtarian, Patricia L. (2003) Telecommunications and travel: The case for complementarity. *Journal of Industrial Ecology* **6(2)**, special issue on E-commerce, the Internet, and the Environment, 43-57. Available at mitpress.mit.edu/jie/e-commerce.

Mokhtarian, Patricia L. and Ravikumar Meenakshisundaram (1999) Beyond tele-substitution: Disaggregate longitudinal structural equations modeling of communication impacts. *Transportation Research C* **7(1),** 33-52.

Mokhtarian, Patricia L. and Ilan Salomon (2002) Emerging travel patterns: Do telecommunications make a difference? In Hani S. Mahmassani, ed., *In Perpetual Motion: Travel Behaviour Research Opportunities and Application Challenges* (pp. 143-182). Oxford, UK: Pergamon Press/Elsevier.

Mokhtarian, Patricia L., Susan L. Handy and Ilan Salomon (1995) Methodological issues in the estimation of travel, energy, and air quality impacts of telecommuting. *Transportation Research A* **29A(4)**, 283-302.

Moulton, Brent R. and Karin E. Moses (1997) Addressing the quality change issue in the Consumer Price Index. *Brookings Papers on Economic Activity* **1997(1)**, 305-350.

Netherlands Organization for Applied Scientific Research (NOASR) (1989) De invloed van telecommunicatie op verker: Gevlgen voor energie en millieu, TNO, Delft.

Niles, John S. (1994) *Beyond Telecommuting: A New Paradigm for the Effect of Telecommunications on Travel*. Prepared for the US Department of Energy, Offices of Energy Research and Scientific Computing, Washington, DC 20585, Report No. DOE/ER-0626, September. Available at http://www.lbl.gov/ICSD/Niles.

Owen, Wilfred (1962) Transportation and technology. *The American Economic Review* **52(2)**, 405-413.

Plaut, Pnina O. (1997) Transportation-communications relationships in industry. *Transportation Research A* **31A(6)**, 419-429.

Plaut, Pnina O. (1999) Do telecommunications reduce industrial uses of transportation? An international comparative analysis among Israel, North America and Europe. *World Transport Policy & Practice* **5(4)**, 42-49.

Salomon, Ilan (1985) Telecommunications and travel: Substitution or modified mobility? *Journal of Transport Economics and Policy* **19(3)**, 219-235.

Salomon, Ilan (1986) Telecommunications and travel relationships: A review. *Transportation Research A* **20A(3)**, 223-238.

Salomon, Ilan and Joseph L. Schofer (1988) Forecasting telecommunications-travel interactions: The transportation manager's perspective. *Transportation Research A* **22(3)**, 219-229.

Selvanathan, E. A. and Saroja Selvanathan (1994) The demand for transport and communication in the United Kingdom and Australia. *Transportation Research B* **28(1)**, 1-9.

United States Census Bureau (2005) *Average Population Per Household and Family: 1940 to Present*. Available on the Internet at http://www.census.gov/population/socdemo/ hh-fam/hh6.xls, accessed July 13, 2005.

U.S. Department of Labor (U.S. DOL) (1997) *BLS Handbook of Methods.* Chapter 16. Consumer Expenditures and Income, Chapter 17. The Consumer Price Index. Bureau of Labor Statistics. Web version available at http://www.bls.gov/opub/hom/pdf/ homch16.pdf , April.

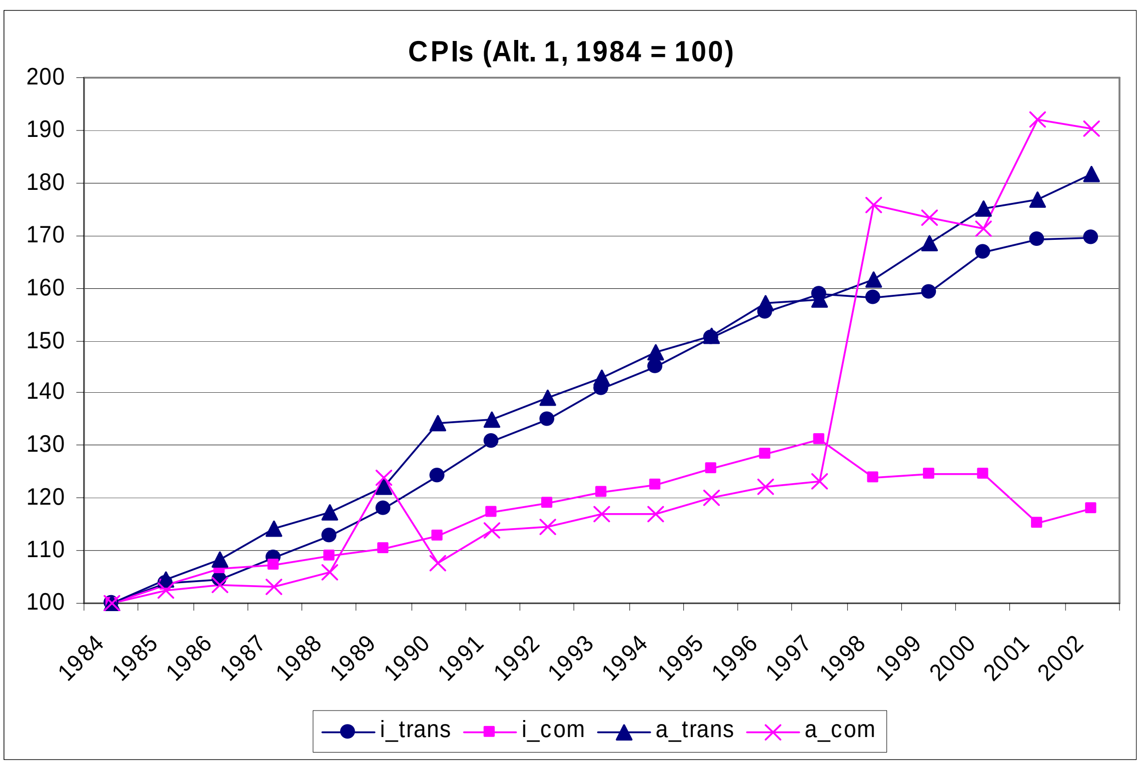
U.S. Department of Labor (U.S. DOL) (2004) *Consumer Expenditures in 2002*. Annual Report provided by U.S. DOL, Bureau of Labor Statistics, Report No. 974, February.

APPENDIX A: CPI Plots

1. *Alternative 1*

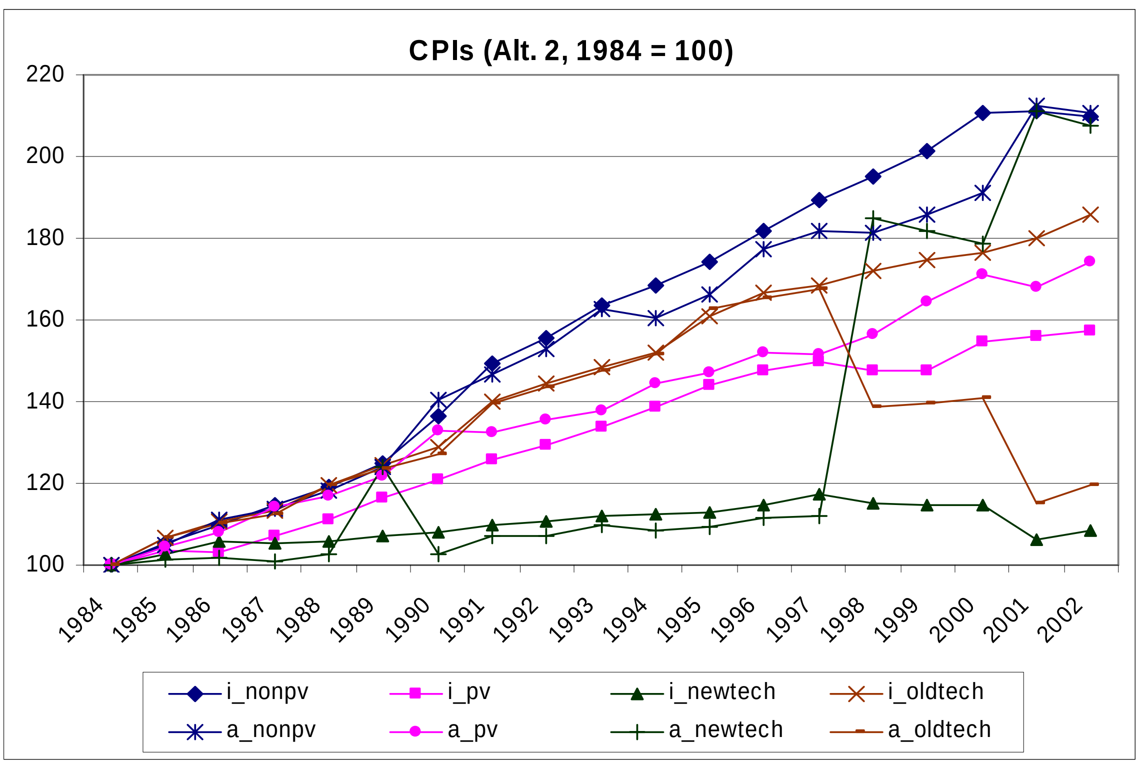
Year	i_trans[1]	i_com	a_trans[2]	a_com
1984	100.00	100.00	100.00	100.00
1985	103.93	103.50	104.44	102.39
1986	104.45	106.69	108.44	103.60
1987	108.54	107.18	114.04	103.03
1988	112.87	109.02	117.27	105.88
1989	118.01	110.54	122.19	123.96
1990	124.15	112.74	134.29	107.53
1991	130.70	117.19	135.09	113.68
1992	135.07	118.95	139.05	114.39
1993	140.66	121.00	142.90	117.12
1994	145.03	122.59	147.79	117.06
1995	150.66	125.69	150.78	119.96
1996	155.32	128.53	157.12	122.02
1997	158.95	131.10	157.74	123.07
1998	158.30	123.92	161.48	175.73
1999	159.15	124.43	168.65	173.51
2000	166.69	124.58	175.08	171.24
2001	169.29	115.07	176.89	192.12
2002	169.53	118.08	181.53	190.20

Notes: [1] The "i" means that the values in the column are based on CPI individual.
[2] The "a" means that the values in the column are based on CPI all.



2. Alternative 2

Year	i_nonpv	i_pv	i_newtech	i_oldtech	a_nonpv	a_pv	a_newtech	a_oldtech
1984	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1985	105.38	103.57	102.66	106.74	105.07	104.29	101.30	106.76
1986	109.76	103.09	105.68	110.51	110.96	107.81	101.98	110.14
1987	114.68	107.02	105.51	113.27	113.66	114.14	100.76	112.23
1988	119.33	111.25	105.97	119.63	118.21	117.03	102.54	119.38
1989	124.77	116.30	107.17	124.24	123.80	121.79	124.06	123.56
1990	136.59	120.89	107.79	128.97	140.24	132.81	102.74	126.90
1991	149.36	125.56	109.88	139.90	146.61	132.23	107.24	139.76
1992	155.51	129.35	110.45	144.65	152.84	135.62	107.20	143.52
1993	163.66	133.91	111.89	148.37	162.84	137.95	109.57	147.66
1994	168.64	138.51	112.44	152.02	160.62	144.59	108.57	151.44
1995	174.39	143.98	112.83	160.71	166.38	146.90	109.41	162.69
1996	181.72	147.68	114.59	166.59	177.19	152.13	111.37	165.16
1997	189.26	149.92	117.30	168.45	181.81	151.76	112.07	167.59
1998	195.12	147.71	114.98	172.21	181.19	156.58	184.91	138.55
1999	201.13	147.37	114.88	174.80	185.68	164.42	181.87	139.66
2000	210.70	154.47	114.47	176.40	191.23	171.07	178.69	141.07
2001	210.99	156.17	106.35	179.79	212.64	168.01	211.12	115.20
2002	209.67	157.47	108.47	185.67	210.77	174.26	207.66	119.50

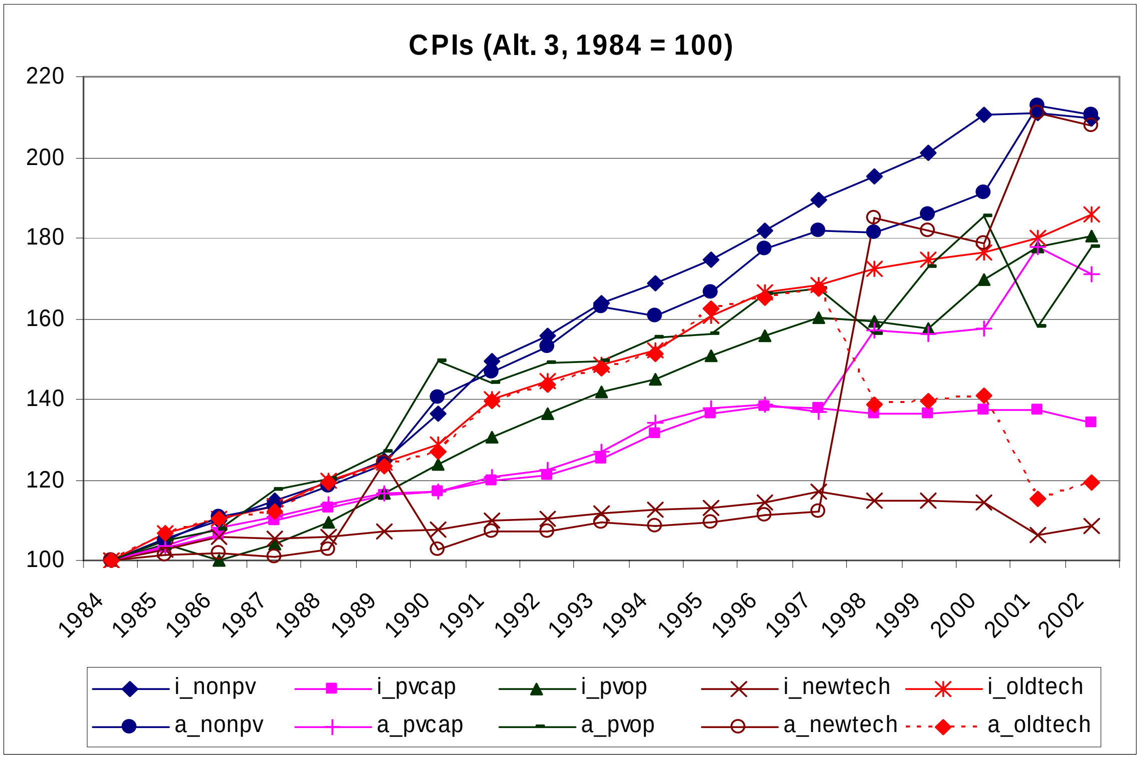


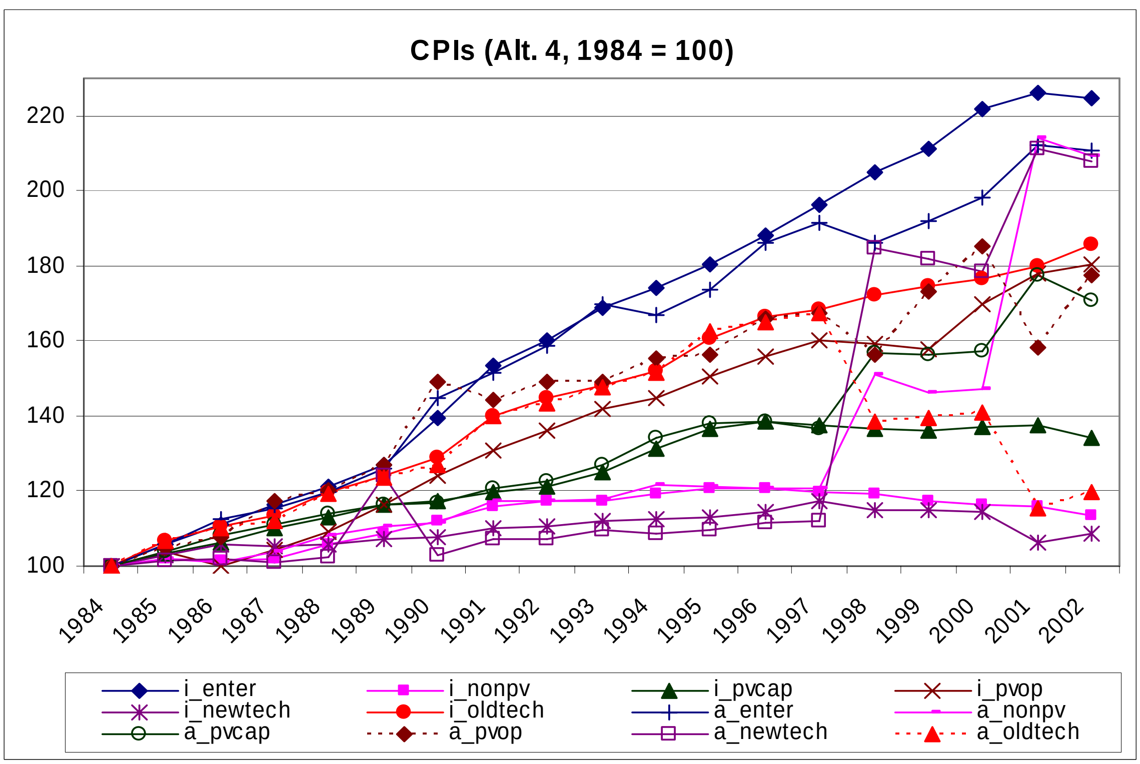
3. Alternative 3

Year	i_nonpv	i_pvcap	i_pvop	i_newtech	i_oldtech	a_nonpv	a_pvcap	a_pvop	a_newtech	a_oldtech
1984	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1985	105.38	103.26	103.89	102.66	106.74	105.07	103.71	104.88	101.30	106.76
1986	109.76	106.13	99.92	105.68	110.51	110.96	107.99	107.63	101.98	110.14
1987	114.68	109.96	104.14	105.51	113.27	113.66	110.85	117.54	100.76	112.23
1988	119.33	113.22	109.32	105.97	119.63	118.21	113.95	120.22	102.54	119.38
1989	124.77	116.15	116.43	107.17	124.24	123.80	116.59	127.17	124.06	123.56
1990	136.59	117.24	123.85	107.79	128.97	140.24	116.93	149.25	102.74	126.90
1991	149.36	119.70	130.63	109.88	139.90	146.61	120.70	144.16	107.24	139.76
1992	155.51	121.21	136.27	110.45	144.65	152.84	122.60	149.10	107.20	143.52
1993	163.66	125.07	141.70	111.89	148.37	162.84	126.99	149.28	109.57	147.66
1994	168.64	131.43	144.85	112.44	152.02	160.62	134.31	155.24	108.57	151.44
1995	174.39	136.55	150.76	112.83	160.71	166.38	137.88	156.24	109.41	162.69
1996	181.72	138.32	155.76	114.59	166.59	177.19	138.54	166.20	111.37	165.16
1997	189.26	137.54	160.40	117.30	168.45	181.81	136.78	167.27	112.07	167.59
1998	195.12	136.50	159.36	114.98	172.21	181.19	156.92	156.23	184.91	138.55
1999	201.13	136.33	157.68	114.88	174.80	185.68	156.15	172.98	181.87	139.66
2000	210.70	137.10	169.74	114.47	176.40	191.23	157.37	185.24	178.69	141.07
2001	210.99	137.49	177.91	106.35	179.79	212.64	177.66	158.02	211.12	115.20
2002	209.67	134.24	180.58	108.47	185.67	210.77	170.89	177.74	207.66	119.50

4. Alternative 4

Year	i_enter	i_nonpv	i_pvcap	i_pvop	i_newtech	i_oldtech	a_enter	a_nonpv	a_pvcap	a_pvop	a_newtech	a_oldtech
1984	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1985	105.88	102.15	103.26	103.89	102.66	106.74	105.57	101.90	103.71	104.88	101.30	106.76
1986	110.93	101.56	106.13	99.92	105.68	110.51	112.57	100.84	107.99	107.63	101.98	110.14
1987	116.53	101.86	109.96	104.14	105.51	113.27	115.22	103.87	110.85	117.54	100.76	112.23
1988	121.31	105.57	113.22	109.32	105.97	119.63	119.81	108.17	113.95	120.22	102.54	119.38
1989	127.05	108.50	116.15	116.43	107.17	124.24	125.92	110.51	116.59	127.17	124.06	123.56
1990	139.58	112.21	117.24	123.85	107.79	128.97	144.78	111.71	116.93	149.25	102.74	126.90
1991	153.51	115.72	119.70	130.63	109.88	139.90	151.29	117.19	120.70	144.16	107.24	139.76
1992	160.00	117.38	121.21	136.27	110.45	144.65	158.51	117.21	122.60	149.10	107.20	143.52
1993	168.78	117.29	125.07	141.70	111.89	148.37	169.99	117.94	126.99	149.28	109.57	147.66
1994	174.36	119.34	131.43	144.85	112.44	152.02	166.85	121.53	134.31	155.24	108.57	151.44
1995	180.36	120.61	136.55	150.76	112.83	160.71	173.59	121.16	137.88	156.24	109.41	162.69
1996	188.02	120.51	138.32	155.76	114.59	166.59	186.21	120.51	138.54	166.20	111.37	165.16
1997	196.25	119.73	137.54	160.40	117.30	168.45	191.52	120.80	136.78	167.27	112.07	167.59
1998	204.97	119.04	136.50	159.36	114.98	172.21	185.96	151.23	156.92	156.23	184.91	138.55
1999	211.28	117.48	136.33	157.68	114.88	174.80	191.96	146.24	156.15	172.98	181.87	139.66
2000	221.87	116.21	137.10	169.74	114.47	176.40	198.25	147.17	157.37	185.24	178.69	141.07
2001	226.28	115.72	137.49	177.91	106.35	179.79	212.41	214.09	177.66	158.02	211.12	115.20
2002	224.85	113.67	134.24	180.58	108.47	185.67	210.97	209.51	170.89	177.74	207.66	119.50


CPIs (Alt. 3, 1984 = 100)
220
200
180
160
140
120
100
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
i_nonpv
i_pvcap
i_pvop
i_newtech
i_oldtech
a_nonpv
a_pvcap
a_pvop
a_newtech
a_oldtech

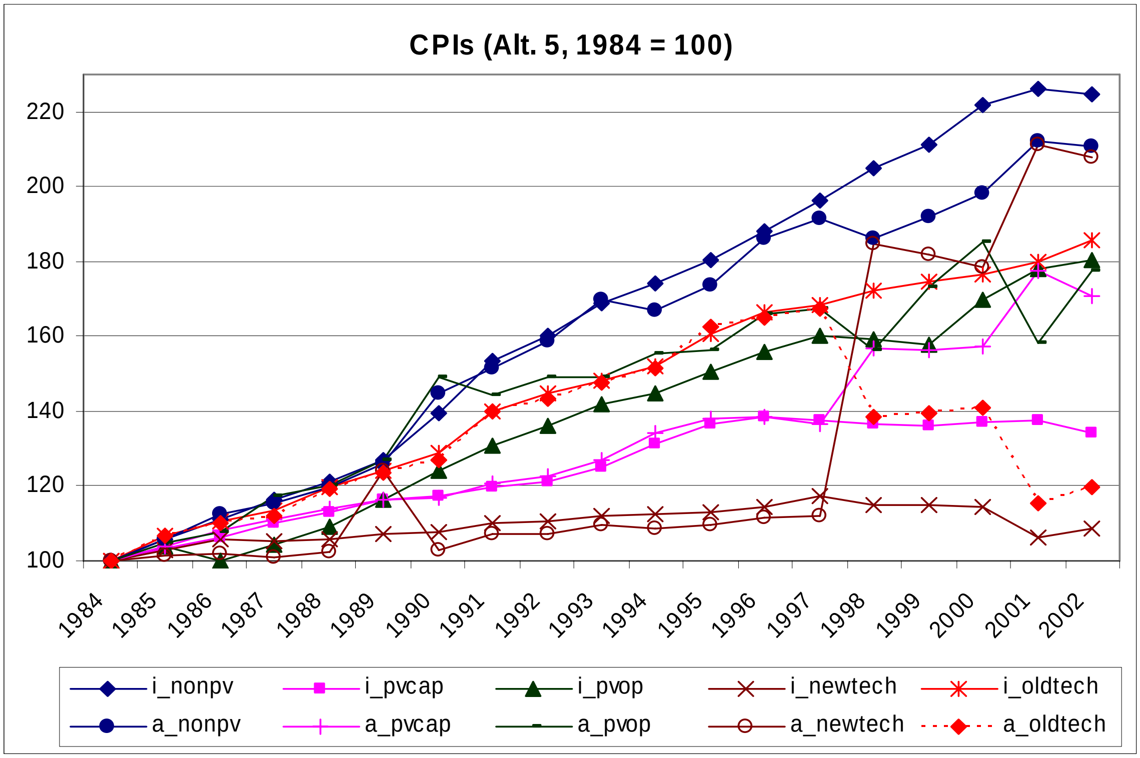

CPIs (Alt. 4, 1984 = 100)
220
200
180
160
140
120
100
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
i_enter
i_nonpv
i_pvcap
i_pvop
i_newtech
i_oldtech
a_enter
a_nonpv
a_pvcap
a_pvop
a_newtech
a_oldtech

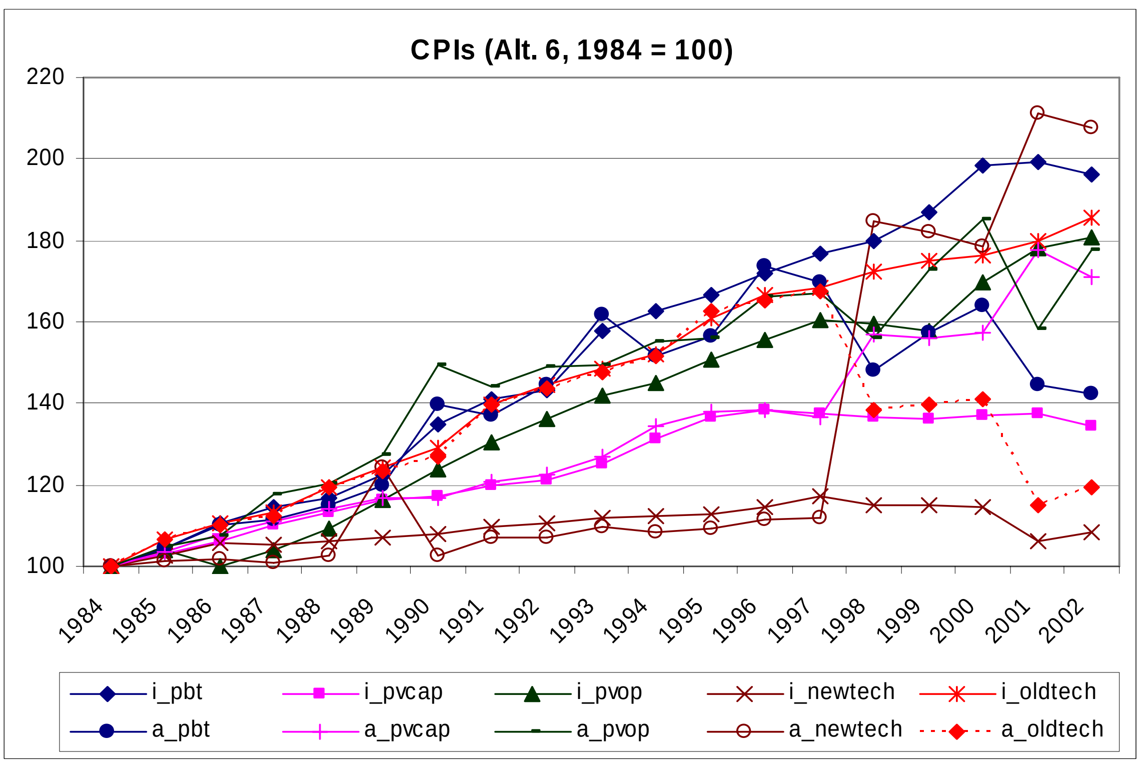
5. Alternative 5

Year	i_nonpv	i_pvcap	i_pvop	i_newtech	i_oldtech	a_nonpv	a_pvcap	a_pvop	a_newtech	a_oldtech
1984	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1985	105.88	103.26	103.89	102.66	106.74	105.57	103.71	104.88	101.30	106.76
1986	110.93	106.13	99.92	105.68	110.51	112.57	107.99	107.63	101.98	110.14
1987	116.53	109.96	104.14	105.51	113.27	115.22	110.85	117.54	100.76	112.23
1988	121.31	113.22	109.32	105.97	119.63	119.81	113.95	120.22	102.54	119.38
1989	127.05	116.15	116.43	107.17	124.24	125.92	116.59	127.17	124.06	123.56
1990	139.58	117.24	123.85	107.79	128.97	144.78	116.93	149.25	102.74	126.90
1991	153.51	119.70	130.63	109.88	139.90	151.29	120.70	144.16	107.24	139.76
1992	160.00	121.21	136.27	110.45	144.65	158.51	122.60	149.10	107.20	143.52
1993	168.78	125.07	141.70	111.89	148.37	169.99	126.99	149.28	109.57	147.66
1994	174.36	131.43	144.85	112.44	152.02	166.85	134.31	155.24	108.57	151.44
1995	180.36	136.55	150.76	112.83	160.71	173.59	137.88	156.24	109.41	162.69
1996	188.02	138.32	155.76	114.59	166.59	186.21	138.54	166.20	111.37	165.16
1997	196.25	137.54	160.40	117.30	168.45	191.52	136.78	167.27	112.07	167.59
1998	204.97	136.50	159.36	114.98	172.21	185.96	156.92	156.23	184.91	138.55
1999	211.28	136.33	157.68	114.88	174.80	191.96	156.15	172.98	181.87	139.66
2000	221.87	137.10	169.74	114.47	176.40	198.25	157.37	185.24	178.69	141.07
2001	226.28	137.49	177.91	106.35	179.79	212.41	177.66	158.02	211.12	115.20
2002	224.85	134.24	180.58	108.47	185.67	210.97	170.89	177.74	207.66	119.50

6. Alternative 6

Year	i_pbt	i_pvcap	i_pvop	i_newtech	i_oldtech	a_pbt	a_pvcap	a_pvop	a_newtech	a_oldtech
1984	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00	100.00
1985	104.54	103.26	103.89	102.66	106.74	104.51	103.71	104.88	101.30	106.76
1986	110.69	106.13	99.92	105.68	110.51	110.07	107.99	107.63	101.98	110.14
1987	114.57	109.96	104.14	105.51	113.27	111.25	110.85	117.54	100.76	112.23
1988	116.65	113.22	109.32	105.97	119.63	114.98	113.95	120.22	102.54	119.38
1989	122.52	116.15	116.43	107.17	124.24	119.85	116.59	127.17	124.06	123.56
1990	134.91	117.24	123.85	107.79	128.97	139.56	116.93	149.25	102.74	126.90
1991	140.87	119.70	130.63	109.88	139.90	136.97	120.70	144.16	107.24	139.76
1992	143.24	121.21	136.27	110.45	144.65	144.69	122.60	149.10	107.20	143.52
1993	157.99	125.07	141.70	111.89	148.37	161.80	126.99	149.28	109.57	147.66
1994	162.72	131.43	144.85	112.44	152.02	151.64	134.31	155.24	108.57	151.44
1995	166.41	136.55	150.76	112.83	160.71	156.66	137.88	156.24	109.41	162.69
1996	172.09	138.32	155.76	114.59	166.59	173.88	138.54	166.20	111.37	165.16
1997	176.63	137.54	160.40	117.30	168.45	169.64	136.78	167.27	112.07	167.59
1998	180.04	136.50	159.36	114.98	172.21	148.08	156.92	156.23	184.91	138.55
1999	187.04	136.33	157.68	114.88	174.80	157.42	156.15	172.98	181.87	139.66
2000	198.30	137.10	169.74	114.47	176.40	163.88	157.37	185.24	178.69	141.07
2001	199.24	137.49	177.91	106.35	179.79	144.75	177.66	158.02	211.12	115.20
2002	196.22	134.24	180.58	108.47	185.67	142.31	170.89	177.74	207.66	119.50

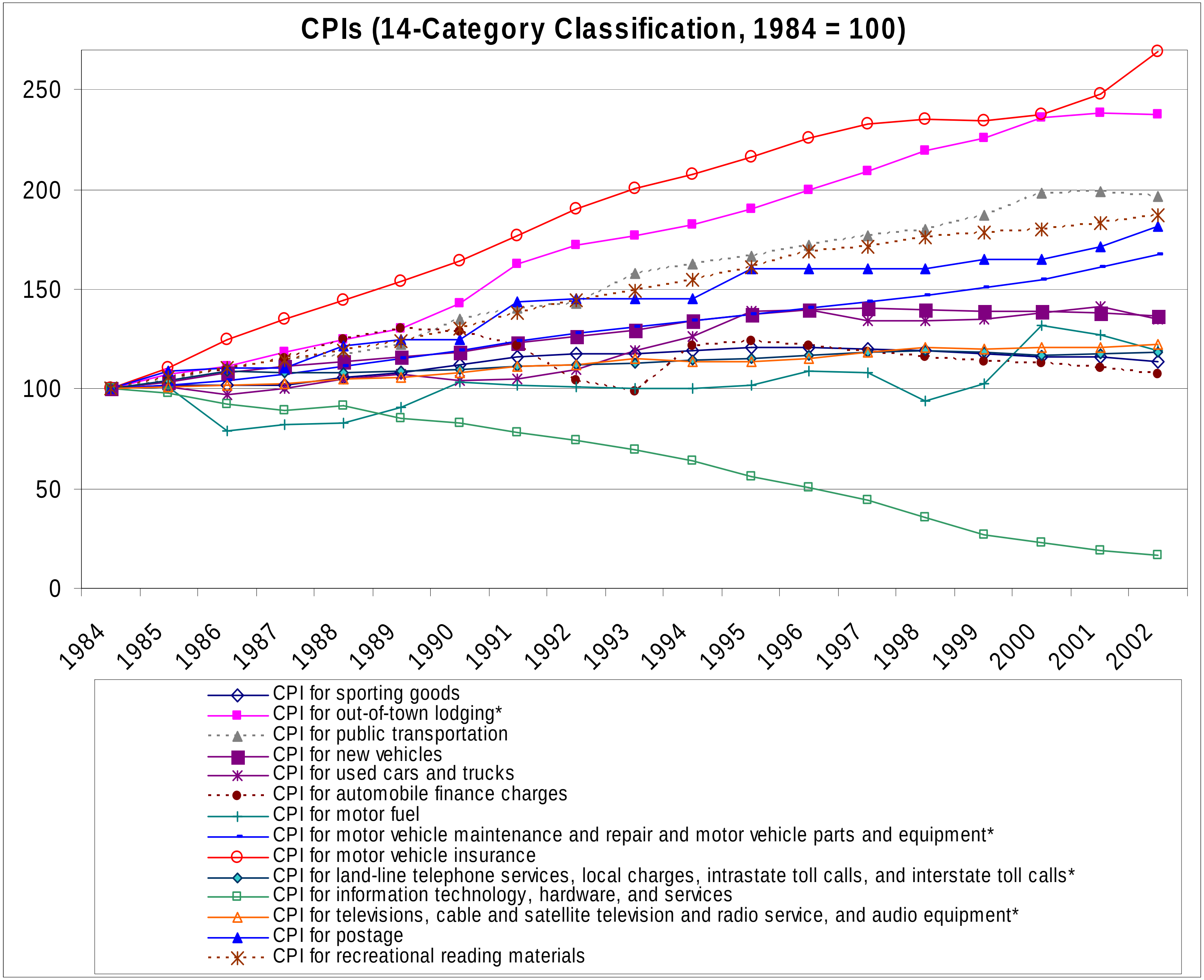

CPIs (Alt. 5, 1984 = 100)
220
200
180
160
140
120
100
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
i_nonpv
i_pvcap
i_pvop
i_newtech
i_oldtech
a_nonpv
a_pvcap
a_pvop
a_newtech
a_oldtech


CPIs (Alt. 6, 1984 = 100)
220
200
180
160
140
120
100
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
i_pbt
i_pvcap
i_pvop
i_newtech
i_oldtech
a_pbt
a_pvcap
a_pvop
a_newtech
a_oldtech

7. 14-Category Classification

Year	CPI for sporting goods	CPI for out-of-town lodging*	CPI for public transportation	CPI for new vehicles	CPI for used cars and trucks	CPI for automobile finance charges	CPI for motor fuel	CPI for motor vehicle maintenance and repair and motor vehicle parts and equipment*	CPI for motor vehicle insurance	CPI for land-line telephone services, local charges, intrastate toll calls, and interstate toll calls*	CPI for information technology, hardware, and services	CPI for televisions, cable and satellite television and radio service, and audio equipment*	CPI for postage	CPI for recreational reading materials
1984	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
1985	102.1	107.0	104.5	103.4	101.1	105.6	100.8	102.1	110.2	103.9	97.7	101.2	108.8	105.9
1986	101.6	111.1	110.7	107.8	96.7	109.4	78.8	104.2	124.8	108.9	92.1	101.7	110.2	110.6
1987	101.9	118.1	114.6	111.5	100.5	115.0	81.9	107.5	135.1	108.3	89.2	102.9	110.2	114.4
1988	105.6	124.9	116.7	113.5	104.9	124.4	82.6	111.4	144.7	107.9	91.3	104.8	121.4	118.9
1989	108.5	130.5	122.5	116.2	107.0	129.9	90.4	115.6	154.0	109.0	85.2	106.0	125.1	123.9
1990	112.2	143.2	134.9	118.3	104.5	129.0	103.4	119.5	164.4	109.5	82.7	108.4	125.1	130.3
1991	115.7	162.3	140.9	122.8	105.0	121.3	101.5	124.1	177.0	111.3	78.4	111.6	143.6	138.5
1992	117.4	171.9	143.2	125.9	109.5	104.3	101.1	128.2	189.9	111.9	74.0	112.3	145.3	144.4
1993	117.3	177.0	158.0	129.3	119.0	98.9	100.1	131.3	200.3	112.7	69.7	115.2	145.3	149.5
1994	119.3	182.5	162.7	134.1	126.0	121.4	100.6	134.4	207.8	114.5	63.7	113.9	145.3	154.4
1995	120.6	190.1	166.4	137.4	139.1	124.1	102.1	137.4	216.5	115.3	56.4	113.5	160.3	160.9
1996	120.5	199.8	172.1	140.1	139.6	121.3	108.6	140.9	225.4	117.0	50.6	115.3	160.3	168.8
1997	119.7	209.4	176.6	140.6	134.3	118.1	108.5	143.8	232.5	118.7	44.3	118.6	160.3	171.3
1998	119.0	219.1	180.0	139.8	133.9	116.1	94.2	147.0	235.0	119.4	35.3	120.7	160.3	176.2
1999	117.5	225.7	187.0	139.3	135.1	113.8	102.9	150.6	234.6	118.7	27.0	120.2	165.1	178.1
2000	116.2	236.0	198.3	139.2	138.5	112.7	132.1	155.0	237.2	116.8	22.9	120.5	165.1	180.2
2001	115.7	238.4	199.2	138.5	141.1	110.7	127.4	161.3	247.8	117.7	18.8	121.1	171.5	183.2
2002	113.7	237.5	196.2	136.5	135.1	107.1	119.1	167.0	269.5	118.2	16.2	122.7	181.8	187.4

Note: *: Composite CPI categories (two or more categories are combined).



Note: *: Composite CPI categories (two or more categories are combined).

APPENDIX B: Estimated Parameters of the AIDS Models with Time Trend "t"

Table B.1: Estimated Parameters of the AIDS Model (Alt. 1)

Category (Shares)	R^2	Parameters					
		α_i	$\gamma_{i1\ (Trans.)}$	$\gamma_{i2\ (Com.)}$	$\gamma_{i3\ (Others)}$	β_i	t
Individual CPI							
Transportation	0.83	1.00543	0.253	0.0172	-0.572**	0.0703	0.00641**
Communications	0.94	0.0252	0.0252	0.0365**	-0.0293	-0.0139	0.000547
Weighted CPI for all items							
Transportation	0.86	1.491	-0.116	-0.0479**	-0.337**	0.120	0.0117**
Communications	0.84	0.169	-0.0111	-0.00572	0.0430	-0.0273	0.000449

Note: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05.

Table B.2: Elasticities among Transportation and Communications (Alt. 1)

Category (Shares)	Expenditure elasticity	Price elasticity			
		Marshallian (uncompensated)		Hicksian (compensated)	
		Transportation	Communications	Transportation	Communications
Individual CPI					
Transportation	1.347**	0.179	0.063	0.452	0.148
Communications	0.779**	0.445	-0.406**	0.603	-0.357**
Weighted CPI for all items					
Transportation	1.594**	-1.693**	-0.274**	-1.370**	-0.173*
Communications	0.566	-0.088	-1.064**	0.027	-1.028**

Note: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities.

Table B.3: Estimated Parameters of the AIDS Model (Alt. 2)

Category (Shares)	R^2	Parameter							
		α_i	γ_{i1} (non-PV)	γ_{i2} (PV)	γ_{i3} (new tec)	γ_{i4} (old tec)	γ_{i5} (others)	β_i	t
Individual CPI									
Transportation (non-PV)	0.84	-0.0976	-0.0304	0.101748**	0.0330	0.0403	-0.190**	0.0405	0.00146
Transportation (PV)	0.80	1.231*	-0.0287	0.159	-0.0168	-0.0189	-0.310	-0.00779	0.00671**
Communications (new tech)	0.97	0.0612	0.00674	0.0136	0.0458**	-0.0210	0.00872	-0.0310*	0.00105*
Communications (old tech)	0.99	-0.0787**	-0.00511	0.000337	0.00559*	0.0118**	-0.00181	0.00466	-0.00049**
Weighted CPI for all items									
Transportation (non-PV)	0.78	0.183	-0.00321	-0.0300	0.000099	0.0235**	-0.134*	0.0604	0.00290**
Transportation (PV)	0.82	1.304*	-0.0495	-0.0459	-0.0324*	-0.0193	-0.205	0.0574	0.00909**
Communications (new tech)	0.96	0.315*	0.01180	-0.0120	0.00315	0.0182**	-0.0240	-0.0304	0.00169**
Communications (old tech)	0.98	-0.0433	0.00328	0.00146	0.00100	0.00437**	-0.0102	0.00639	-0.00034**

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. PV = personal vehicle.

Table B.4: Elasticities among Transportation and Communications (Alt. 2)

Category (Shares)	Expenditure elasticity	Price elasticity							
		Marshallian (uncompensated)				Hicksian (compensated)			
		Non-PV	PV	New tech	Old tech	Non-PV	PV	New tech	Old tech
Individual CPI									
Transportation (non-PV)	2.118**	-1.878**	2.620**	0.848	1.101	-1.801**	2.972**	0.963	1.119
Transportation (PV)	0.953	-0.171	-0.038	-0.098	-0.113	-0.136	0.120	-0.047	-0.105
Communications (new tech)	0.426	0.145	0.347	-0.122	-0.382	0.161	0.418	-0.099	-0.378
Communications (old tech)	1.523**	-0.592	-0.049	0.598*	0.314	-0.536	0.204	0.680*	0.328
Weighted CPI for all items									
Transportation (non-PV)	2.666**	-1.149	-1.102	-0.087	0.633*	-1.052	-0.659	0.057	0.657**
Transportation (PV)	1.345**	-0.310	-1.333**	-0.213*	-0.119	-0.262	-1.110**	-0.141	-0.107
Communications (new tech)	0.438	0.239	-0.128	-0.911**	0.342**	0.255	-0.055	-0.888**	0.346**
Communications (old tech)	1.716**	0.342	0.044	0.073	-0.517**	0.404	0.330	0.166	-0.502**

Note: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities.

Table B.5: Estimated Parameters of the AIDS Model (Alt. 3)

Category	R^2	Parameter								
		α_i	γ_{i1} (non-PV)	γ_{i2} (PV-capital)	γ_{i3} (PV-op)	γ_{i4} (new tech)	γ_{i5} (old tech)	γ_{i6} (others)	β_i	t
Individual CPI										
Transportation (non-PV)	0.86	-0.102	-0.0364	0.0509**	0.0416	0.0406	0.0271	-0.159*	0.0352	0.00169*
Transportation (PV-capital)	0.78	1.138	-0.0056	0.0925	-0.0347	-0.0538	0.0336	-0.262	0.00078	0.00690**
Transportation (PV-op)	0.98	0.215	-0.0340*	-0.00137	0.0375*	0.0207	-0.0948**	0.106**	-0.0341*	0.000338
Communications (new tech)	0.97	0.0489	0.00754	0.00982	0.00911	0.0460**	-0.0233	0.00466	-0.0296	0.00105*
Communications (old tech)	0.99	-0.0766**	-0.00448	0.00217	-0.00186	0.00366	0.0104**	0.000575	0.00462	-0.00049**
Weighted CPI for all items										
Transportation (non-PV)	0.80	0.0537	-0.0081	0.00566	-0.0161	-0.00291	0.0244**	-0.132*	0.0681*	0.00238*
Transportation (PV-capital)	0.86	0.589	-0.00569	0.0991*	-0.0186	-0.0337*	0.0225	-0.383**	0.114	0.00762**
Transportation (PV-op)	0.96	0.176	-0.0624**	-0.0372*	-0.00701	-0.0113*	-0.0388**	0.184**	-0.0255	-0.00073
Communications (new tech)	0.96	0.328*	0.0118	-0.00785	-0.00613	0.00343	0.0183**	-0.0241	-0.0309	0.00175*
Communications (old tech)	0.98	-0.0596	0.00280	0.00333	0.00073	0.000622	0.00443**	-0.0100	0.00724	-0.00041**

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05.

Table B.6: Elasticities among Transportation and Communications (Alt. 3)

Category	Expen-diture elasticity	Price elasticity									
		Marshallian (uncompensated)					Hicksian (compensated)				
		Non-PV	PV-capital	PV-op	New tech	Old tech	Non-PV	PV-capital	PV-op	New tech	Old tech
Individual CPI											
Transportation (non-PV)	1.970**	-2.039**	1.314**	1.075	1.067	0.737	-1.967**	1.495**	1.221	1.174	0.755
Transportation (PV-capital)	1.008	-0.061	0.004	-0.378	-0.585	0.365	-0.025	0.097	-0.303	-0.530	0.374
Transportation (PV-op)	0.540**	-0.441*	0.024	-0.461*	0.304	-1.273**	-0.421*	0.074	-0.421	0.333	-1.268**
Communications (new tech)	0.452	0.159	0.232	0.209	-0.119	-0.425	0.176	0.274	0.243	-0.094	-0.421
Communications (old tech)	1.517**	-0.521	0.195	-0.247	0.382	0.157	-0.466	0.335	-0.134	0.464	0.171
Weighted CPI for all items											
Transportation (non-PV)	2.879**	-1.291	-0.017	-0.584	-0.182	0.656**	-1.187	0.248	-0.371	-0.026	0.682**
Transportation (PV-capital)	2.239**	-0.107	-0.037	-0.294	-0.433**	0.234	-0.026	0.169	-0.127	-0.312*	0.254
Transportation (PV-op)	0.657*	-0.828**	-0.470*	-1.069**	-0.133	-0.520**	-0.804**	-0.409	-1.020**	-0.098	-0.514**
Communications (new tech)	0.428	0.239	-0.093	-0.071	-0.906**	0.343**	0.255	-0.053	-0.039	-0.882**	0.347**
Communications (old tech)	1.811**	0.284	0.299	0.022	0.026	-0.511*	0.350	0.465	0.156	0.124	-0.495**

Note: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities.

Table B.7: Estimated Parameters of the AIDS Model (Alt. 4)

Category	R^2	Parameters									
		α_i	γ_{i1} (enter)	γ_{i2} (non-PV)	γ_{i3} (PV-capital)	γ_{i4} (PV-op)	γ_{i5} (new tech)	γ_{i6} (old-tech)	γ_{i7} (others)	β_i	t
Individual CPI											
Trans (entertainment)	0.56	-0.283	-0.0122	-0.0231	-0.00335	0.00474	0.0157	0.0474	-0.0249	0.0324	-0.00070
Transportation (non-PV)	0.95	0.0966	-0.0259	-0.00261	0.0615**	0.0368**	0.0179	-0.00606	-0.117**	0.0107	0.00103
Transportation (PV-capital)	0.78	0.992	-0.0602	0.00409	0.104	-0.0308	-0.0528	0.0530	-0.230	0.009	0.00478
Transportation (PV-op)	0.98	0.263	0.00867	-0.0393*	-0.00577	0.0313	0.0154	-0.0941**	0.113**	-0.0367*	0.000817
Communications (new tech)	0.97	-0.0260	-0.0249	0.0158	0.0162	0.0134	0.0470**	-0.0165	0.00952	-0.0243	0.000054
Communications (old tech)	0.99	-0.0756**	-0.00025	-0.00385	0.00223	-0.00222	0.00262	0.0107**	0.000363	0.00494	-0.00050*
Weighted CPI for all items											
Trans (entertainment)	0.55	-0.0152	0.0156	0.0173	-0.0262	-0.00389	0.00522	0.0277	-0.101*	0.0383	0.00111
Transportation (non-PV)	0.92	0.0127	-0.0217	-0.0264*	0.0360*	-0.0138	-0.00918	-0.00914	-0.0172	0.0351	0.00102
Transportation (PV-capital)	0.88	0.105	-0.0531	-0.0087	0.136*	-0.0369	-0.0431**	-0.0346	-0.267	0.165*	0.00535
Transportation (PV-op)	0.97	-0.136	-0.0397**	-0.0584**	-0.0129	-0.0173*	-0.0167**	-0.0738**	0.257**	0.00582	-0.00221*
Communications (new tech)	0.97	0.1403	-0.0192	0.00898	0.00615	-0.0136	-0.00035	-0.00409	0.0216	-0.0108	0.000887
Communications (old tech)	0.99	-0.00106	0.00661**	0.00295	-0.00112	0.00289*	0.00174*	0.0112**	-0.024**	0.00114	-0.00014

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05.

Table B.8: Elasticities among Transportation and Communications (Alt. 4)

Category	Expen-diture elasticity	Price elasticity											
		Marshallian (uncompensated)						Hicksian (compensated)					
		Enter-tain	Non-PV	PV-cap	PV-op	New tech	Old tech	Enter-tain	Non-PV	PV-cap	PV-op	New tech	Old tech
Individual CPI													
Trans (entertainment)	3.792*	-2.087	-2.063	-0.546	0.201	1.199	4.058	-2.043	-1.969	-0.197	0.483	1.404	4.092
Transportation (non-PV)	1.435*	-1.056	-1.117	2.454**	1.461**	0.704	-0.250	-1.040	-1.081	2.586**	1.567**	0.781	-0.237
Transportation (PV-capital)	1.098	-0.655	0.042	0.117	-0.342	-0.579	0.575	-0.643	0.069	0.218	-0.260	-0.519	0.585
Transportation (PV-op)	0.505*	0.123	-0.517*	-0.032	-0.541*	0.234	-1.264**	0.128	-0.505*	0.014	-0.504*	0.262**	-1.260
Communications (new tech)	0.551	-0.456	0.304	0.341	0.282	-0.106	-0.302	-0.449	0.317	0.392	0.322	-0.076	-0.297
Communications (old tech)	1.554**	-0.034	-0.445	0.199	-0.290	0.263	0.195	-0.016	-0.407	0.342	-0.175	0.347	0.209
Weighted CPI for all items													
Trans (entertainment)	4.305*	0.307	1.407	-2.567	-0.581	0.271	2.360	0.357	1.513	-2.171	-0.261	0.504	2.399
Transportation (non-PV)	2.422**	-0.895	-2.106**	1.329*	-0.667	-0.449	-0.383	-0.867	-2.047**	1.552*	-0.487	-0.318	-0.362
Transportation (PV-capital)	2.790**	-0.597	-0.139	0.314	-0.534	-0.564**	-0.392	-0.565	-0.070	0.571	-0.327	-0.414*	-0.367
Transportation (PV-op)	1.078**	-0.536**	-0.790**	-0.181	-1.239**	-0.230**	-0.996**	-0.523**	-0.763**	-0.081	-1.159**	-0.172**	-0.986**
Communications (new tech)	0.800	-0.353	0.171	0.132	-0.236	-0.996**	-0.074	-0.343	0.191	0.206	-0.177	-0.952**	-0.067
Communications (old tech)	1.128**	0.740**	0.328	-0.137	0.315	0.188	0.259	0.753**	0.356	-0.033	0.398**	0.249**	0.269

Note: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities.

Table B.9: Estimated Parameters of the AIDS Model (Alt. 5)

Category	R^2	Parameter								
		α_i	γ_{i1} (non-PV)	γ_{i2} (PV-capital)	γ_{i3} (PV-op)	γ_{i4} (new tech)	γ_{i5} (old tech)	γ_{i6} (others)	β_i	t
Individual CPI										
Transportation (non-PV)	0.95	0.180	-0.00894	0.0556**	0.0337*	0.0145	-0.0129	-0.127**	0.00641	0.00202**
Transportation (PV-capital)	0.78	1.175*	-0.00954	0.0906	-0.0362	-0.0599	0.0376	-0.259	0.000232	0.00704**
Transportation (PV-op)	0.98	0.224*	-0.0369**	-0.00341	0.0333**	0.0185	-0.0921**	0.115**	-0.0351*	0.000461
Communications (new tech)	0.97	0.0428	0.00894	0.0105	0.00988	0.0471**	-0.0246	0.00303	-0.0294	0.000999*
Communications (old tech)	0.99	-0.0748**	-0.00395	0.00215	-0.00229	0.00262	0.0106**	0.0004	0.00487	-0.00049**
Weighted CPI for all items										
Transportation (non-PV)	0.90	0.218	-0.0219	0.0209	-0.00663	-0.00515	0.0143**	-0.0700*	0.0146	0.00196**
Transportation (PV-capital)	0.86	0.591	0.00228	0.100*	-0.0200	-0.0337**	0.0213	-0.395**	0.117	0.00762**
Transportation (PV-op)	0.95	0.257	-0.0498**	-0.0419*	-0.00331	-0.00888	-0.0288**	0.157**	-0.0336	-0.00040
Communications (new tech)	0.96	0.323*	0.0130	-0.00736	-0.00711	0.00327	0.0169**	-0.0257	-0.0291	0.00173**
Communications (old tech)	0.98	-0.0653*	0.00153	0.00361	0.000619	0.000457	0.00389**	-0.00755	0.00756	-0.00043**

Notes: * $0.05 < \text{p-value} < 0.1$, ** $\text{p-value} \leq 0.05$.

Table B.10: Elasticities among Transportation and Communications (Alt. 5)

Category	Expen-diture elasticity	Price elasticity									
		Marshallian (uncompensated)					Hicksian (compensated)				
		Non-PV[1]	PV-capital	PV-op	New tech	Old tech	Non-PV[1]	PV-capital	PV-op	New tech	Old tech
Individual CPI											
Transportation (non-PV)	1.260*	-1.369**	2.230**	1.346*	0.574	-0.526	-1.338**	2.346**	1.439**	0.642	-0.515
Transportation (PV-capital)	1.003	-0.104	-0.016	-0.393	-0.651	0.408	-0.079	0.076	-0.319	-0.596	0.417
Transportation (PV-op)	0.527**	-0.485**	-0.002	-0.516**	0.275	-1.237**	-0.472**	0.046	-0.477*	0.303	-1.232**
Communications (new tech)	0.456	0.179	0.244	0.223	-0.099	-0.450	0.190	0.286	0.257	-0.074	-0.446
Communications (old tech)	1.545**	-0.456	0.191	-0.297	0.264	0.186	-0.418	0.333	-0.182	0.347	0.200
Weighted CPI for all items											
Transportation (non-PV)	1.591	-1.904**	0.792	-0.313	-0.241	0.574**	-1.865**	0.938	-0.195	-0.155	0.588**
Transportation (PV-capital)	2.269**	-0.007	-0.030	-0.311	-0.434**	0.219	0.049	0.179	-0.143	-0.311*	0.240
Transportation (PV-op)	0.547	-0.660**	-0.522**	-1.011**	-0.095	-0.385**	-0.646**	-0.472*	-0.970**	-0.066	-0.380**
Communications (new tech)	0.462	0.255	-0.087	-0.092	-0.910**	0.317**	0.266	-0.044	-0.057	-0.885**	0.321**
Communications (old tech)	1.847**	0.150	0.327	0.007	0.005	-0.572 **	0.196	0.497	0.144	0.105	-0.555**

Notes:

1. This category does not include the other entertainment equipment/service, compared to the non-PV category of alternative 3.

* 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities.

Table B.11: Estimated Parameters of the AIDS Model (Alt. 6)

Category	R^2	Parameter								
		α_i	γ_{i1} (PT)	γ_{i2} (PV capital)	γ_{i3} (PV-operation)	γ_{i4} (new tech)	γ_{i5} (old tech)	γ_{i6} (others)	β_i	t
Individual CPI										
Transportation (public transit)	0.73	0.0413	0.00739	0.0197**	0.0304**	0.00996	-0.00172	-0.0639**	-0.00463	0.000391
Transportation (PV-capital)	0.80	1.095	0.0633	0.0784	-0.0185	-0.103	0.0888	-0.382*	0.0295	0.00531*
Transportation (PV-op)	0.97	0.197	-0.0244	0.0139	0.0415*	0.0188	-0.113**	0.0898*	-0.0279	0.000296
Communications (new tech)	0.97	0.0466	0.00559	0.00687	0.00797	0.0483**	-0.0208	0.00956	-0.0313*	0.00104*
Communications (old tech)	0.99	-0.0724**	-0.00479*	0.00413*	-0.00255	0.00333	0.00679	0.00276	0.00453	-0.00045**
Weighted CPI for all items										
Transportation (public transit)	0.41	0.154	0.00311	0.00747	-0.00121	0.000419	0.00532	-0.0163	-0.0164	0.000576
Transportation (PV-capital)	0.88	0.451	0.0266	0.104*	-0.0318	-0.0353**	0.00635	-0.405**	0.139*	0.00756**
Transportation (PV-op)	0.91	0.421	-0.00595	-0.0470*	-0.00506	-0.00484	-0.0202*	0.0705*	-0.0331	0.000136
Communications (new tech)	0.96	0.255	0.0109	-0.00513	-0.0103	0.00216	0.0112*	-0.0132	-0.0224	0.00162**
Communications (old tech)	0.98	-0.0670*	-0.00112	0.00365	0.00117	0.000338	0.00409**	-0.00346	0.0066	-0.00045**

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05.

Table B.12: Elasticities among Transportation and Communications (Alt. 6)

Category	Expen-diture elasticity	Price Elasticity									
		Marshallian (uncompensated)					Hicksian (compensated)				
		Public transit	PV-capital	PV-op	New tech	Old tech	Public transit	PV-capital	PV-op	New tech	Old tech
Individual CPI											
Transportation (public transit)	0.575	-0.317	1.851**	2.824**	0.936	-0.154	-0.311	1.904**	2.867**	0.967	-0.149
Transportation (PV-capital)	1.320	0.684	-0.178	-0.225	-1.134	0.962	0.699	-0.056	-0.127	-1.063	0.974
Transportation (PV-operation)	0.624**	-0.325	0.222	-0.412	0.274	-1.516**	-0.318	0.280	-0.366	0.308	-1.510**
Communications (new tech)	0.421	0.110	0.181	0.190	-0.075	-0.380	0.114	0.219	0.222	-0.052	-0.376
Communications (old tech)	1.507**	-0.542*	0.416*	-0.323	0.345	-0.244	-0.526*	0.554**	-0.212	0.427	-0.230
Weighted CPI for all items											
Transportation (public transit)	-0.504	-0.699	0.824	0.001	0.120	0.501	-0.704	0.777	-0.037	0.092	0.497
Transportation (PV-capital)	2.508**	0.272	-0.008	-0.457	-0.465**	0.055	0.300	0.223	-0.271	-0.329*	0.078
Transportation (PV-op)	0.554	-0.075	-0.592	-1.035**	-0.041	-0.269*	-0.069	-0.541	-0.994**	-0.011	-0.264*
Communications (new tech)	0.586	0.207	-0.057	-0.160	-0.938**	0.210*	0.213	-0.003	-0.116	-0.906**	0.216*
Communications (old tech)	1.740**	-0.134	0.341	0.077	-0.002	-0.548**	-0.115	0.501	0.206	0.092	-0.532**

Notes: * 0.05 < p-value < 0.1, ** p-value ≤ 0.05. Shaded cells indicate own-price elasticities.