BASELINE ECONOMIC IMPACTS OF THE ATP DIGITAL VIDEO PROGRAM

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The views and interpretations expressed in this report are those of the authors alone, and do not necessarily represent the views of the Institute for Public Policy and Business Research, the University of Kansas, the Advanced Technology Program, the National Institute of Standards and Technology, or any of the consultants engaged on this project.

TABLE OF CONTENTS

ACKNOWLEDGMENTS ii

TABLE OF CONTENTS iii

1. INTRODUCTION 1

2. SURVEY OF CONSUMERS 7

3. CONSUMER DEMAND ESTIMATES 25

4. EVENT STUDY OF DV PATENT SPILLOVERS 48
Appendix 4.1: Key Digital Video Patents 52

5. SURVEY OF ATP CLIENT FIRMS 56
Appendix 5.1: Interviews with ATP Client Firms 67

6. PARTIAL EQUILIBRIUM BASELINE IMPACT ESTIMATES 128

7. CGE MODEL OF ATP INTERVENTIONS 144
Appendix 7.1: The SAM Matrix 151
Appendix 7.2: Price Elasticity Parameters 154

8. GENERAL EQUILIBRIUM BASELINE IMPACT ESTIMATES 162
Appendix 8.1: Unreliability of Demand Price Elasticity Measurements: The Case of Energy 172

9. CONCLUSION 173

REFERENCES 178

INDEX 181

1. INTRODUCTION

Overview

This report describes baseline data on the economic impacts of digital video on the US economy. The focus is on impacts that have resulted or are likely to result from the Digital Video Focused Program Area of the Advanced Technology Program (ATP), National Institute of Standards and Technology (NIST), US Department of Commerce. In order to estimate these impacts, it was necessary for us to create a much broader framework: a framework that includes models of consumer demand for digital video and models of costs and production. The chapters that follow contain specific data on digital video outcomes and partial and general equilibrium models that use that data.

This report is part of a series of reports on the economic impacts of the Digital Video Focused Program Area. The series is being prepared by the Policy Research Institute (PRI) at the University of Kansas. Four previous reports in this series have provided a preliminary analysis of the digital video (DV) market place and its economic impacts:

- Burress *et al.* (1998) establishes an approach for mapping complex marketplaces in terms of the general attributes of goods (based partly on Lancaster's (1971) model of demands for attributes). The approach is then applied to provide a detailed empirical description of existing and potential DV-related markets.
- Burress *et al.* (1999a) extends this approach to provide a map of technologies needed to implement the identified types of DV goods. It also provides theoretical and empirical maps of the spillovers and other channels through which innovations in digital video technology could potentially affect the US economy. And it proposes a Computable General Equilibrium (CGE) model of the US to be used as an accounting frame and aggregation method for summarizing economic impact channels. (A CGE model is one that numerically calculates the effects of all interactions of all markets in the economy, based on moderately to highly aggregated markets.)
- Burress *et al.* (1999b) proposes general methodologies for the entire study, including possible follow-ons and *ex post* economic impact analyses. It also proposes specific methodology for gathering the baseline data (but not the detailed protocols), and proposes a research plan for gathering and analyzing the baseline data needed for the over-all study.
- Burress *et al.* (2000) describes methods and protocols for gathering the baseline data and also analyzes some of the test data so gathered.

It is anticipated that follow-on research will track the Digital Video Focused Program Area over time, and then provide comprehensive *ex post* (i.e., retrospective) measurements of its economic impacts on the US.

Purposes of study

Our methods and assumptions are laid out in considerable detail in our four previous reports. In this report we provide baseline empirical results. The study that this report describes has three overall purposes:

- Gathering important baseline. The emphasis is on data that are transitory in nature and might not be available in future years.
- Detection and modeling of spillover effects.
- Proof of concept and testing of estimation methods.

The report organized into an introduction, seven substantive chapters, plus a conclusion. Each of the substantive chapters reports on a discrete piece of research performed in support of the study purposes. Our approach to the overall study is multi-dimensional. That is, we often use multiple approaches to try to solve the same problem. The clearest example of this is the use of both partial and general equilibrium models. Below we discuss the overall approach undertaken in each chapter. We then highlight the contributions of each chapter to the three major purposes of the study.

Contributions of individual chapters to study purposes

Chapter 2. Survey of consumers

This chapter discusses a national survey of consumers conducted by PRI during the Spring of 2000. The survey topics include current use and purchases of video and other entertainment products, and willingness to pay for new goods and services.

Gathering baseline data. The survey gathers detailed data on the consumers' current expenditures on and use of video products and services. Although it might be possible to piece some of this data together from other sources, data from other sources would probably not be linked with household characteristics such as age and income. The survey also gathers attitudinal data about desired features of video products. More importantly, it provides data on consumers' willingness to purchase new products at various prices. Most of the new products discussed in the survey are just now emerging in the market place (some don't even exist yet). So the consumer survey provides data on the *potential* digital video market. Furthermore, the survey is designed so that we gather information on consumer demand for video *attributes* such as picture quality. Much of the empirical literature on new products models consumer demand for product attributes.

Detection and modeling of spillover effects. Many of the spillovers from digital video research will be consumer market spillovers. That is, consumer welfare will increase due to lower prices, higher quality, and new products with new mixtures of attributes. The consumer survey provides the raw data from which models of consumer demand could be built and welfare changes estimated.

Proof of concept. The consumer survey illustrates how information on a) current consumption of video goods and services, and b) demand for product attributes can be gathered. The survey guides the respondent through a series of pairwise choices, an approach which, for the most part, is successful at eliciting information on consumer preferences.

Chapter 3. Consumer demand estimates

Chapter 3 uses data from the consumer survey to estimate of several types of functions describing consumer demands for selected DV goods or for selected attributes of goods.

Baseline data. This chapter estimates consumer demand functions for digital video goods. Changes in measured preferences could be tracked over time while new technology gets adopted by consumers.

Detection and modeling of spillover effects. This chapter looks at ways of placing values on changes in the prices or attributes of digital video consumer goods that may result from ATP interventions. This exercise is necessarily hypothetical: ATP-supported DV innovations have not yet had a measurable effect on attributes or prices of DV goods actually received by consumers. Most innovations are not yet marketed. The techniques described here could be tailored more specifically to goods and attributes actually affected by ATP-backed R&D once they become known.

Proof of concept. The chapter shows how data from a consumer survey can be used to build models of video demand. The chapter shows how the value of the consumer's time can be integrated into the models. In fact, the chapter shows results from a preliminary model of consumer indirect utility that includes time, price, income, and other variables. The chapter suggests how survey questions could be improved in order to better estimate welfare changes.

Chapter 4. Event study of DV patent spillovers

This chapter discusses how patent data can combined with stock price data to estimate the net impact of an innovation on competing firms. Unlike most of the other work in this report, the event study does *not* focus specifically on ATP-affected innovations. Rather, it looks at a broader set of DV firms.

Baseline data. This chapter, along with a companion chapter in an earlier report (Burress *et al.*, 2000, Chapter 4) shows how a set of patents related to digital video can be compiled. The patent data are by no means transitory - all patent data are preserved by the US Patent and Trademark Office. Our contribution is to compile the data into a form useful for detecting key patents, and to match the data on patents to data on publicly traded firms.

Detection and modeling of spillover effects. The event study estimates the net spillovers from innovating firms to a (limited) set of rival firms. Unlike most other approaches, this approach theoretically sums the effects of *all* spillovers on competing firms. That is to say, it accounts not only for market spillovers (including both negative competitive effects and positive supplier effects), but also for knowledge spillovers and network spillovers. The approach measures spillovers as they are *expected* or anticipated by stock market investors at the time the patent is issued, rather than measuring actual outcomes *ex post*. However, according to efficient market theories of stock prices the expected spillovers would be unbiased (though highly noisy) estimators of the *ex post* spillovers.

Proof of concept. The work described in Chapter 34 is intended to see whether net spillover effects are large enough to be detected in stock market data. Burress *et al.* (2000) notes that it is necessary to restrict firm sample to small or medium-sized firms in order to detect the effect of patents on the innovating firm. Chapter 4 considers whether the same kinds of restrictions are sufficient.

Chapter 5. Survey of ATP client firms

This chapter reports on telephone interviews conducted with key staff at firms that have received ATP funding for DV research. The interviews were conducted in January - July, 2000, based on an interview protocol developed and tested during an earlier phase of this project (Burress *et al.*, 2000).

Baseline data. Baseline data on ATP client firms are needed for a variety of purposes. First, information on the innovations produced by ATP funded projects is necessary to identify the "pathways" through which each innovation is likely to affect the economy. This information is needed both to develop appropriate strategies to gather data needed to track the economic impacts produced by the innovations, and as an input in the construction of models used to aggregate the impacts of multiple projects. Second, information on how ATP support affected client firms' research and development efforts is needed to establish how much of the benefits produced by each innovation to attribute to ATP, what we have termed the "attribution effect." Third, for those projects sufficiently advanced to have produced a commercial product, it is possible to construct preliminary estimates of the economic impacts realized to date.

Detection and modeling of spillover effects. Both actual and potential market spillovers can be detected through the interview method. Successful innovations are likely to lead to downstream cost and price reductions, and hence increases in producer and consumer surplus for downstream users. Equally as important is documentation of network and knowledge spillovers that may be diffuse and may be difficult to quantify.

Proof of concept. The interviews test whether meaningful economic data on project outcomes can be gathered from project research staff.

Chapter 6. Partial equilibrium baseline impact estimates

Chapter 6 uses the data collected from the interviews described in Chapter 5 to calculate partial equilibrium impacts. To date, three innovations that have resulted in commercial products:

- Transmitter technology for HDTV terrestrial broadcast
- Compressed domain processing of DV signals
- Adaptive video codec for information networks.

Two of these products reached the market during the Spring of 2000, close to the time we were conducting our interviews. The third has been available commercially since 1998.

Baseline data. The outcomes of Chapter 6 provide baseline estimates of actual impacts of ATP innovations that have already been brought to market.

Detection and modeling of spillover effects. Chapter 6 provides measures of actual market spillovers for products that have reached the market as of Spring, 2000. These spillovers are estimated using consumer and producer surplus techniques.

Proof of concept. The approach used in Chapter 6 is similar to that of Mansfield *et al.* (1977). Much of the work of Chapter 6 is not so much a proof of concept as an application of previously-developed techniques. A contribution of Chapter 6 is the theoretical framework for measuring the economic impacts of the impacts of ATP's *intervention* as opposed to the impacts of an *innovation.* Only some fraction of the benefits arising from the innovations studied should be attributed to ATP's support. Measuring the ATP "attribution effect" requires us to compare the realized benefits of an innovation with the benefits that would have been realized in a counterfactual situation in which ATP had not supported the project in question.

Chapter 7. CGE model of ATP interventions

This chapter is primarily technical and sets up a Computable General Equilibrium (CGE) framework of the U.S. economy. The CGE model will be combined with a Monte Carlo method for aggregating various uncertainties.

Baseline data. This chapter shows how input-output data for the U.S. economy can be combined with data from other sources in order to create a transactions matrix with appropriate DV sectors. In other words, it shows how a model can be "benchmarked" in order to create digital video sectors that have approximately the correct size and composition.

Detection and modeling of spillover effects. The CGE model that is set up in this chapter is an appropriate tool for tracing through the market spillovers that affect consumers and producers. Multiplier effects of market spillovers are included.

Proof of concept. The chapter explores the feasibility of benchmarking a transactions matrix with specific DV sectors. It formalizes the construction of a baseline CGE model. It also formalizes a Monte Carlo method for examining the combined error from all uncertainties.

Chapter 8. General equilibrium baseline impact estimates

This chapter applies the CGE model developed in Chapter 7 to the three ATP outcomes that have been realized to date.

Baseline data. The results of this chapter provide baseline estimates of impacts using a general equilibrium approach.

Detection and modeling of spillover effects. As documented in Burress *et al.* (1999a), there are many possible types of connections or "contact points" between a technological innovation and a CGE model. Consideration of these categories will help us insure that all identified economic impacts of each innovation (that is, all market spillovers) have been fully accounted for, without any double counting.

Proof of concept. One major benefit of constructing a CGE model is that the process of specifying, solving, and interpreting the model requires great explicitness about the underlying assumptions. Any underlying assumptions may be challenged. Nevertheless, we believe it is a real contribution to simply have a concrete example showing all the kinds of assumptions that must be made in order to fully determine the actual impact of a R&D intervention by ATP. At a bare minimum, the process of building a full CGE model substantially reduces the possibilities for either double counting or omitting significant pathways of effect. No similar level of explicitness can ever be achieved using partial equilibrium methods.

Summary

Our approach to estimating impacts of ATP programs is to use multiple data sources and multiple models. The conduct of this study required collection of the new data and construction of new models in order to estimate market spillovers and to document other type of spillovers. Some of the models, for example, the partial equilibrium model of Chapter 6, are fairly complete. That is, they can be applied with few modifications as outcomes of additional ATP projects become known. Other models, in particular the general equilibrium model of Chapter 8, should be thought of as a proof of concept. They will need added detail to accommodate the study of additional DV market successes.

2. SURVEY OF CONSUMERS

Introduction

During the spring of 2000, the University of Kansas Policy Research Institute conducted a telephone survey of households to gather information on potential consumer demand for digital video products and services. At the time that the survey was conducted, most of the effects of ATP-supported digital video technologies had not yet been incorporated into products available in the market place. Therefore, our primary approach was to look at consumer valuation of various functions and characteristics of video technology, functions and characteristics that may be actualized in consumer products available in the future. Our concept of valuation involves both the monetary payments that might be made by the consumer and the of expenditure of the consumer's time.

Concretely, the survey asked about three categories of information:

- Demographic characteristics;
- Current household consumption of video technologies and entertainment services;
- Preferences for and evaluation of potential new digital video entertainment goods and services.

This chapter provides descriptive information on consumer responses to many of the survey questions. Chapter 3 integrates these responses into a model of consumer demand. The survey form is included in Burress *et al.* (2000).

Characteristics of the survey sample

Cooperation rate

During April - June, 2000, the Survey Research Center (SRC) at the Policy Research Institute conducted a survey of households throughout the US. The SRC started with a list of randomly-generated telephone numbers drawn from active telephone exchanges across the country. Because the numbers were random, some of them proved to be out of service. Other numbers belonged to businesses rather than households. If a valid telephone number could not be reached on the first try, the SRC called the number back at least four times at various times of the day. The SRC reached 1052 households. A total of 315 households initially agreed to participate in the survey. Of these, 288 actually completed the telephone interview process - fewer than 6 percent of participants stopped the survey midway. The cooperation rate for the survey is (288/1062) or 27 percent.

We were concerned about the fairly low cooperation rate for the survey (the SRC generally achieves cooperation rates over 50 percent). We spoke with the individual surveyors, who told us that potential respondents seemed to be suspicious of the topic of the survey (use of technology). Potential respondents often commented that they thought we were trying to sell them something (despite our claims to the contrary). Similarly, several potential respondents commented that they were "tired of telemarketers."

Despite the fairly low cooperation rate, a very high percentage of respondents finished the survey once they started it. This indicates to us that the survey is appropriate in length (it takes about 12-15 minutes to complete) and that the subject matter and wording can be understood by the participants. Most individual survey questions have an item response rate of at least 95 percent (respondents who actually answer question/respondents who are eligible to answer question). This reinforces the idea that the questions are appropriate and understandable.

Demographics and representativeness

The survey asks a number of demographic and income questions. These questions serve two purposes: a) to test if the resulting survey sample is representative of the population in terms of measurable characteristics, and b) to provide explanatory variables for the regression models estimated in Chapter 3. Key demographic and income variables include:

- Respondent age;
- Gender;
- Employment;
- Home ownership;
- Household income before taxes;
- Household size;
- Hours worked.[1]
-

We were able to find up-to-date counterparts from widely-available U.S. data sources for all of the variables except hours worked.

We found that the survey sample is similar to the U.S. population with regards to several measurable criteria (see Tables 2.1-2.4). The sample represents the age distribution of the U.S. population fairly well (note that only people age 18 and older were included in the group of potential survey respondents). The sample does not significantly differ from the U.S. population in gender distribution. The percentage of respondents employed (69%) is close to the employment percentage for the U.S. adult population as a whole (66%). Approximately 70 percent of respondents own their own homes, in comparison to 67 percent nationwide, a difference that is not significant.

The survey does significantly under-represent low income households - those with incomes under $15,000 per year (see Table 2.5). Fewer than 10 percent of the surveyed households fall into this income category, in contrast with over 16 percent of households nationwide. Similarly, the survey over-represents middle income households in the $50,000-$80,000 per year income category. Under-representation of low income households in the survey sample may be due in part to lack of telephone service. Recent data from the Federal Communications Commission indicates that about 15 percent

[1] In some cases, raw survey data are transformed in order to create meaningful variables. For example, household size is determined by adding up household members in various age categories. In the regression models in Chapter 3, some categorical variables such as income are replaced by the midpoints of the categories. Complete documentation on survey variable transformations is available from the authors.

of households with incomes under $15,000 lack phone service. In contrast, only about 2 percent of households with incomes over $60,000 lack service (Belinfante, 1999).

The average size of households in the survey sample is somewhat larger than for the U.S. as a whole (2.93 persons versus 2.61 persons). The number of employed people per household (1.65) exceeds the national average (1.34), due mainly to the larger than average household size. Although these differences are statistically significant, they are small in size (see Table 2.6).

As mentioned earlier, the demographics and income section of the survey also contains questions on hours worked. We could not find recent U.S. data for these variables, so they do not contribute to the discussion of representativeness. However, the variables prove useful in some of the regression models of Chapter 3. For those respondents who are employed, full time employment (35 to 50 hours per week) is the most common choice. Fully 18 percent of employed respondents work more than full time, that is, more than 50 hours per week. On average, the respondent plus other household members together work about 57 paid hours per week (see Tables 2.7 and 2.8).

To summarize, the survey sample appears to be representative of the U.S. population in age, gender composition, employment, and home ownership. The most important characteristic for which the sample is not representative is income - low income households are significantly under-represented. The non-representativeness of the sample does not affect its usefulness for formulating consumption models in Chapter 3 - there, income and demographic variables are used to help explain consumer behavior.

Table 2.1
Age of Respondent

age	18-25	26-44	44-64	65+
% of survey respondents	15.4	36.4	32.5	15.7
% of U.S. population age 18+	14.5	39.2	29.2	17.1

N = 286

Source: PRI consumer survey U.S. Bureau of the Census (2000a). Comparison data from 1999.
Significance: A chi-square test of the age distribution of the survey respondents against the age distribution of the general population shows that the survey distribution is not significantly different from the population as a whole ($p = .55$).

Table 2.2
Gender

gender	male	female
% of survey respondents	43.7	56.3
% of U.S. population age 18+	48.1	51.9

N = 286

Source: PRI consumer survey and U.S. Bureau of the Census (2000a). 1999 comparison data.
Significance: A chi-square test of the gender distribution of the survey respondents against the gender distribution of the general population shows that the survey distribution is not significantly different from the population as a whole (p = .14).

Table 2.3
Employment of Respondent

gender	employed	not employed
% of survey respondents	68.8	31.2
% of US Population age 20+	66.0	34.0

N = 286

Source: PRI consumer survey and U.S. Bureau of Labor Statistics (2000b). 1999 comparison data. The consumer survey includes respondents age 18 and over, while the BLS data includes persons age 20 and over.
Significance: A chi-square test of the gender distribution of the survey respondents against the employment distribution of the general population shows that the survey distribution is not significantly different from the population as a whole (p = .32).

Table 2.4
Home Ownership

ownership	own home	do not own home
% of survey respondents	70.3	29.7
% of U.S. households	66.2	33.8

N = 286

Source: PRI consumer survey and U.S. Bureau of the Census (2000c). 2000 comparison data.
Significance: A chi-square test comparing the home ownership distribution of the survey respondents against the home ownership distribution of the general population shows that the survey distribution is not significantly different from the population as a whole (p = .28).

Table 2.5
Household Income before Taxes

income	under $15,000	$15,000-29,999	$30,000-49,999	$50,000-79,999	$80,000 +
% of survey respondents	09.4	18.5	23.6	26.8	21.7
% of U.S. households	16.5	20.5	22.2	20.6	20.2

N = 253

Source: Consumer survey and U.S. Bureau of the Census (2000d). Interpolation was necessary to make income categories match.
Significance: A chi-square test shows that the income distribution of households participating in the survey differs significantly from the income distribution of households in the U.S. as a whole (p = .01). In particular, the survey under-represents low income households and over-represents households in the upper middle income category ($50,000-79,999).

Table 2.6
Household Size and Employment per Household

household size	mean # people	Standard error of mean	Mean employed people	Standard error of mean
Survey respondents	2.93	.09	1.65	.07
U.S. households, 1998	2.61	-	1.34	-

N = 288

Source: PRI consumer survey; U.S. Bureau of the Census (1998); and U.S. Bureau of Labor Statistics (2000a).
Significance: T tests (t = (2.93-2.61)/.09 and t = (1.65-1.34)/.07) show that both the average household size and average employment per household are significantly greater for the survey respondents than that for the US as a whole. But although the differences are statistically significant, they are small (about 1/3 of a person).

Table 2.7
Hours Worked by Respondents

	Number of respondents	Percent of employed
15 hours or under	10	05.1%
16 to 34 hours	44	22.3%
35 to 50 hours	107	54.3%
more than 50 hours	36	18.3%
not employed	90	

N=287

Source: PRI consumer survey. Most of the respondents who worked at paid jobs or in their own businesses reported full time employment, working between 35 and 50 hours per week.

Table 2.8
Total Hours Worked by Household

	Mean	Standard Error
Total household work hours	56.6	2.0

N = 287.

Source: PRI consumer survey. Total hours worked by household members are calculated using the midpoints of reported ranges of hours.

Current household consumption of video technologies and entertainment services

A central hypothesis discussed in Chapter 3 is the common-sense notion that those consumers who currently are intense consumers of video goods and services will also have the highest willingness to pay for advanced goods and services that are just coming into the market place. In order to test this hypothesis, we asked consumers about their ownership and use of a number of video, electronic, and entertainment goods and services. The survey focuses on television, movies, and video entertainment.

Market penetration of video goods and services

Market penetration of color TVs and VCRs is almost universal among the households that we interviewed (see Table 2.9). Cable or satellite service is also very common - fully 80 percent of households receive cable or satellite TV service, and a few households receive both. A majority of the households have Internet access in the home. About one-third of households currently have access to one or more premium channels such as HBO. About 15 percent of households in the sample currently own DVD players. About 3 percent (8 respondents) report that they already own HDTV. Although the survey questionnaire briefly explained what we meant by HDTV, we found that only 3 of the 8 households reporting HDTV also reported a TV price (>$2000) consistent with owning HDTV. We adjusted our statistics accordingly.

Table 2.9
Market Penetration of Video Goods and Services

Good or Service	% owning or receiving	Number of respondents
Color TV	99.0%	288
VCR	97.6%	288
Cable or satellite TV	79.7%	286
Cable TV	67.0%	286
Internet access at home	57.8%	287
Premium channels	33.0%	288
Satellite TV	16.2%	284
DVD player	14.8%	283
HDTV	01.9%	280

Source: PRI consumer survey

Equipment ages and prices

We asked consumers about the prices and ages of the video equipment that they owned (see Table 2.10). In the case that the consumers had more than one TV, more than one VCR, or more than one DVD player, they were asked to report on their best piece of equipment. We report median as well as mean values for age and price, because outliers (such as a TV costing $7500 or a TV 30 years old) have a large effect on means but almost no effect on medians.

To generalize, mean expenditures and mean equipment ages exceed medians of the corresponding variables. Consumers who have purchased HDTV pull up the average TV expenditure. Similarly, early adopters of DVD players, who paid a high price for their equipment, pull up the DVD expenditure average. For each equipment type, considerably more consumers are able to recall approximately when they acquired their equipment than what the equipment cost.

As mentioned earlier, the overwhelming majority of households report owning TVs and VCRs. The median expenditures on these items are modest ($400 and $200 respectively). Half the households purchased their best TV more than four years ago. Only around 15 percent of households have DVD players - the median expenditure on DVD players is $300, and the majority have been purchased within the last year.

Table 2.10
Equipment Expenditures and Ages

	mean	median	number of responses
TV expenditure ($)	642	400	213
TV age (years)	4.7	4.0	271
VCR expenditure ($)	204	200	202
VCR age (years)	3.8	3.0	263
DVD expenditure ($)	516	300	26
DVD age (years)	.85	.67	41

Source: PRI consumer survey.

Equipment quality

Consumers were asked a few questions assessing the quality of video equipment and services. Most households have small- or modest-sized TVs. About 31 percent of the households currently own large screen TVs with screen sizes greater than 27 inches (see Table 2.11). Most households receive fewer than 50 TV channels, and about one-fourth of households receive fewer than 20 channels. About 16 percent of households receive more than 100 channels (see Table 2.12).

Table 2.11
Screen Size of Best Color TV

	Number of respondents	Percent
21 inches or under	61	21.9
22 to 27 inches	132	47.3
28 to 36 inches	60	21.5
37 to 49 inches	9	3.2
larger than 49 inches	17	6.1
Total	279	100.0

Source: PRI consumer survey.

Table 2.12
Number of TV Channels with Good Reception

	Number of respondents	Percent
under 20 channels	73	26.0
20 to 49 channels	72	25.6
50 to 99 channels	91	32.4
100 channels or over	45	16.0
Total	281	100.0

Source: PRI consumer survey.

Desired characteristics of TV purchases

Consumers were asked an open-ended question about the TV features that they desired (see Table 2.13). The question was worded as "What features will be important to you in the next color television that you purchase?" The answers were then coded into categories. Over one-fourth of consumer want a "bigger screen." This is followed closely by "better sound" and "sharper-clearer image." "Easier controls" are mentioned by 18 percent of respondents, and "better color" and "high definition" are each mentioned by 14 percent of respondents.

Table 2.13
Features Wanted in Next Color TV Purchased

Desired Feature	Number mentioning	Percent mentioning
Bigger screen	79	27.5
Better sound	65	22.6
Sharper-clearer image	56	19.5
Easier controls	52	18.1
Better color	41	14.3
High definition or digital	41	14.3
Cable ready	22	07.7
Picture within picture	10	03.5
Built-in VCR/DVD	8	02.8
Wide-screen/letter-box	6	02.1
Flat screen	6	02.1
More reliability	4	01.4
Better programs	4	01.4

N = 286
Source: PRI consumer survey.

Intensity of use of video entertainment

The average consumer spends a considerable amount of time each week watching TV, going to movies, and renting videos (see Tables 2.14-2.16). More than half of consumers spend at least 11 hours per week watching television programs. More than 40 percent of consumers go out to the movies at least once a month. Fully 36 percent of consumers rent a video at least once per week, and another 30 percent rent at least once per month.

It is interesting to ask whether those consumers who watch TV a high number of hours also rent videos and go the movies frequently. To assess this, we divided each type of entertainment into two groups - intense consumers and less-intense consumers. Intense TV consumers are defined as those watching at least 11 hours per week, intense high movie goers are defined as those going to the movies at least once per month, and intense video renters are defined as those renting at least once per month. We created three 2-way tables (movies versus TV; videos versus TV, and videos versus movies) and performed chi-squared tests. We found that:

- Going to the movies is unrelated to hours of TV watched. That is, intense movie goers are just as likely to be intense TV watchers as are less-intense movie goers (Table 2.17).
- Renting videos is *negatively* related to watching TV programs. About half of intense video renters watch TV 11 hours or more per week; in contrast, 70 percent of less intense video renters watch TV 11 hours or more. Differences are significant at the 1 percent level. It appears that video renting is a substitute for watching TV programs (Table 2.18).
- Renting videos is *positively* related to going to movies. About half of the intense video renters are also intense movie goers. In contrast, only 30 percent of the less-intense video renters are

intense movie goers. The results are significant at the 1 percent level. It appears that the underlying preferences that make a person want to go to the movies also influence the person to rent videos (Table 2.19).

Table 2.14
Hours of TV watched per Week by Respondent

Hours	Number of respondents	Percent
zero	5	1.7
1 to 5	43	15.0
6 to 10	77	26.9
11 to 20	97	33.9
21 to 30	33	11.5
31 to 40	20	7.0
over 40	11	3.8
Total	286	100.0

Source: PRI consumer survey.

Table 2.15
Frequency of Going to the Movies

Frequency	Number of respondents	Percent
At least once per week	22	7.7
At least once per month	101	35.2
A few times per year	81	28.2
About once per year	17	05.9
Almost never	66	23.0
Total	287	100.0

Source: PRI consumer survey.

Table 2.16
Frequency of Renting Videos

At least once per week?	103	36.0
At least once per month?	87	30.4
A few times per year?	37	12.9
About once per year?	8	2.8
Almost never?	51	17.8
Total	286	100.0

Source: PRI consumer survey.

Table 2.17
Intensity of Movie Going Versus Intensity of TV Watching

		Intense TV watcher	
Intense movie goer		no	yes
no	Count	71	93
	%	43.3	56.7
yes	Count	54	67
	%	44.6	55.4

Source: PRI consumer survey.

Table 2.18
Intensity of Video Renting Versus Intensity of TV Watching

		Intense TV watcher	
Intense video renter			
		no	yes
no	Count	28	67
	%	29.5	70.5
yes	Count	95	94
	%	50.3	49.7

Source: PRI consumer survey.

Table 2.18
Intensity of Video Renting Versus Intensity of Movie Going

		Intense movie goer	
Intense video renter			
		no	yes
no	Count	66	29
	%	69.5	30.5
yes	Count	97	93
	%	51.0	49.0

Source: PRI consumer survey.

Willingness to pay for advanced video products and services

The final section of the survey focuses on consumer preferences for and willingness to pay for advanced video products and services. Some of these products (for example, large screen TV) are already well established in the market place. But many of the products and services are just emerging. Because survey respondents might not be familiar with the goods and services we were trying to evaluate, the survey provides brief descriptions of what the products and services can do in terms that consumers can understand. Among the goods and services covered by the survey are:

- TVs with movie-quality screens defined as "as crisp, clear, and colorful as what you would see in a movie theater." Consumers were asked about their trade-offs between screen size and picture quality, and also about their willingness to pay for a movie-quality picture.
- Advanced DVD players that would also allow the consumer to record. Consumers were asked about their willingness to pay to own the device.
- Instant replay devices that would "allow you to stop what you were watching, even if it were a live telecast, and go back and watch part of the telecast again. ...At the same time, the device would record anything you were missing" Consumers were asked what monthly fee they would be willing to pay to rent such a device.
- Video on demand that would make "a huge library of movies, documentaries, and educational programs" available within 5 minutes for a fixed monthly fee. Consumers were asked about their willingness to pay for monthly service.
- The "big package" providing a large screen TV with movie picture quality, a DVD player and recorder, instant replay, and video on demand services. Consumers were asked about their willingness to pay for monthly rental of the "big package." They were also asked if, given the big package, they would watch more TV. If so, they were asked what they would do less. The idea here is that the big package (as well as other video services) have a "time use" cost as well as a monetary cost.

Tradeoff of image quality and screen size

Consumers were asked explicit questions about their trade-offs between TV screen size and image quality (see Table 2.19). Consumers initially were given two hypothetical choices: a 49 inch TV with conventional picture quality or a 27 inch TV with a picture quality"as crisp, clear, and colorful as what you would see in a movie theater." The consumers were asked to imagine that one of the TVs were available to them without cost. The overwhelming majority of consumers - 234 of 284 answering the question - chose the 27 inch movie quality TV. This result is not inconsistent with the previous result that consumers desired "larger size" more than any other feature in a new TV. For the previous question, consumers were talking about TVs of existing quality. For most people, this means conventional TV because they have not even seen HDTV. In this question, consumers are asked to imaging a TV of higher quality than they have actually seen. Consumers are clearly willing to sacrifice size if the image is clear enough and if no price differentials are involved.

The 50 respondents who chose the 49 inch TV in the initial stage were given one of two other questions: a) choice of a 49 inch TV with conventional quality or 36 inch movie quality (asked to 25 respondents); or b) choice of a 36 inch TV with conventional quality or a 27 inch TV with movie quality (asked to 25 respondents). Ten respondents (40% of those asked) said that they would also choose the 49 inch conventional TV over a 36 inch movie quality TV. Seventeen respondents (68% of those asked) said they would choose a 36 inch conventional TV over the 27 inch movie quality TV.

Table 2.19
Tradeoffs of Size and Image Quality

Choice	Number of respondents	Percent
Prefers 49" conventional TV over 27" movie quality	50	17.6
Also prefers 49" conventional over 36 inch movie quality	*10*	
Also prefers 36 inch conventional over 27 inch movie quality	*17*	
Prefers 27" movie-quality TV over 49" conventional	234	82.4
Total	284	100.0

Source: PRI consumer survey.

Willingness to pay for image quality

We then asked consumers how much they would be willing to pay to get a movie-quality TV. Consumers were asked to compare two TVs of the same size (49 inch), one with conventional quality picture and one with a movie quality picture. Consumers were given one of four price differentials ($50, $200, $500, and $2000) and asked which TV they would buy. At a price differential of $50, about 90 percent of consumers would choose movie-quality TV. For a price differential of $200, that percentage falls to 64 percent. About 40 percent of consumers say they are willing to pay a price differential of $500 and about 20% say they are to pay $2000. The graph below (Figure 2.1) shows the tradeoff between the price differential for movie quality and the percentage of consumers who say they are willing to pay that price. Note that Chapter 3 contains a more complete analysis of consumer responsiveness to price.

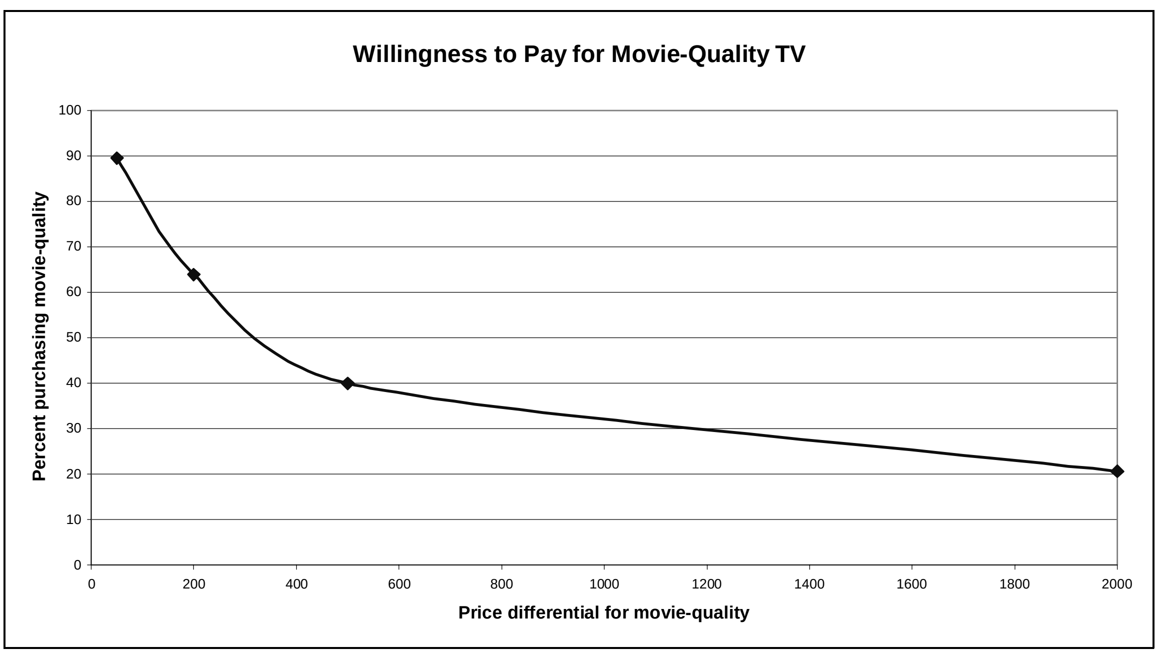

Figure 2.1

Willingness to pay for advanced DVD device

Consumers were asked to place themselves in a situation where they were going to buy a new video recorder and player. They were asked to choose between an advanced DVD player that allowed recording and a conventional VCR. Consumers were told that the advanced DVD player would cost more than the VCR - consumers were presented with one of four price differentials ($50, $100, $250, and $500). They were asked whether they would buy the more expensive “super DVD” player or the conventional VCR. A large majority of consumers (84 percent) were willing to pay a price differential of $50 for the super VCR. Slightly more than 25 percent of consumers were willing to pay a $500 price differential (see Figure 2.2).

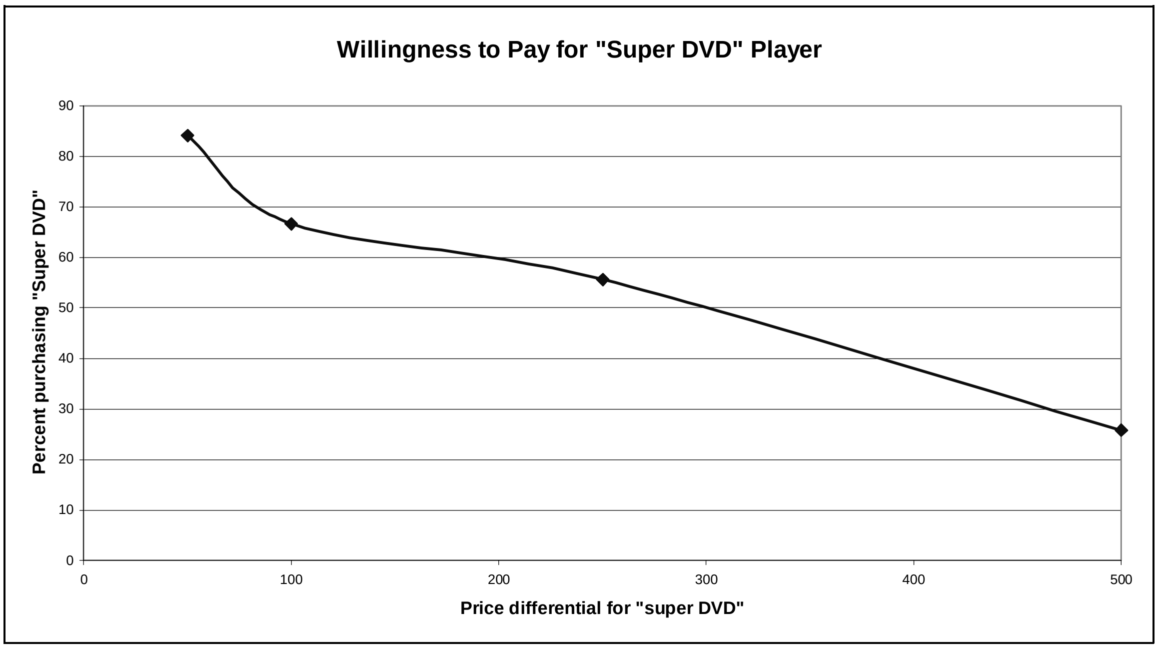

Figure 2.2

Willingness to pay for instant replay

Consumers were asked to place themselves in a situation were they could rent an instant replay device without installation charges or long term commitments. Consumers were told that the monthly rental fee would be one of four dollar amounts ($3, $7, $15, and $30). They were asked whether they would rent the device. al VCR. About 75 percent of consumers said they are willing to pay $3 per month. Willingness to pay drops off slowly, with 33 percent of consumers saying that they would pay $30 per month (see Figure 2.3).

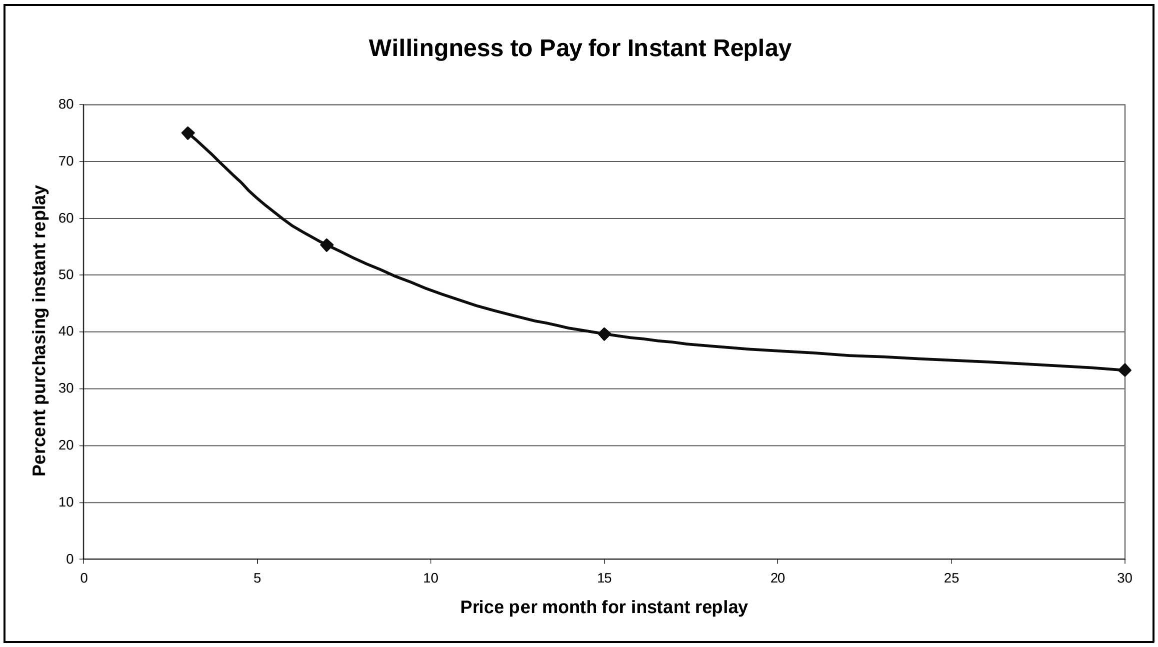

Figure 2.3

Willingness to pay for video on demand

Video on demand (VOD) services were described to consumers. Consumers were asked to imagine that VOD services were available for a monthly fee, without installation charges or long term commitments. Consumers were told that the monthly fee would be one of four dollar amounts ($8, $16, $40, and $80). They were asked whether they would subscribe to the VOD services. About 71 percent of consumers say they are willing to pay a monthly subscription fee of $8. Willingness to pay drops off rapidly, with 28 percent of consumers willing to pay $40 per month and only 6 percent of consumers willing to pay $80 per month (see Figure 2.4).

Willingness to pay for the "big package"

Finally, consumers were asked about their willingness to pay for a package of video goods and services. Consumers were asked to imagine that all of their video goods and services could be provided by a subscription service, again without installation fees or long term commitments. The subscription service would provide a large screen TV with a movie quality picture, a recordable DVD, instant replay, video on demand, and at least 100 cable channels. Consumers were asked about their willingness to pay for such a subscription service. They were presented with one of four possible monthly subscription fees ($16, $40, $80, and $160). Over three-fourths of consumers are willing to pay $40 for the all-inclusive package. About 40 percent are willing to pay $80 per month, and 13 percent are willing to pay $200 (see Figure 2.5). Valuations for the big package appear to be on the low side, given that the great majority of households are already paying $20 to $30 per month for cable or satellite TV.

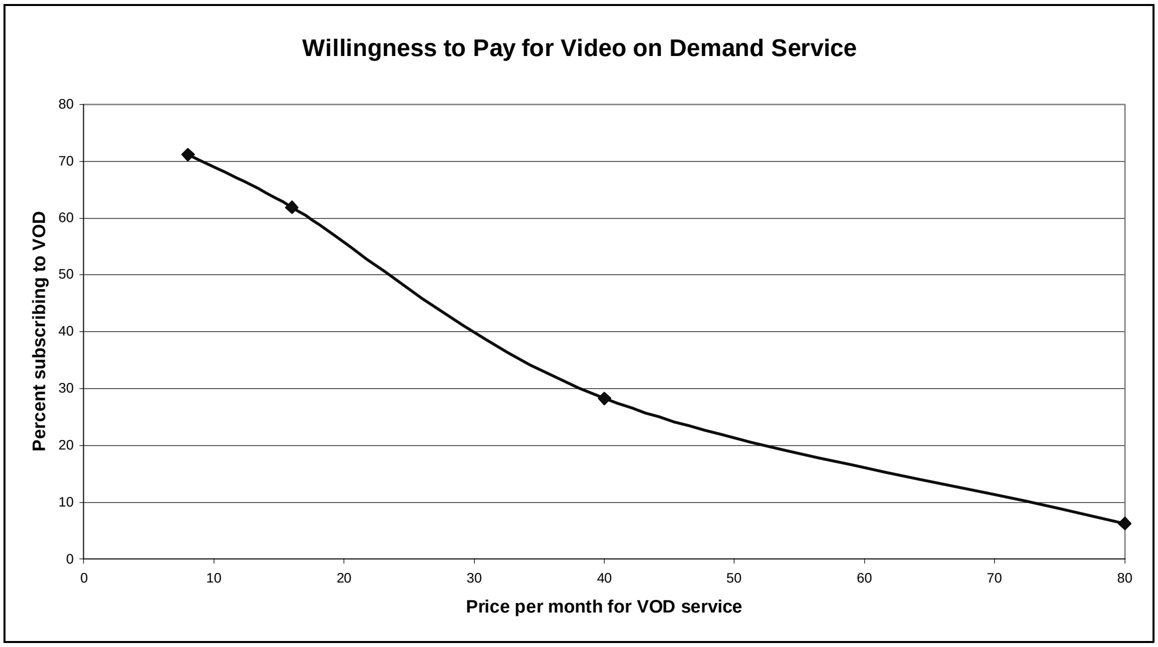

Figure 2.4

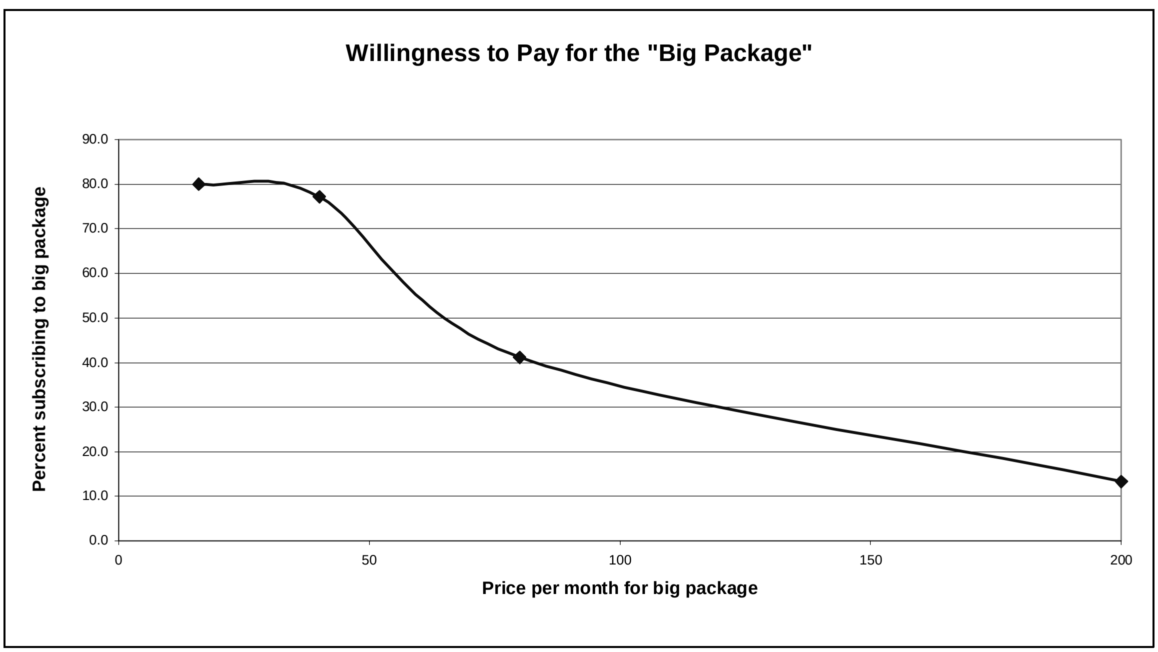

Figure 2.5

The willingness to pay assessment for the "big package" also included a second round of pricing. If a consumer answered "no" to a given price, she or he was then presented with a price half as much; if the consumer answered "yes," she or he was presented with a price twice as much. The results were generally consistent with the relationships shown in Figure 2.5. However, there are a few anomalies: for example, 77 percent of consumers are willing to pay $40 for the package, but only 63 percent are willing to pay $32. In the second-round pricing, some consumers were asked to if they would pay $400 per month - no one said "yes."

Increased time spent watching TV

Consumers were asked whether they though they would spend more time watching TV if they had the "big package" available. Only 44 percent of those responding (120 respondents) anticipate that their viewing time will increase. Among those who will spend more time viewing, the average anticipated increase is 8.5 hours.

Additional time spent watching TV must come from somewhere. Those consumers who reported they will spend more time watching TV were asked an open-ended question about what they would spend less time doing (Table 2.20). The most frequent response is active sports and hobbies, followed by other entertainment and paid work.

Table 2.20
Activities that Decrease as TV Viewing Increases

	Number mentioning	Percent mentioning
Active sports and hobbies	30	25.0
Other entertainment	22	18.3
Paid work	20	16.7
Sleep	13	10.8
House and yard work	13	10.8
Computer and Internet use	9	07.5
Reading	8	06.7
Studying	4	03.3

N = 120 = number increasing in TV viewing as result of big package.
Source: PRI consumer survey.

Summary

The consumer survey described in this chapter was successful in gathering information about:
- Respondent and household demographic and income characteristics;
- Current ownership and use of video goods and services;
- Consumer valuations of new and emerging video goods and services.

Key findings include:

- Market penetration of color TV and VCRs is almost universal.
- The great majority (80 percent) of households currently get satellite or cable TV services.
- Most consumers spend at least 11 hours per week watching television.
- People who rent videos frequently spend less time watching TV programs. On the other hand, people who rent videos frequently also spend more time going to the movies.
- Most consumers currently make only modest expenditures for video equipment and their equipment is fairly old (median age of TVs is 4 years).
- Over three-fourths of consumers claim that they are willing to pay $40 for an all-inclusive package including cable, rental of a “movie quality” TV and DVD, and advanced services such as video on demand. About 40 percent are willing to pay $80 per month, and 13 percent are willing to pay $200. Valuations for the big package appear to be on the low side, given that the great majority of households are already paying $20 to $30 per month for cable or satellite TV.

3. CONSUMER DEMAND ESTIMATES

Purpose

This chapter illustrates estimates of several types of functions describing consumer demands for selected DV goods, or for selected attributes of goods, using data from the consumer demand survey. The purpose of this exercise is to place values on changes in the prices or attributes of digital video consumer goods that may result from ATP interventions. This exercise is necessarily hypothetical, because ATP-supported DV innovations have not yet had a measurable effect on attributes or prices of DV goods actually received by consumers. Therefore we will study a relatively arbitrary selection of DV goods and attributes.

In follow-on research, the techniques described here could be tailored more specifically to goods and attributes actually affected by ATP-backed R&D. Also, changes in measured preferences could be tracked over time while new technology gets adopted by consumers. If we assume that learning is going on which affects the optimality of behavior, but does not affect “true” or biologically-derived preferences, then preferences measured after the new DV innovations are widely adopted would support a better welfare measure than would preferences measured now.

This chapter includes single equation estimates of demand functions in two forms:

- logistic regression estimates of the probability of expressing willingness purchase particular items (contingent valuation), as functions of income, family size, an assumed price, and other variables; and
- Ordinary Least Squares (OLS) regression estimates of recollected amounts purchased, as functions of income, family size, in some cases a recollected price, and other variables.

It also includes non-linear least squares estimates of the underlying utility functions, from which general equilibrium demands could be inferred, again in two forms:

- sub-utility as a function of two attributes, estimated using a discrete choice regression model over varying proportions of the attributes; and
- aggregate utility as a function of a composite DV good, time, and all other goods, using a non-linear vector regression.

The utility function would be useful in a general equilibrium measurement of DV-induced welfare change. The single equation demand function would be directly useful in a partial equilibrium (consumer surplus) measurement, or the estimated coefficients could be used to help specify a utility function.

In general, the R^2 values of the least squares models are rather low. There is a considerable amount of heterogeneity of demand for video-related entertainment goods. The R^2 values of the models can be improved by adding various proxies for taste, such as attitudinal questions about what features are especially desirable. However, these proxies may be endogenous, depending partly on income and prices, and therefore would tend to distort the measured elasticities. Moreover, DV goods are generally a “necessity,” in the sense that income shares decline with income (income elasticities are less than 1), and even the poorest of households do consume them. Consequently, demand-theoretic variables such as price, income, and family size do not explain much of the variance in demands. At the same time, demand-theoretic variables are generally statistically significant and do have the expected signs.

The age of the survey respondent is highly statistically significant in many of these regression, and the overall pattern of demands for video-related goods is observed to change with age. Unlike most attitudinal questions, age can be viewed as an exogenous proxy for differences in preferences. For that reason, we have included age of the survey respondent as a variable in most of the reported regressions. As it happens, including the age of the respondent in the model does not seriously affect estimated income and price elasticities of demand.

Logistic models of willingness to purchase

This section presents estimates of the probability of expressing willingness to purchase particular DV attributes or goods, as functions of an assumed price, income, family size, and age. Such estimates can be used in partial equilibrium estimates of the value of DV items to consumers.

Note that these estimates are not quite the same as demand functions, unless we are willing to assume that each household buys at most one of the items in question. To measure correctly specified demand functions, we could either use an additional estimate of the number of units per household, or else use some other discrete choice modeling form that allowed for multiple units, such as the Poisson model. However, income, family size, and price elasticities based on the logistic model are probably accurate enough for many purposes.

Models in this logistic regression form do tend to correctly predict a reasonable percentage of purchase choices (e.g.,70- 80 percent).[2] The predictive accuracy can be substantially increased by including attitudinal proxies for tastes measured in the survey, but again that would tend to distort the measured price elasticities. One example with included attitudinal variables is shown below (in particular, for the “big package”).

Table 3.1 contains logistic regression estimates for the following goods and attributes:

- Video on demand (VOD)
- Instant replay feature
- DVD that also records like a VCR
- Movie-like quality of TV picture
- A “big package” including all major goods and attributes addressed in the survey

[2] But note that a simple model using no information other than the percentage of positive or negative choices could still correctly predict at least 50 percent of choices.

The table shows log-linear estimates. (Results using linear rather than log-linear variables were comparable). These log-linear coefficients are directly related to elasticities; in particular, for a household which has a 50 percent probability of buying the good, the elasticity equals one-half of the corresponding coefficient.[3] In general, these estimates look reasonable. The signs are generally consistent with theory or prior beliefs: positive income and family size elasticities, negative price elasticities.

The estimated price elasticities are always negative and always highly statistically significantly different from zero (p<.0001). For families with a 50percent probability of purchase, the price elasticities vary between -.5 and -.9, depending on the particular good or attribute.

The estimated family size elasticities are generally positive but sometimes not statistically significant. For families with a 50percent probability of purchase, the family size elasticities vary between 0 and .4, depending on the particular good or attribute.

The estimated income elasticities are either positive or around zero but usually not statistically significant. For families with a 50percent probability of purchase, the income elasticities vary between 0 and .2, depending on the particular good or attribute.

In most of these cases, reported demands for DV goods declined significantly with age of the respondent (p =.03 or better). The demand for movie-like picture quality was estimated to increase with age, but the significance level was only p=.2.

Factor analysis model of video quantity aggregate

Several of the subsequent analyses will employ a proxy measure for the aggregate quantity of video-related goods consumed by the household. We used a principal components factor analysis over 11 relevant consumption quantity or quality variables to create such an aggregate. (The analysis is based purely on the correlation matrix of included variables, without regard for the relative scale of the various variables.) Results of the analysis are reported in Tables 3.2 and 3.3. The first factor is a good candidate for an aggregate consumption measure: it has a high eigenvalue, explains a reasonably high 20percent of the aggregate normalized variance of all 11 variables, and has positive and reasonably large factor loadings for each variable.

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[3] More precisely, let the logistic estimate of the probability of purchase at a given set of household attributes **x** be given by $P(\mathbf{x}) = \exp(\boldsymbol{\alpha}'\mathbf{x})/[\exp(\boldsymbol{\alpha}'\mathbf{x})+1]$. Assume **x** is in logarithmic terms (say, $x_i = \log(X_i)$). If a particular household has $P(\mathbf{x}) = .5$, then its elasticity with respect to $X_i = \exp(x_i)$ (say, η_i) is $.5\alpha_i$. More generally, elasticities decline with $P(\mathbf{x})$ according to the formula $\eta_i = \alpha_i(1-P(\mathbf{x}))$.

Table 3.1
Logistic Regression Estimates of Willingness to Pay for Selected DV Features

Predicted and observed counts of willingness to pay for video on demand (VOD)

Observed / Predicted	No	Yes	Percent Correct
No	128	20	86.49
Yes	36	79	68.70
Overall			78.71

Variables in the video on demand equation

Variable	B	S.W.	Wald	Sig	Exp(B)
Constant	7.4444	2.6751	7.7440	0.0054	
Age of respondent	-0.0516	0.0119	18.7375	0.0000	0.9497
# people in household (log)	0.5255	0.4815	1.1910	0.2751	1.6913
Household income (log)	-0.0320	0.2299	0.0194	0.8893	0.9685
Price (log)	-1.8036	0.2352	58.8119	0.0000	0.1647

Predicted and observed counts of willingness to pay for instant replay feature

Observed / Predicted	No	Yes	Percent Correct
No	87	39	69.05
Yes	35	96	73.28
Overall			71.21

Variables in the instant replay equation

Variable	B	S.W.	Wald	Sig	Exp(B)
Constant	7.4444	2.6751	7.7440	0.0054	
Age of respondent	-0.0516	0.0119	18.7375	0.0000	0.9497
# people in household (log)	0.5255	0.4815	1.1910	0.2751	1.6913
Household income (log)	-0.0320	0.2299	0.0194	0.8893	0.9685
Price (log)	-1.8036	0.2352	58.8119	0.0000	0.1647

Table 3.1 continued

Predicted and actual counts of willingness to pay for DVD that records like VCR

Observed / Predicted	No	Yes	Percent Correct
No	65	39	62.50
Yes	30	117	79.59
Overall			72.51

Variables in the equation for DVD that records like VCR

Variable	B	S.W.	Wald	Sig	Exp(B)
Constant	2.6685	2.3125	1.3316	0.2485	
Age of respondent	-0.0205	0.0102	4.0403	0.0444	0.9797
# people in household (log)	0.2894	0.4318	0.4493	0.5027	1.3356
Household income (log)	0.3773	0.2125	3.1537	0.0758	1.4583
Price (log)	-1.1355	0.1797	39.9061	0.0000	0.3213

Predicted and observed counts of willingness to pay for movie-like quality of TV picture

Observed / Predicted	No	Yes	Percent Correct
No	85	38	69.11
Yes	34	119	77.78
Overall			73.91

Variables in the equation for movie-like quality of TV picture

Variable	B	S.W.	Wald	Sig	Exp(B)
Constant	1.7759	2.2004	0.6514	0.4196	
Age of respondent	0.0127	0.0098	1.6844	0.1943	1.0128
# people in household (log)	0.4118	0.4364	0.8903	0.3454	1.5095
Household income (log)	0.2834	0.2050	1.9112	0.1668	1.3277
Price (log)	-0.9884	0.1271	60.4570	0.0000	0.3722

Table 3.1 continued

Predicted and observed counts of willingness to pay for a "big package" including all major goods and attributes addressed in the survey

Observed \ Predicted	No	Yes	Percent Correct
No	193	65	74.81
Yes	70	162	69.83
Overall			72.45

Variables in equation for "big package"

Variable	B	S.W.	Wald	Sig	Exp(B)
Constant	5.0761	1.7524	8.3906	0.0038	
Age of respondent	-0.0351	0.0073	22.9701	0.0000	0.9655
# people in household (log)	-0.0693	0.3172	0.0477	0.8272	0.9331
Household income (log)	0.1787	0.1507	1.4065	0.2356	1.1957
Price (log)	-1.3457	0.1468	84.0161	0.0000	0.2604

Alternative specification: Predicted and observed counts of willingness to pay for "big package"

Observed \ Predicted	No	Yes	Percent Correct
No	69	14	83.13
Yes	32	70	68.63
Overall			75.14

Alternative specification: Variables in equation for "big package"

Variable	B	S.W.	Wald	Sig	Exp(B)
Constant	6.5501	3.1943	4.2048	0.0403	
Age of respondent	-0.0308	0.0142	4.7075	0.0300	0.9697
Number of people in household (log)	0.0815	0.6356	0.0164	0.8980	1.0849
Household Income (log)	0.2105	0.2683	0.6159	0.4326	1.2344
Price (log)	-1.9474	0.3031	41.2880	0.0000	0.1426
Perceived DVD advantages: none	1.6797	0.8773	3.6654	0.0556	5.3639
Perceived DVD advantaged: don't know	1.5481	0.5726	7.3087	0.0069	4.7026
Perceived DVD disadvantages: higher cost	1.0645	0.4488	5.6265	0.0177	2.8995

Source: PRI.

Factor scores were estimated using the regression method. The video consumption aggregate was then defined by means of an affine transform on the first factor that set the smallest possible factor score to zero. (The consumption units are arbitrary.)

Similar factor analyses were performed over dollar expenditure data from the survey, and also over a mixture of quantity/quality and expenditure data. The results in each case were quite similar to those for quantity data alone. However, as pointed out in the next section, expenditure data is not entirely comparable to quantity/quality data, because it depends on the price paid as well as on quantity and quality. In the case of an hardware expenditure, price paid depends on the age of the equipment. Therefore including the ages of equipment in the factor analysis would appear to be desirable. When we did so, however, the signs on the ages of equipment were mixed, which raises problems of interpretation. For that reason we chose to omit expenditure data from our quantity aggregate.

OLS regression models of reported video-related purchases

We have survey data on quantity and/or quality consumed for a number of video-related goods and attributes, but in most cases no price variable is available. Since prices can be assumed to be fairly constant across the US, regressions in logarithmic terms should provide reasonable estimates of income and family size elasticities. Selected OLS results for quantitative purchases are shown in Table 3.4, beginning with the video quantity aggregate described above.

Table 3.2
Factor Analysis of Video-related Consumption Quantities:
Eigenvalues and Total Variance Explained

Component	Eigenvalue	% of Variance	Cumulative %
1	2.259	20.536	20.536
2	1.523	13.842	34.379
3	1.232	11.199	45.578
4	1.100	9.997	55.575
5	.930	8.454	64.029
6	.814	7.404	71.432
7	.801	7.282	78.714
8	.720	6.548	85.262
9	.663	6.023	91.285
10	.622	5.658	96.943
11	.336	3.057	100.000

Source: PRI.

Table 3.3
Factor Analysis of Video-related Consumption Quantities:
Component Matrix

Consumption variable	Component			
	1	2	3	4
Household has Internet access at home	.492	.145	-.047	.399
Household has working color TV	.317	.051	.685	-.073
Household gets satellite TV	.528	-.630	-.114	.044
Number of channels with good reception	.748	-.441	-.126	.063
Household gets premium channels	.631	-.067	-.230	-.078
Screen size of best color TV	.544	.334	.169	-.315
Household has HDTV	.273	.489	-.049	-.488
Household has DVD player	.454	.413	-.169	-.192
Household has VCR	.241	-.044	.670	.249
Frequency of going to movies (times per year)	.175	.383	-.400	.410
Frequency of renting videos (times per year)	.118	.484	.103	.564

Source: PRI.

Other variables in the survey describe dollar expenditures (as opposed to quantity or quality variables.) Assuming constant prices across locations and purchase times, difference in expenditure represent quality differences rather than price differences. Therefore a regression of log-expenditure on log-income for a particular item tends to reveal the income elasticity of quality. OLS regressions of this type are shown in Table 3.5.

In regressions for expenditures for hardware, age of the appliance is an important variable and is included in the regressions where available. Both nominal and real prices of video-related hardware have tended to decline over time, while quality generally increased, so the age variable is positively related to price. However, age of hardware is also a proxy for preferences – video lovers are likely to be early adopters, but they also purchase new equipment more often than those with weaker preferences. Therefore the coefficient of hardware age cannot be interpreted as a price elasticity.

In these regressions, hours worked by the respondent is often a statistically important predictive variable which has an independent, generally positive effect on consumption. Work hours can be viewed of as exogenous, or at least predetermined, in the sense that for most people the decision to work would expected to take strong priority over the video consumption decision. Therefore it is feasible to view it, like age, as a proxy for tastes or preferences (or at least as an independent conditioning variable). This variable usually does not affect the measured elasticities very strongly. We have included respondents' work hours in the regressions reported in this section. Estimated elasticities with respect to the respondent's hours of work are generally small, ranging from around 0 to .1. About half are significant with $p<.05$.

Hours worked by other members of the household tends to have an effect in the same direction as hours worked by respondent, but the effect is even smaller and statistically less significant. This variable is not included in the reported regressions.

Gender and home ownership are two predetermined predictive variables that are statistically important in some but not all models. Home ownership and female gender both tend to reduce video-related consumption. In some cases, including home ownership in the model tends to increase measured income elasticities by .1 or .2. We have omitted both variables from the exhibited regressions.

In the model for frequency of attending movies, a price variable was available and is included. This variable measures average ticket price when attending movies. Since the ticket price does not include transportation or extras such as popcorn and soda, it does not fully reflect differences in the full price of the movie experience. Therefor the measured ticket price elasticity of -.5 probably understates the "full-price" elasticity in terms of absolute value.

In these regressions, the income elasticities are always positive and almost always significant with $p<.05$. The elasticities vary between .1 and .6, but most are .3 or below.

The family size elasticities are either positive, or insignificantly negative ($p>.05$). The measured elasticities range widely, from .1 to .9 among those are significant.

The estimated effect of age of the respondent on purchases is either negative, or insignificantly positive ($p>.05$).

The observed pattern of elasticities for reported consumption is reasonably consistent with that for expressed willingness to pay. Income elasticities are generally between .1 and .5, price elasticities are generally between .5 and 1, while family size elasticities vary more widely between 0 and 1. Video-related consumption declines with age and increase with hours of work. The rough consistency of these findings across various video-related goods and characteristics suggests that an approximate welfare valuation of any new DV innovations that achieve wide popularity could be based on average or typical elasticities for existing video goods.[4]

[4] In addition, similar results which can be obtained using logistic regressions on the binary quantity consumption variables (i.e. presence or absence of DVD, VCR, Internet access, premium channels), but these are not shown here.

Table 3.4
OLS Regression Estimates for Video-Related Quantities

Dependent variable = aggregate video quantity (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	.033	.573		.058	.954
# people in household (log)	.309	.110	.181	2.801	.005
# hours worked by respondent (log)	.050	.023	.136	2.156	.032
Household income (log)	.074	.054	.082	1.381	.168
Age of respondent	-.002	.003	-.041	-.604	.546

Dependent variable = screen size (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	1.644	.425		3.867	.000
# people in household (log)	.203	.082	.160	2.470	.014
Age of respondent	.001	.002	.038	0.559	.577
Household income (log)	.111	.040	.167	2.794	.006
# hours worked by respondent (log)	.035	.017	.129	2.048	.041
Ownership of dwelling	.144	.067	.140	2.135	.034

Dependent variable = number of TV channels (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	-.096	.869		-.110	.912
# people in household (log)	.618	.168	.234	3.686	.000
Age of respondent	.006	.004	.093	1.393	.165
Household income (log)	.235	.081	.169	2.891	.004
# hours worked by respondent (log)	.095	.035	.167	2.698	.007

Table 3.4 continued

Dependent variable = frequency of going to movies (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	2.056	1.231		1.671	.096
# people in household (log)	-.330	.222	-.095	-1.489	.138
Age of respondent	-.028	.005	-.355	-5.242	.000
# hours worked by respondent (log)	.018	.047	.024	0.389	.698
Household income (log)	.222	.109	.121	2.035	.043
Price of movies	-.507	.311	-.095	-1.631	.104

Dependent variable = frequency of renting videos (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	2.814	1.238		2.273	.024
# people in household (log)	.076	.239	.019	.320	.749
Age of respondent	-.037	.006	-.403	-6.357	.000
# hours worked by respondent (log)	.069	.050	.080	1.369	.172
Household income (log)	.102	.116	.049	.882	.378

Source: PRI

Table 3.5
OLS Regression Estimates for Video-Related Expenditures

Dependent variable = expenditures on VCR (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	2.630	.807		3.259	.001
# people in household (log)	.164	.156	.068	1.050	.294
Age of respondent	-.085	.004	-.153	-2.241	.026
# hours worked by respondent (log)	-.005	.033	-.009	-.148	.882
Household income (log)	.225	.075	.177	2.987	.003
Age of VCR (years)	.0006	.017	.219	3.797	.000

Table 3.5 continued

Dependent variable = expenditures on DVD player (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	-3.309	1.827		-1.811	.071
# people in household (log)	.552	.352	.100	1.571	.117
Age of respondent	-.025	.008	-.200	-2.995	.003
# hours worked by respondent (log)	.010	.074	.008	.131	.896
Household income (log)	.369	.171	.126	2.163	.031
Age of DVD player (years)	.908	.287	.177	3.165	.002

Dependent variable = expenditures on best color TV (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	2.275	1.128		2.016	.045
# people in household (log)	.218	.217	.066	1.004	.316
Age of respondent	.010	.005	.133	1.914	.057
# hours worked by respondent (log)	.102	.046	.143	2.232	.026
Household income (log)	.258	.105	.149	2.447	.015
Age of best color TV (years)	-.0018	.018	-.057	-.974	.331

Dependent variable = expenditures on cable TV (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	-1.571	1.636		-.961	.338
# people in household (log)	.031	.316	.006	.097	.923
Age of respondent	.004	.008	.040	.574	.567
# hours worked by respondent (log)	.098	.066	.096	1.474	.142
Household income (log)	.325	.153	.130	2.120	.035

Table 3.5 Continued

Dependent variable = expenditures on satellite TV (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	-1.805	1.220		-1.480	.140
# people in household (log)	.875	.235	.245	3.718	.000
Age of respondent	.0096	.006	.117	1.689	.092
# hours worked by respondent (log)	-.001	.050	-.001	-.023	.982
Household income (log)	.076	.114	.040	.664	.507

Dependent variable = expenditures on Internet (log)

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	-6.488	1.328		-4.886	.000
# people in household (log)	.891	.256	.212	3.476	.001
Age of respondent	-.000	.006	.000	-.002	.999
# hours worked by respondent (log)	.134	.054	.147	2.479	.014
Household income (log)	.618	.124	.278	4.967	.000

Source: PRI

Modeling the consumption of time

An individual's consumption of video experiences requires two kinds of resource expenditure: dollars and personal time. Of the two, time is far more significant than dollars for measuring the net welfare costs and benefits of a DV innovation. This can be illustrated using a simple calculation. Survey respondents reported watching an average of 15 hours of TV per week. Assuming a relatively modest time value of $10/hour, that amounts to some $150 worth of weekly time expended on TV, or more than $7,000 per year. In contrast, survey respondents reported total variable costs for surveyed items (movies, Internet and cable rental, and so) averaging about $54/month, or about $71/month when estimated hardware depreciation and carrying costs are added in. (Computer and monitor costs were not surveyed and are not included). That amounts to less than $900/year, or less than 1/7 of the value of time.

It follows that video-related welfare measures based on dollar expenditures alone are not very meaningful. It is important to measure time consumption as well.

Because of practical limitations in the length of a telephone interview, the survey data do not include all the information that might be relevant. We constructed a simplified model of demand for TV time based on the following assumptions:

- Individuals in the household view the opportunity cost of time for all uses of time as equal to the average household wage rate.
- Average household wage rate can be approximated as household income divided by total paid hours of work performed by household members.
- Hours of work is a predetermined conditioning variable.
- The effect of non-labor income on time demand can be ignored. (Total household income cannot appear in the model because it is co-linear with the number of hours worked and the wage rate. The survey did not ask about non-labor income.)

Results of the model are given in Table3.6. The estimated wage rate elasticity is around -.1; family size elasticity is around -.3; and work hours elasticity around -.1. However, TV watching increases with age of the respondent. Notably, these elasticities and effects are always opposite in sign to those for consumption of market goods. This suggests that a kind of substitution is going on between the chosen number of hours for TV watching hours and the chosen quality of video-related goods purchased from the market.

In particular, all these signs of effects can be explained according to a simple pattern: when time becomes more scarce and more valuable, individuals watch TV less but demand a higher quality of experience when they do watch. Time becomes scarcer and more valuable as the wage rate increases, as the family size increases (e.g., because family size is positively correlated with numbers of dependents per adult), and as work hours increase. On the other hand, retired people on average have considerably more free time than others, and also tend to have a higher age, so in gross average terms, time grows less valuable with age.

In variant regressions, we found that adding other variables had little impact on the estimated elasticities. After controlling for the measured elasticities, males watch about 20 percent more TV than females and their elasticity of TV time with respect to video-related expenditure is about +.3. Home ownership and work hours of other household members had very little estimated effect on TV hours.

The positive elasticity of TV time with respect to video-related expenditure seems to imply that time and market goods are complements, not substitutes. That conclusion would be incorrect. Video expenditure, unlike other variables discussed above, is endogenous. Moreover, a variety of data convinces us that preferences for video experiences are highly heterogeneous. It follows that video expenditure acts, in part, as a proxy for the degree of desire for video experiences; *ceteris paribus*, higher desire leads both to higher dollar expenditure and to higher time expenditure. This interpretation is confirmed by the fact that adding other proxies for preferences to the model reduces the expenditure elasticity to a point insignificantly different from zero (regressions not shown).[5]

Since prices are approximately constant across survey respondents, the model that includes video expenditures can be interpreted as a demand for market goods in terms of time. The substitution effect between time and market goods then raises some questions for welfare evaluation. In the usual partial equilibrium framework, household welfare gains from a DV innovation would be estimated as the increased consumers surplus (e.g., the area between the demand curve for an appropriately chosen video aggregate and the price paid). But two kinds of consumer surpluses are potentially available: one denominated in dollars paid, and one denominated in terms of time used. Even if we can translate time into dollars using a marginal utility of time (such as the wage rate), it would be wrong to add up the two types of consumer surplus. By conventional argument, the demand curve for market goods already includes the value of all effects on time allocation and all other markets (see e.g., Mishan (1973), Chapter 6). However, the converse is also theoretically true - correctly specified consumer surplus in terms of demand for goods in terms of time used could also be used to estimate welfare, and it would include effects in all other markets. The disproportion of values between $7000 and $900 per year suggests that time allocation could potentially provide a more accurate measure of welfare than market allocation. Even better, of course, would be to combine the two sources of information. This is best done by estimating a utility function in a general equilibrium framework, as discussed further below.

Table 3.6
OLS Regression Estimates for TV Viewing Time

Independent variables	Unstandardized Coefficients B	Std. Error	Standardized Coefficients BETA	t	Sig.
Constant	3.197	.375		8.515	.000
# people in household (log)	-.273	.128	-.134	-2.129	.034
Age of respondent	.005	.003	.114	1.688	.092
# hours worked by respondent (log)	-.082	.027	-.186	-2.981	.003
Household income (log)	-.125	.085	-.085	-1.469	.143

Source: PRI.

[5] For example, the residual from a regression of video-related expenditure on all the various exogenous variables used in this chapter would be expected to be a better proxy for tastes than raw expenditure; and in fact it is a highly significant, positive predictor of TV time and does reduce the raw expenditure co-efficient to insignificance. Also, various attitudinal questions about desired features greatly reduce the importance of the expenditure variable, without having much effect on estimated demand-theoretic elasticities.

Nonlinear estimate of sub-utility function for picture size and quality

We performed an experimental exercise that illustrates a method of recovering utility from a series of pairwise comparisons. That is, survey respondents were asked to chose between hypothetical pairs of video attribute bundles. These pair-wise choices can be used to estimate the dependence of utility on the surveyed attributes, under the assumption that utility is nested (e.g. U = U(G(surveyed attributes), other variables)). The advantages of this informational approach are:

- No questions are asked about trade-offs between money and hypothetical attributes. Instead, attributes are compared directly to attributes, holding all other conditions constant. In the absence of previous consumption experience with the given attributes, the latter comparison is more balanced and likely to be easier for the consumer to process.
- No particular assumptions about functional form of utility are implied by the data structure. In contrast, if information is restricted to a series of trade-offs between attributes and money, then utility is recoverable only under strong conditions such as separability of attributes.

The disadvantage of this approach is that much more information is needed in order to recover the utility function. With N attributes there are N measurable trade-off curves between attributes and money; while there are N(N-1)/2 trade-off curves between pairs of attributes.

In particular, respondents were asked to chose between various crossed combinations of:

- picture screen size: 27 inches, 36 inches, or 49 inches; and
- picture quality: conventional picture (represented as: picture quality = 0) versus "picture quality as crisp, clear, and colorful as what you would see in a movie theater" (represented as: picture quality = 1)

To estimate the relative utility of picture size and quality, we assume that sub-utility G is given by the CES functional form:[6]

39. $G = \alpha*(\text{picture quality})^{\gamma} + \beta*(\text{picture screen size})^{\gamma}$

To estimate he parameters, we use a non-linear logistic regression. That is, for bundles of attributes b_1 and b_2 we set define a choice variable $C(b_1, b_2)$ defined as:

$$C(b_1, b_2) = \begin{cases} 1 \text{ if } b_1 \text{ is preferred to } b_2 \\ 0 \text{ if } b_2 \text{ is preferred to } b_1 \end{cases}$$

[6] In the restricted context with only 3 varieties of screen size and 2 varieties of picture quality, assuming CES is without loss of generality. (Proof of this depends on the fact that, since picture quality is a dummy variable, the exponent γ has no effect on it.) Moreover, choice of linear screen size versus area (or any other power of linear screen size) is also without loss of generality, since any exponent of the linear dimension would be absorbed into the γ coefficient.

$$= \begin{cases} 1 \text{ if } G(b_1) > G(b_2) \\ 0 \text{ if } G(b_2) > G(b_1) \end{cases}$$

$$= \begin{cases} 1 \text{ if } \alpha*(\text{pic.quality})_1 + \beta*(\text{scrn. size})_1^{\gamma} > \alpha*(\text{pic. quality})_2 + \beta*(\text{scrn. size})_2^{\gamma} \\ 0 \text{ if } \alpha*(\text{pic.quality})_1 + \beta*(\text{scrn. size})_1^{\gamma} < \alpha*(\text{pic. quality})_2 + \beta*(\text{scrn. size})_2^{\gamma}. \end{cases}$$

The non-linear logistic function used to approximate $C(b_1, b_2)$ is:

40. $$F = \exp[\alpha*(\text{pic.quality})_1 + \beta*(\text{scrn. size})_1^{\gamma} - \alpha*(\text{pic. quality})_2 - \beta*(\text{scrn. size})_2^{\gamma}] / \{1 + \exp[\alpha*(\text{pic.quality})_1 + \beta*(\text{scrn. size})_1^{\gamma} - \alpha*(\text{pic. quality})_2 - \beta*(\text{scrn. size})_2^{\gamma}]\}.$$

The model can be improved by expanding α, β, and γ as functions of exogenous proxies for preferences. In particular, the estimate reported in Table 3.7 below expands

41. $\alpha = \alpha_0 + \alpha_1 * \text{gender} + \alpha_2 * \text{age}.$

The low R^2 is typical of all of the consumption models estimated in this chapter. α, α_1 and α_2 are reasonably well determined, but the standard errors on β and γ are rather large. This is related to their highly correlated estimates (with an asymptotic correlation of .9981). The underlying reason is that the particular tradeoffs asked on survey question were poorly chosen leading to very limited variation in the sample. About 90 percent of respondents preferred the movie-quality picture over the larger screen for the particular screen size choices given. Presumably this question would have worked better using a comparison between, for example, 19 inch and 49 inch screens.

Table 3.7
Non-linear Regression Estimate for Screen Size and Quality trade-off

Dependent variable = Choice of attributes

Source	DF	Sum of Squares	Mean Square
Regression	5	11.01	2.203
Residual	792	65.99	.08332
Uncorrected total	797	77.00	
Corrected total	796	69.56	

R squared = 1 - Residual SS / Corrected SS = .0514

Table 3.7 continued

Parameter estimates

Parameter	Asymptotic Estimate	Std. Error
α	-3.94	.625
α1	.419	.215
α	-.0148	.0071
β	-180.0	584.0
γ	-1.017	1.244

Asymptotic Correlation Matrix of the Parameter Estimates

	α	α1	α2	β	γ
α	1.0000	-0.2170	-0.4230	0.1963	0.1442
α1	-0.2170	1.0000	-0.0170	-0.0051	-0.0029
α2	-0.4230	-0.0170	1.0000	0.0004	-0.0018
β	0.1963	-0.0051	0.0004	1.0000	0.9981
γ	0.1442	-0.0029	-0.0018	0.9981	1.0000

Source: PRI

Non-linear estimate of utility for time and market goods

As noted previously, it would be very useful to form a welfare measure for video goods that uses information equally from choices in the video goods market and from choices for time allocation. In this section we estimate aggregate utility for a video composite good, video viewing time, and all other goods. The assumed functional form is a variant of one developed in Burress *et al.* (2000, Appendix 3.1). In particular, indirect utility is assumed to be given by

(4) $V = [(\alpha + F)/(1 + F)](W_0T_0^* + Y)H/[A(\mathbf{P})B(\mathbf{W})] + G(\mathbf{P}) + L(\mathbf{W})$, where

(5) $F = F(\mathbf{P}, \mathbf{W}) = [P_{VID}/C(\mathbf{P})]^{\beta}[W_{VID}/D(\mathbf{W})]^{\gamma}$ and

(6) $G = G(\mathbf{P}) = P_{VID}/E(\mathbf{P})$.

In the above:

- A(.), B(.), C(.), D(.), E(.), and L(.) are homogeneous degree 1 functions of non-video prices or time costs, but these functions will be treated as constants in the present application, because time costs are set to 1 and non-video prices do not vary in our dataset.
- **P** is a vector of prices of goods and/or attributes.
- **X** is a vector of quantities of goods and/or attributes.
- W_0 is the wage rate.
- T_0 is labor hours, which is assumed fixed at T_0* and is not included in the time budget. (It is empirically reasonable to assume that the labor supply is fixed, provided that housework is included in the definition of labor.[7])
- H is the total time available (except T_0).
- **W** is a set of relative psychic time costs for various activities. After optimizing (using Roy's identity), we will set $W_i = 1$ for all i>0 so that non-work hours add up to H. (In a more complex application with detailed time use data, the W_i could be parameters of the fit, but in the current application they are purely formal constructs.)
- Y is non-labor income (and hence ($W_0T_0^* + Y$) is total household income.)
- **T** is a vector of time allocations to activities.
- All Greek characters are free parameters.

This functional form has certain desirable features:

- since V is linear in income, changes in V are already in a money metric.
- dollar expenditures for the video commodity fall with the video price P_{VID}.
- time expenditure can either fall or rise with Video price P_{VID}.
- utility is bounded even when video price P_{VID} approaches 0 or ∞. (This is important so that we do not get an unrealistically infinite consumer surplus either for introducing new goods, or for dropping the price to zero.)

In this formalism there are two independent constraints on consumption (time and money), and hence two simultaneous kinds of optimization. (See Burress *et al.* (2000, Appendix 3.1) for further details.) After using Roy's identity for each type of optimization and absorbing various constants and prices that do not vary in the data set into identifiable parameters, the demands for video goods and video viewing time are given respectively by:

(7) $X_{VID} = \beta F (\alpha - 1)/[(\alpha + F)(1+F)](W_0T_0 + Y)/P_{VID} + \tau(1+F)/(\alpha+F)$, and

(8) $T_{VID} = \delta F /[(\alpha + F)(1+F)] + \omega(1 + F)/[(\alpha + F)(W_0T_0^* + Y)]$, where

(9) $F = \eta P_{VID}^{\beta}$.

[7] It follows from Roy's identity that (4) provides a simple indirect utility representation for the fixed labor supply.

Because video quantity X_{VID} should increase as video price P_{VID} falls, we assume $\alpha>1$ and $\beta*\eta>0$. δ, ω, and τ are unconstrained.[8] To estimate the parameters of these demand functions, we made use of several different variables in the survey data set, including both recollected actual consumption choices and hypothetical (contingent evaluation) choices :

- Respondent were asked whether they would be willing to purchase the "big package" as a particular (randomly chosen) hypothetical rental price. Then the rent was varied by a factor of 2 (downward if they rejected the hypothetical purchase, upward if they accepted it), and they were asked the same question again.
- Respondents were asked how many hours they watch video now (i.e. given their existing video equipment.)
- Respondents were asked how many additional hours (if any) they would watch video if they had obtained the "big package".
- We also used the video consumption quantity composite defined from the factor analysis discussed above as a key datum.

We also made several additional assumptions, including:

- that a video quantity aggregate is a valid consumption aggregate;
- that the "big package" could be viewed as belonging to the same quantity aggregate, but with a larger value (the larger value was treated as a free parameter of the least squares fit, denoted θ);
- that the existing video composite consumed by the household could be viewed as having been purchased at a price that was constant across households (so that quantity variations represent variations in income or family size or preferences; the fixed price was taken to be the average ratio of estimated video expenditures to amount of the video quantity aggregate);
- that the relevant rental cost of the "big package" corresponding to the hours of video viewing when the package is present could be estimated as:
    - the average of the two hypothetical rents presented to the respondent, in cases where the respondent accepted one price and rejected the other
    - ½ of the lesser rent, in case where respondent rejected both prices
    - twice the higher rent, in cases where respondent accepted both prices; and
- that the relevant price of the "big package" consisted of the marginal change in cost (paying the hypothetical rent presented to the respondent, but discontinuing existing variable expenditures such as cable rental), divided by the marginal change in quantity (parameter for quantity-value of the "big package", less existing video aggregate).

The parameters were estimated using a non-linear vector least squares algorithm. The loss function for the fit (i.e. the sum of square residuals to be minimized) was a weighted aggregate of three types of squared residuals, corresponding to three aspects of the model, namely:

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[8] This can lead to negative quantities of video goods and/or video time for certain combinations of parameter values and independent variables. In particular, if there are any negative parameter values then the assumed functional form is only locally valid.

- a non-linear logistic regression function that estimates the dummy variable for purchase/no purchase of the "big package" at the hypothetical rental price. (The squared residual was weighted by 1/.25, where .25 is the expected variance of the logistic function residual in the case of zero information.)
- an ordinary residual for the existing quantity of video composite actually consumed. (The squared residual was weighted by the reciprocal of the variance of the video composite.)
- an ordinary residual for viewing time, both before and after obtaining the "big package." (The squared residual was weighted by the inverse variance of viewing time.)

Results of for a particular set of parameter estimates are given in Table 3.8. As usual in this chapter, the statistical fit was not very precise. Defining R^2 = 1- SSR/SST (i.e., 1 - sum of squared residuals divided by total sum of squares), then R^2 = .113 for the existing video quantity aggregate, and R^2 = .030 for the hour of TV watched.[9] The local asymptotic standard errors reported Table 3.8 significantly understates the global error, because multiple local minima exist for the loss function; we have selected this particular minimum on grounds of plausibility (the others occurred at various corner solutions). However, some of the parameters are estimated in log terms; so the standard errors need to be interpreted carefully.

The fit can be improved by including some dependence of parameters on age, gender, or work hours, and also by variables related to attitudes and preferences, but these results are not reported here.

We would anticipate that future *ex post* data sets would produce substantially better fits to the model, for several reasons:

- no contingent evaluation consumption data would be needed. (These data are generally believed to be substantially less accurate than recollected consumption data.)
- fewer distinct variables would need to be mixed in the loss function.
- data would replace the free parameter for θ, i.e., the video quantity-equivalent of the big package.

The most interesting result is the estimate of α-1, a parameter that represents the utility value of setting the video aggregate price to zero, expressed as a share of income.[10] According to the model, the value of receiving free use of unlimited quality and quantity of video goods would equal around 5 percent of household income.

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[9] This is a conventional definition of R^2, but it does not necessarily have asymptotic statistical properties like the R^2 that is defined for an OLS regression. Due to the complex loss function used here, the mean residual is somewhat different from 0, and the residuals are not exactly orthogonal to the predicted values.

[10] In this model, this would correspond to the maximal utility that could be afforded by obtaining an infinite extension of the video quantity into all possible video entertainment services (at least to the extent that those services formed a natural extension of the existing aggregate.) But of course, such an extrapolation would go well beyond the existing data and can not be taken seriously. Instead, $(\alpha-1)(W_0T_0^* + Y)$ should simply be viewed as an extreme upper bound on the utility value of receiving the big package for free.

The estimate for the ω parameter implies that individual video watching will fall by about 1 hour/week when household income increases from $32500/year to $65000/year. The estimate for δ implies that individuals with even the highest incomes (but average preferences) watch at least 16 hours per week.

The estimate for β implies a sample median price elasticity for quantity demanded of around -.6. The estimate for θ implies that the "big package" has a quantity composite index about 20 percent higher than the maximum currently available goods observed in the sample. The estimate for τ implies that the video composite good is distinctly a "necessity;" even the poorest household with average preferences would consume at least 1/5 of the maximum observed level, and yields a median income elasticity around 0.7.

Table 3.8
Non-linear Regression Estimate
for Utility of Video Time, Video Quantity Composite, and Other Goods

Parameter estimates

Parameter	Asymptotic Estimate	Std. Error
$\ln(\alpha)$	-3.09	.423
$\ln(\beta)$	-3.39	85.9[11]
$\ln(\eta)$	-5.21	.392
δ	3010	763
ω	65100	187
θ	7.96	.780
τ	1.214	.0227

Note: β and η were estimated to have negative signs

[11] The distribution of $\ln(\beta)$ is highly non-normal, so its standard error is misleading. A 95 percent trimmed confidence interval was estimated by the bootstrap method as [-51.7, +2.50].

Table 3.8 continued

Bootstrap Correlation Matrix of the Parameter Estimates

	ln(α)	ln(β)	ln(η)	δ	ω	θ	τ
ln(α)	1.0000	0.0093	-0.9535	0.7728	0.0088	-0.0769	0.2730
ln(β)	0.0093	1.0000	0.0343	0.0079	-0.0724	0.0910	-0.0194
ln(η)	-0.9535	0.0343	1.0000	-0.8081	0.0026	0.1255	0.4310
δ	0.7728	0.0079	-0.8081	1.0000	-0.0948	-0.0697	0.5550
ω	0.0088	-0.0724	0.0026	-0.0948	1.0000	0.0237	0.0461
θ	-0.0769	0.0910	0.1255	-0.0697	0.0237	1.0000	0.0823
τ	0.2729	-0.0194	-0.4314	0.5548	0.0461	0.0823	1.0000

Source: PRI.

Conclusions

There is an extremely high degree of heterogeneity in preferences for video-related goods. Nevertheless, single equation demands for video goods present a consistent pattern of elasticities in the general neighborhood of .3 for income, -.7 for prices, and .05 for hours of work time. Family size elasticities center on .5 but seem to vary more widely than other elasticities. Demands for video goods fall with age. Absent more specific data, these stylized elasticities could provide a reasonable basis for measuring the economic value of new DV innovations.

However it is important to look at time use as well as demand for market goods. Elasticities for video time use are generally opposite in sign to those for video market goods, and the opportunity cost of time (proxied by the average household wage rate) has a negative elasticity. The pattern here is that all characteristics that make personal time more scare or more valuable, tend to reduce video viewing time but tend to increase expenditures on video market goods. We might crudely characterize this behavior as tending to hold the quality-adjusted amount of video experience constant when the opportunity cost of time changes.

Building a more detailed picture of video consumption could be extremely data intensive. We have demonstrated a method of pair-wise comparisons between bundles of attributes that could be used to build up a very detailed utility function, but the survey costs needed to support this method would be quite expensive. We have also demonstrated a much more aggregative indirect utility approach that seems to have some promise.

4. EVENT STUDY OF DV PATENT SPILLOVERS

Introduction

"Event studies" are used in economics and finance to estimate the impact of discrete events on the market valuations of traded firms or groups of firms. For example, researchers may investigate the impact of mergers or of a changes in corporate management. An underlying assumption in an event study is that impact of the event is reflected within a narrow time window surrounding the event date. An overview of the "event study" methodology is provided by MacKinlay (1997). The key elements of an event study are:

- Identification of a set of related events that may affect firm valuations. The events must be associated with a date or range of dates on which they occur.
- Specification of a "window" or time period during which effects of the events are expected to materialize.
- Estimation of "normal" returns (percentage changes in prices) for firms that may be affected by the events. The normal return for a firm is predicted by an equation relating the firm's return to the overall market return and other variables. It is estimated using data for time periods excluding the chosen window. MacKinlay (1997) discusses alternative forms of the equation to estimate normal returns.
- Estimation of "abnormal" returns during the event window. The abnormal return is the difference between the actual stock market return and the predicted normal return.
- Testing of abnormal returns to see if the null hypothesis (no impact) can be rejected.

This chapter uses an event study approach to try to estimate spillover effects of digital video patents.

Results from previous project work

In our earlier work (Burress *et al.,* 2000), we used an event study approach to detect the impacts of patents on digital video firms. We found that the issue of a patent related to digital video increases the market value of the innovating firm. Our analysis was limited to publicly traded firms with market valuations under 13 billion. We estimated results for a number of different models, and found that, depending on the model, a patent issue was associated with an increase in the market price of the firm of about 3 to 4 percent. As discussed in our previous work, the effects do not seem to be artifacts of stock market price patterns.

We continue the study of patents in this chapter. We use patents as an indicator of innovation and ask "how does the announcement of a patent for a firm affect the valuation of rival firms within the same industry?" On average, does information about the innovation of one firm enhance the value of other firms or decrease their value?

To the best our knowledge, only one other researcher (Austin 1993, 1994a, 1994b) has used an event study approach to address this issue of spillovers. Austin estimated the effect of patents on innovating firms in the bio-technology industry. More importantly, Austin estimated spillover effects across firms in the industry; that is, he estimated the impact of patent announcements on firms related to the innovating firms. Austin found significant positive effects of patent grants on innovating firms and small negative effects on rival firms. We adopt Austin's event study approach (although not his exact models of returns) to examine spillover effects in the digital video industry.

Identifying key patents

Following Austin (1994a), we define "key" patents as those patents that have been cited frequently in the years after their issue. We downloaded data from U.S. Patent and Trademark Office (2000) that contains brief patent abstracts and information on patent titles, assignment numbers, classifications, patent owners, dates, and patents cited. The data extends from September, 1996 through June, 2000. We developed a list of key patents as follows:

- We searched the data base for any patents that contained the terms "digital" and "video" in either the title or abstract fields. The procedure yielded 1590 DV patents.
- We then searched our database for any patents that cited the patents on digital video list. The data for each patent on the DV list was supplemented by a count of later patents citing the original patent. About half of the patents (814) were cited at least once. We also created a field for "citations per year" to adjust for the various ages of the patents on the initial list.
- We sorted the list by two related criteria - total patent citations and citations per year.
- We then decided on a somewhat arbitrary cut-offs for "key" patents: at least 6 citations total and at least 2.7 citations per year.
- We scanned the patents that met these criteria for self citations. We removed for patents from the key patent list because the majority of their citations were from within the same firm. The final list contains 63 patents. Appendix 4.1 contains a list of key patents and dates.

Bridge between key patents and "events" for digital video firms

To detect spillovers, we want to see whether an event that takes place at the innovating firm (the firm receiving the key digital video patent) creates impacts on other firms (in this case, other digital video firms). To put this into the event study structure, we need to create event-records for other digital video firms (other than the firms receiving the key patent) on days for which key patents are issued. We then need to test whether the issue of key patents has a significant impact on firms other than the initial innovator.

Technically speaking, we created the "cross-product" of two different lists of firms, combining each item on list A with every item on list B. Here List A is the list of 63 key patents. List B is a list of digital video firms (47 firms). For this pilot project, we used the same list developed in Burress *et al.* (2000). The firms are publicly traded and are small to medium in size (our earlier work found that patent effects get "swamped" by the noisiness of returns for large firms). Each firm on the list has been issued at least one patent in the digital video area.

The initial cross product list contains 2961 entries. The entries were reduced using the following procedures:

- We eliminated records where the key patent firm and the "other" digital video firm were the same. These events represent direct effects of a patent, not spillover effects.

- We eliminated records where the key patent had no patent class in common with the other digital video firm (note that more than one patent class could be associated with the other digital video firm). Our reasoning was that the match of patent classes indicated that the firms were doing, or at least had done, research in a topic area related to the key patent.

The final list of potential spillover events consisted of a list of key patent dates matched with firm numbers that were most likely to be affected by the key patents. There were 516 such matches.

Event study models

In order to carry out the event study, we made use of specialized software called Eventus (Cowan Research, 1998). The Eventus software reads stock market return files and implements an event study based on options chosen by the user.

MacKinlay (1997) points out that when events take place on the same dates, the usual assumptions used to create tests of abnormal returns in event studies will not hold. In particular, covariances across securities experiencing an event are probably non-zero. The standard practice in this case is to combine those securities that are likely to be correlated into a single portfolio. We followed this practice. The event study results are estimated using 42 portfolios of firms, where each portfolio consists of firms affected by a patent on the same date.

We experimented with two different models of normal stock market returns:

- The straightforward market model. In this model, an individual firm's returns are estimated as a simple linear relationship to the overall market return. Technically,

  $R_{jt} = \alpha_j + \beta_j R_{mt} + \varepsilon_{jt}$,

  where R_{jt} is the rate of return for stock j on day t, R_{mt} is the market rate of return for the same day, and ε_{jt} is a homoskedastic random variable with mean zero and no autocorrelation. α_j and β_j are regression parameters.

- The market model with Scholes-Williams adjustments. This model is similar to the market model described above, but it allows for one-period autocorrelation of error terms.

Event study results

Results from the event study have the expected sign - negative (see Table 4.1). That is, key patents appear to have negative effects on competitor firms. However, significance levels are poor; at most, results are significant at the 13 percent level. The best results are for the event window starting one day before the event and ending three days after. The next best event window is one day before to five days after the event, the same event window used in our earlier work. The size of the spillover effect is small, a cumulative decrease in value of competitors of about 0.8 percent in most cases. In comparison, our earlier work found that the average patent moved the stock price of the innovating firm by 3 to 4 percent. The size of the spillover is similar for the shorter and the longer event windows, but significance levels are generally lower for the longer windows.

Conclusions

The event study results suggest that key patents have a negative impact on competitors - that is, that any positive knowledge gains accrued by immediate competitors are more than offset by negative effects on market position. Our results mirror Austin(1993, 1994a, 1994b), who found positive "own firm" patent impacts and small negative "rivalry" effects. Unfortunately, the statistical precision of our impact estimates is poor.

We speculate that there are two reasons for our disappointing results. The first is related to small sample size. Using simulation studies, Brown and Warner (1985) and others have shown that event studies have little ability to pick up small abnormal returns in small samples - that is, the null hypotheses of "no abnormal returns"may get accepted even when it is false. Larger sample sizes make it easier to detect small returns, because the variance of estimators is reduced.

The second reason is that the event study for patents may be somewhat mis-specified. The typical event study models assume that event impacts should be measured in terms of percentage changes in a firm's valuation. However, a key patent may affect a small firm more than a larger firm. The small firm may be doing research on only one or a few technologies. The larger firm may be doing research in several different areas, so that, as a whole, it is not as adversely affected by a competing patent. We plan to investigate this issue further.

Table 4.1
Event Study Spillover Results

Model	Event window	Cumulative Average Abnormal Return	t statistic	Significance level (2-tailed test)
Model Specification				
Number of events = 42				
Market Model, no autocorrelation	(-1,+5)	-0.81%	-1.24	22%
Market Model, Scholes Williams	(-1,+5)	-1.08%	-1.45	15%
Market Model, no autocorrelation	(-2,+5)	-0.79%	-1.14	26%
Market Model, Scholes Williams	(-2,+5)	-0.86%	-1.08	29%
Market Model, no autocorrelation	(-1,+3)	-0.86%	-1.56	13%
Market Model, Scholes Williams	(-1,+3)	-0.91%	-1.45	15%
Market Model, no autocorrelation	(-2,+3)	-0.84%	-1.40	17%
Market Model, Scholes Williams	(-2,+3)	-0.70%	-1.01	32%

Source: Policy Research Institute

APPENDIX 4.1 KEY DIGITAL VIDEO PATENTS

Table 4A.1
Key Digital Video Patents
September, 1996 - June, 2000

Patent Number and Title	Issue Date	Company	# of Citations	Cites per yr.
5,555,244 Scalable multimedia network	10-Sep-96	Integrated Network Corporation	46	12.1
5,586,264 Video optimized media streamer with cache management	17-Dec-96	IBM Corporation	39	11.0
5,576,765 Video decoder	19-Nov-96	International Business Machines, Corporation	34	9.4
5,629,980 System for controlling the distribution and use of digital works	13-May-97	Xerox Corporation	31	9.9
5,583,561 Multi-cast digital video data server using synchronization groups	10-Dec-96	Unisys Corporation	31	8.7
5,557,541 Apparatus for distributing subscription and on-demand audio programming	17-Sep-96	Information Highway Media Corporation	31	8.2
5,608,458 Method and apparatus for a region-based approach to coding a sequence of video images	4-Mar-97	Lucent Technologies Inc.	28	8.4
5,600,364 Network controller for cable television delivery systems	4-Feb-97	Discovery Communications, Inc.	25	7.3
5,570,355 Method and apparatus enabling synchronous transfer mode and packet mode access for multiple services on a broadband communication network	29-Oct-96	Lucent Technologies Inc.	24	6.5
5,592,477 Video and TELCO network control functionality	7-Jan-97	Bell Atlantic Network Services, Inc.	23	6.6
5,583,562 System and method for transmitting a plurality of digital services including imaging services	10-Dec-96	Scientific-Atlanta, Inc.	21	5.9
5,559,548 System and method for generating an information display schedule for an electronic program guide	24-Sep-96	<individual>	20	5.3
5,583,863 Full service network using asynchronous transfer mode multiplexing	10-Dec-96	Bell Atlantic Network Services, Inc.	19	5.3
5,572,442 System for distributing subscription and on-demand audio programming	5-Nov-96	Information Highway Media Corporation	18	4.9
5,675,390 Home entertainment system combining complex processor capability with a high quality display	7-Oct-97	Gateway 2000, Inc.	17	6.2
5,635,979 Dynamically programmable digital entertainment terminal using downloaded software to control broadband data operations	3-Jun-97	Bell Atlantic	17	5.5

Patent Number and Title	**Issue Date**	**Company**	**# of Citations**	**Cites per yr.**
5,574,662 Disk-based digital video recorder	12-Nov-96	Tektronix, Inc.	17	4.7
5,742,816 Method and apparatus for identifying textual documents and multi-media files corresponding to a search topic	21-Apr-98	Infonautics Corporation	16	7.3
5,596,604 Multicarrier modulation transmission system with variable delay	21-Jan-97	AMATI Communications Corporation	16	4.6
5,583,864 Level 1 gateway for video dial tone networks	10-Dec-96	Bell Atlantic Network Services, Inc.	15	4.2
5,650,831 Adjustable power remote control drive	22-Jul-97	Gateway 2000, Inc.	14	4.8
5,594,491 Near-video-on-demand digital video distribution system utilizing asymmetric digital subscriber lines	14-Jan-97	VXL/HCR Technology Corporation	14	4.0
5,585,858 Simulcast of interactive signals with a conventional video signal	17-Dec-96	ACTV, Inc.	14	4.0
5,576,902 Method and apparatus directed to processing trick play video data to compensate for intentionally omitted data	19-Nov-96	Hitachi America, Ltd.	14	3.9
5,603,058 Video optimized media streamer having communication nodes received digital data from storage node and transmitted said data to adapters for generating isochronous digital data streams	11-Feb-97	International Business Machines Corporation	13	3.8
5,574,787 Apparatus and method for comprehensive copy protection for video platforms and unprotected source material	12-Nov-96	<individual>	13	3.6
5,708,659 Method for hashing in a packet network switching system	13-Jan-98	LSI Logic Corporation	12	4.9
5,608,447 Full service network	4-Mar-97	Bell Atlantic	12	3.6
5,566,073 Pilot aid using a synthetic environment	15-Oct-96	<individual>	12	3.2
5,565,923 Apparatus for formatting a digital signal to include multiple time stamps for system synchronization	15-Oct-96	RCA Licensing Corporation	12	3.2
5,559,808 Simulcasting digital video programs	24-Sep-96	Bell Atlantic Network Services, Inc.	12	3.2
5,553,064 High speed bidirectional digital cable transmission system	3-Sep-96	Stanford Telecommunications, Inc.	12	3.1
5,724,475 Compressed digital video reload and playback system	3-Mar-98	<individual>	11	4.7
5,715,403 System for controlling the distribution and use of digital works having attached usage rights where the usage rights are defined by a usage rights grammar	3-Feb-98	Xerox Corporation	11	4.6
5,687,236 Steganographic method and device	11-Nov-97	The Dice Company	11	4.2

Patent Number and Title	Issue Date	Company	# of Citations	Cites per yr.
5,661,822 Data compression and decompression	26-Aug-97	Klics, Ltd.	11	3.9
5,596,647 Integrated video and audio signal distribution system and method for use on commercial aircraft and other vehicles	21-Jan-97	Matsushita Avionics Development Corporation	11	3.2
5,585,850 Adaptive distribution system for transmitting wideband video data over narrowband multichannel wireless communication system	17-Dec-96	<individual>	11	3.1
5,583,652 Synchronized, variable-speed playback of digitally recorded audio and video	10-Dec-96	International Business Machines Corporation	11	3.1
5,579,057 Display system for selectively overlaying symbols and graphics onto a video signal	26-Nov-96	Scientific-Atlanta, Inc.	11	3.1
5,559,549 Television program delivery system	24-Sep-96	Discovery Communications, Inc.	11	2.9
5,712,976 Video data streamer for simultaneously conveying same one or different ones of data blocks stored in storage node to each of plurality of communication nodes	27-Jan-98	International Business Machines Corporation	10	4.1
5,654,800 Triangulation-based 3D imaging and processing method and system	5-Aug-97	General Scanning Inc,	10	3.4
5,635,978 Electronic television program guide channel system and method	3-Jun-97	News America Publications, Inc.	10	3.3
5,621,455 Video modem for transmitting video data over ordinary telephone wires	15-Apr-97	Objective Communications, Inc.	10	3.1
5,613,032 System and method for recording, playing back and searching multimedia events wherein video, audio and text can be searched and retrieved	18-Mar-97	Bell Communications Research, Inc.	10	3.0
5,600,378 Logical and composite channel mapping in an MPEG network	4-Feb-97	Scientific-Atlanta, Inc.	10	2.9
5,600,366 Methods and apparatus for digital advertisement insertion in video programming	4-Feb-97	NPB Partners, Ltd.	10	2.9
5,593,350 Video game card having interrupt resistant behavior	14-Jan-97	Thrustmaster, Inc.	10	2.9
5,589,947 Karaoke system having a plurality of terminal and a center system	31-Dec-96	Pioneer Electronic Corporation	10	2.9
5,579,308 Crossbar/hub arrangement for multimedia network	26-Nov-96	Samsung Electronics, Ltd.	10	2.8
5,576,757 Electronic still video camera with direct personal computer (PC) compatible digital format output	19-Nov-96	St. Clair Intellectual Property Consultants, Inc.	10	2.8
5,673,265 Scalable multimedia network	30-Sep-97	Integrated Network Corporation	9	3.3

Patent Number and Title	Issue Date	Company	# of Citations	Cites per yr.
5,668,948 Media streamer with control node enabling same isochronous streams to appear simultaneously at output ports or different streams to appear simultaneously at output ports	16-Sep-97	International Business Machines Corporation	9	3.2
5,630,204 Customer premise wireless distribution of broad band signals and two-way communication of control signals over power lines	13-May-97	Bell Atlantic Network Services, Inc.	9	2.9
5,613,191 Customer premise wireless distribution of audio-video, control signals and voice using CDMA	18-Mar-97	Bell Atlantic Network Services, Inc.	9	2.7
5,608,653 Video teleconferencing for networked workstations	4-Mar-97	Digital Equipment Corporation	9	2.7
5,867,821 Method and apparatus for electronically accessing and distributing personal health care information and services in hospitals and homes	2-Feb-99	Paxton Developments Inc.	8	5.7
5,708,961 Wireless on-premises video distribution using digital multiplexing	13-Jan-98	Bell Atlantic Network Services, Inc.	8	3.2
5,657,462 Method and apparatus for displaying animated characters upon a computer screen in which a composite video display is merged into a static background such that the border between the background and the video is indiscernible	12-Aug-97	CollegeView Partnership	8	2.8
5,652,717 Apparatus and method for collecting, analyzing and presenting geographical information	29-Jul-97	City of Scottsdale	8	2.7
5,729,300 Double-screen simultaneous viewing circuit of a wide-television	17-Mar-98	Samsung Electronics Co., Ltd.	7	3.1
5,694,334 Method and apparatus for electronic distribution of digital multi-media information	2-Dec-97	Starguide Digital Networks, Inc.	7	2.7

Note: Key patents were defined as those having at least 6 citations and at least 2.7 citations per year.
Source: Data extracted from U.S. Patent and Trademark Office (2000).

5. SURVEY OF ATP CLIENT FIRMS

Introduction

Baseline data on ATP client firms are needed for a variety of purposes. First, information on the innovations produced by ATP funded projects is necessary to identify the "pathways" through which each innovation is likely to affect the economy. This information is needed both to develop appropriate strategies to gather data needed to track the economic impacts produced by the innovations, and as an input in the construction of models used to aggregate the impacts of multiple projects. Second, information on how ATP support affected client firms' research and development efforts is needed to establish how much of the benefits produced by each innovation to attribute to ATP, what we have termed the "attribution effect." Third, for those projects sufficiently advanced to have produced a commercial product, it is possible to construct preliminary estimates of the economic impacts realized to date.

We have gathered baseline data on ATP client firms from telephone interviews.[12] In this chapter we discuss baseline data on the pathways by which the projects in this focused program are likely to affect the economy, and on ATP attribution effects. In the next chapter we review the evidence on economic impacts realized to date, and likely in the near future, using a partial equilibrium approach. In Chapter 8 we revisit these issues using a general equilibrium approach.

The data reviewed in the present chapter examine ATP's focused program on Digital Video in Information Networks. They show the program is producing a number of significant technological innovations that will affect a broad range of economic activities. Moreover, they indicate that ATP's funding was critical to the achievement of these innovations. Most of the firms interviewed reported that they would not have undertaken the research that has led to their innovations without ATP support, and they believed that in the absence of ATP support commercial introduction of the technologies they had developed (or its functional equivalent) would have been delayed on average by about 3 years.

Theoretical considerations

Burress *et al.* (1999b, pp. 13-29) discussed in detail the theoretical issues surrounding efforts to measure economic impacts. Here we briefly summarize some key points of that discussion.

The economic impacts of any innovation can be divided into two components: (1) privately appropriated benefits that accrue to the innovator as a result of increased profits, and (2) benefits that the innovator is unable to appropriate, which are commonly referred to as *spillovers*. Spillovers can be both positive–e.g., benefits to users of the innovation, producers of complementary products whose value is enhanced by the innovation, other innovators who gain valuable knowledge–or

[12] Data paralleling some of the information we collected is also available in ATP's Business Reporting System Database, but we did not have access to these data.

negative–e.g., reductions in profits of producers of competing products displaced by the innovation (see Mansfield 1977; Jaffe 1996, 1998).

Implicit in the calculation of the size of each of these impacts is a hypothetical, or *counterfactual*, situation that would have existed in the absence of the innovation. Each relevant magnitude must be measured relative to what it would have been in the counterfactual situation.

Assessing the economic impact of an ATP intervention requires that in addition to measuring the magnitude of the economic impacts flowing from innovations produced by ATP funded projects we must determine what fraction of those impacts to attribute to ATP. In other words, it is necessary to establish the ways in which ATP intervention altered the course of technological innovations. As in the case of computing the benefits of a new technology, we are implicitly comparing the actual course of events to a counterfactual situation–one in which there was no ATP intervention. Since this counterfactual is not observed it must be modeled on the basis of reasonable assumptions.

In our investigation of "attribution" effects, our starting assumption is that the primary effect of ATP funding operates through the *acceleration* (rather than the mere realization) of commercially viable innovations. That is, we assume that, in the absence of ATP funding, functionally equivalent innovations to those produced by ATP client firms would eventually have been realized either by the same firms, or by other firms. In the extreme case, of course, it is possible that, in the absence of ATP funding, the realization of an innovation would have occurred so far in the future as to be irrelevant. In that sense, our approach encompasses the case in which ATP funding is entirely responsible for a particular innovation as a special case.

If the chief competitors in the development of a particular technology are foreign, accelerating innovations by US-based firms may also lead to a shift in the national location of an innovation. In this case, domestic benefits are increased not just because of the acceleration of innovation, but also through the transfer of benefits that in the counterfactual would have been realized by foreign-based companies.

It is important to understand that, at best, ATP intervention would not merely accelerate the innovation being supported; it would also accelerate the development, at some time down the road, of a successor innovation that will eventually replace the innovation under study. However, our baseline study cannot shed much light on this essentially predictive question.

In our framework, another possible kind of change due to ATP intervention is a qualitative change in the detailed nature of the technology that is adopted, possibly leading to long term effects. This is most likely to be the case in situations where industrial standards are an important element of technological innovation. First movers in this case may establish particular standards that are subject to important economies of scale as other components are adapted to them. (For example, we would view the invention of the typewriter keyboard as a functional innovation; within that innovation, the choice between the QWERTY or Dvorak keyboard would be a qualitative difference rather than a difference in the fundamental innovation.)

Data collection

In 1995 NIST-ATP funded six projects as part of its focused program on Digital Video in Information Systems. In 1999 it funded an additional four projects. Table 5.1 summarizes a variety of information about these 10 projects, listing the project title, lead company, partners, project duration, and ATP and private funding of the projects. As part of our evaluation of the economic impacts of these projects we conducted interviews with representatives of 10 companies involved in 8 projects.

We attempted to schedule interviews with representatives of companies involved in all of the projects that received ATP funding, with the exception of the "Advanced Distributed Video ATM Network for Creation, Editing and Distribution"project, which was terminated at an early stage by Tektronix. In most cases the project personnel we contacted were extremely generous with their time and insights. There was only one instance–the project directed by Intersil Corporation–in which we were unable to reach the designated contact person to schedule an interview. The full results of each interview are reported in a standardized format in the appendix to this chapter. The next section summarizes the key findings arising from the interviews.[13]

Interview results

Pathways to economic impacts

DV technologies have the potential to affect a wide array of economic activities. Indeed, In Burress *et al.* (1999a) we identified over 500 distinct functions or economic activities that appeared likely to be affected by digital video technologies. These diverse activities can, however, be aggregated into four very broad categories:

- DV content creation, capture and display;
- DV data storage, access and retrieval;
- Transmission and management of DV data streams and intellectual property; and
- End uses of DV data streams.

Here we use this framework to organize our discussion of the likely impacts of ATP funded DV technologies. In examining these impacts it is helpful to divide them into activities directly affected by each innovation, and activities affected through spillovers.

In Table 5.2 we summarize the activities that are likely to be directly affected by the innovations resulting from each of the ATP funded projects for which we collected interview data. The information presented in the table necessarily is abbreviated, but more complete information is available in the appendix to this chapter.

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[13]For additional information on the protocols used to contact each company and the script used for the interviews see Burress *et al.* (2000).

ATP funded innovations will affect a wide range of economic activities in diverse markets. For the most part the technologies being pursued are process technologies aimed at facilitating distribution of and access to DV data streams. Such a focus appears sensible as advances in these areas are essential to enabling a wide range of end uses of DV. At the moment, solutions to these technological problems remain relatively specialized because of the different characteristics needed to make DV feasible for different end uses. In the future, however it seems likely that progress on these more specialized solutions will encourage an increased technological convergence.

In addition to the direct effects identified in Table 5.2, each of the innovations is likely to have important spillover effects for other markets. Here we briefly summarize for each project some of the most likely “knowledge” and “network” spillovers (See Burress *et al.* 1999b, especially chapter 5, for the formal definitions we have adopted for these categories of spillover).

Market and fiscal spillovers are not discussed here because these spillovers are present in very straightforward forms in all cases under discussion. In particular, each successful innovation is likely to lead to downstream cost and price reductions, sales increases, and changes in profits, labor income, and taxes paid by firms and households. In some cases price reductions may be so great that they allow producers or consumers to obtain goods and services that previously were priced entirely out of reach - and in that sense, there could be qualitative producer and consumer benefits that go beyond mere price reductions. Some of these qualitative benefits are documented in the interviews. However, trying to predict the dollar value of these qualitative benefits would go beyond the scope of this baseline research.

Also, material spillovers are not discussed here. No examples of material spillovers were identified in the course of the interviews.

1) Adaptive Video Codec for Information Networks–Cubic Video Systems:

- Network spillovers: there will be increased demand for video capture devices, PCs, and networking equipment as a result of this innovation; there will also be increased demand for data storage hardware, and software to access and analyze recorded data produced by security systems.
- Knowledge spillovers: This innovation will increase the stock of knowledge about compression algorithms with likely benefits for future efforts to improve transmission of DV images in other contexts.

2) Perceptual-Based Video Encoding and Quality Measurement–Sarnoff Corporation:

- Network spillovers: there will be positive effects created for products using this new recording algorithm because of their increased capacity. These effects will be concentrated in end uses of DV, such as home playback and recording devices.
- Knowledge spillovers: This innovation will increase the stock of knowledge about compression algorithms with likely benefits for future efforts to improve transmission of DV images in other contexts. The focus of this project on embedding knowledge about

perceived image quality will make possible the development of better metrics for standardized quality measurement of compression approaches.

3) HDTV Broadcast Technology–Sarnoff Corporation, lead:

- Network spillovers: by lowering the cost of entry into HDTV broadcasting this innovation will speed up diffusion of HDTV broadcasts, with consequent positive network effects on creation of content to be broadcast in this format and consumer electronics devices employed in the end use of DV data streams.
- Knowledge spillovers: none identified.

4) Interoperability Tools for Digital Video Systems–Telcordia (formerly Bellcore):

- No spillovers–the project was terminated.

5) Integrated Speech, Language, and Image Processing for Real-Time Creation of a Video Conferencing Library System–MediaSite (formerly ISLIP):

- Network spillovers: improved access to and retrieval of DV data will increase demand for all types of DV content by raising its value. Demand for DV storage devices will also be positively affected. The end uses of DV data will also be affected, making it possible to automate the assembly of DV data on specific subjects for research, or entertainment purposes.
- Knowledge spillovers: improvements in parallel processing techniques and improvements in image, speech and movement recognition algorithms may have broader applications.

6) Compressed Live Object Video Interactive Singular–Physical Optics:

- Network spillovers: ability to separately manipulate objects within images will facilitate viewer interaction with DV data delivered using this compression algorithm. There will be positive network spillovers to creators of interactive DV content for entertainment and training. There will also be positive effects on the demand for remote monitoring equipment and services including image capture devices and networking hardware.
- Knowledge spillovers: advances in compression technologies may be applicable to a wider range of DV distribution problems.

7) Integrated Layered Compression System Prototype–DemoGraFX:

- Network spillovers: there will be positive effects on demand for digital projection systems, and negative effects on conventional projection systems. Encryption and watermarking features will increase intellectual property security enhancing the value of DV assets, and encouraging increased production. The shift to digital delivery will also encourage increased use of digital image capture and editing technologies. Film-based systems will be negatively affected. There will also be increased demand for networking hardware to carry signals.

- Knowledge spillovers: compression techniques can be applied to other aspects of cinema production and post production processes, such as digital editing systems.

8) Improving DTV Broadcast Reception–General Electric Corporate Research and Development:

- Network spillovers: by lowering the cost of entry into HDTV broadcasting this innovation will speed up diffusion of HDTV broadcasts, with consequent positive network effects on creation of content to be broadcast in this format and consumer electronics devices employed in the end use of DV data streams.
- Knowledge spillovers: innovations in DTV reception may be applicable to a wide range of other wireless applications.

Attribution effects

One of the chief reasons for conducting interviews is to assess how ATP funding affected the timing, characteristics, and scope of specific innovations. Because it may be difficult to locate key project participants after the fact, and because perceptions may change with time, these data may be classified is transitory in nature. As a result it is important to collect impressions about the impact of ATP funding contemporaneously.

ATP's Business Reporting System (BRS) does collect a variety of data on acceleration effects of ATP funding, but the BRS questions focus strictly on the effects on funded firms, and do not clearly articulate what would have happened in a counterfactual world in which ATP had not funded a particular project. As a result a central objective of our interviews was to develop the best possible characterization of such a counterfactual situation.

The results of these inquiries are necessarily speculative, but they do suggest that ATP funding has had important impacts in accelerating the realization of funded technologies. Specifically our interviews revealed the following:

- ATP funding was essential for all but one of the projects. Only DemoGraFX indicated that it would have pursued a similar innovation strategy in the absence of ATP funding, but without that funding its progress would have been considerably slower.
- All of the funded companies indicated that the projects they were pursuing were too "risky" and that the pay-offs were too far in the future to attract significant private investment without ATP support.
- ATP support accelerated progress by between 18 and 42 months. The median estimate of the acceleration effect was 36 months. Seven of the companies we interviewed were able to estimate when they believed that innovations on which they were working would have been developed *either by their own company or by another* had their project not received ATP funding. Of these three, estimated the acceleration was 42 months, two estimated 36 months, and one estimated 18 months.
- In two cases, ATP funding was believed to have affected the national location of innovations.
- ATP funding had other beneficial effects on a number of projects. Several of the companies interviewed reported that ATP project management helped to focus their research and resulted

in an acceleration of commercial innovations. Contact with NIST labs, was also mentioned as an important factor by one company, and one company indicated that it pursued broader research goals in general with a longer payback period because of ATP support.

Impacts on national location of innovations

In most cases the ATP DV client firms did not identify important foreign competitors. In several cases, however, we found evidence that suggests that ATP support may have shifted the national location of innovations. Perhaps the most importance such instance concerns the HDTV Broadcast Technology project coordinated by Sarnoff Corporation. In this case the chief competitors for many of the hardware and software tools being developed were foreign, and ATP support helped to create domestic capabilities to supply important technologies needed by the television industry as it makes the transition to HDTV broadcasting.

A second instance in which ATP funding may have affected national location is the Adaptive Video Codec for Information Systems project directed by Cubic Video Systems.

Conclusions

Interviews with ATP-client firms indicate that ATP intervention has stimulated the development of a number of potentially beneficial technologies. These technologies will directly affect all aspects of the creation, storage, distribution, and use of DV data. These direct effects appear likely to produce significant market spillovers (see Chapter 6). In addition our interviews identified a wide range of potential network and knowledge spillovers that will need to be monitored in the future if a complete accounting of the economic impacts of ATP's intervention is to be constructed.

Table 5.1
Projects Funded by ATP's Digital Video in Information Systems Focused Program

			Duration		Funding ($M)	
Project Title	**Lead Company**	**Partners**	**begin date**	**end date**	**ATP**	**Non-ATP**
Adaptive Video Codec for Information Networks	Cubic Video		Oct. 1995	March 1998	1.74	1.24
Perceptual-Based Video Encoding and Quality Measurement	Sarnoff Corporation	Agilevision	Oct. 1995	May 2000	7.85	13.13
Advanced Distributed Video ATM Network for Creation, Editing, and Distribution	Tektronix		Sept. 1995	Sept. 1998	1.91	1.70
HDTV Broadcast Technology	Sarnoff Corporation	Thomcast, New Jersey Networks, Sun Micro-systems, Thomson Electronics, MCI, IBM	Oct. 1995	Sept. 2000* ?	28.42	29.67
Mobil Information Infrastructure for Digital Video and Multimedia Applications	Intersil (formerly Harris Corp.)	Sun Microsystems	Nov. 1995	June 2000	13.84	17.23
Interoperability Tools for Digital Video Systems	Telcordia (formerly Bell Atlantic)		Nov. 1995	Dec. 1997	1.26	1.81
Integrated Speech, Language, and Image Processing for Real Time Creation of a Videoconferencing Library	MediaSite, Inc. (formerly ISLIP)		March 1999	March 2002*	1.67	0.28
Integrated Layered Compression System Prototype	DemoGraFX		Jan. 1999	Dec. 2000*	2.0	0.51
Compressed Live Object Video Interactive Singular Technology	Physical Optics Corporation		Jan. 1999	Dec. 2001*	1.57	1.91
Improving Digital TV Broadcast Reception	General Electric Corporate R&D		Jan. 1999	March 2002*	1.52	1.81
* Planned completion date						

Table 5.2
Economic Activities Directly Affected by ATP Funded DV Innovations

	Functional uses			
Project, Client Firm, and Innovation	**DV content creation, capture and display**	**DV data storage, access and retrieval**	**Transmission and management of DV data streams and intellectual property**	**End uses of DV data streams.**
Adaptive Video Codec for Information Networks – Cubic Video compression algorithm implemented in software designed to run on conventional Intel-compatible PCs using the Windows OS, optimized for packet-switched and/or wireless networks.				1) remote monitoring and security systems; 2) Video integration with other web content
Perceptual-Based Video Encoding and Quality Measurement – Sarnoff Corporation MPEG compatible compression algorithm that is 10-20 percent more efficient than existing approaches for a given level of viewer-perceived image quality	1) compression of recordings made using camcorders	1) compression of recorded DV content	1) encoder for transmission of HDTV	1) playback of recorded or broadcast content
HDTV Broadcast Technology – Sarnoff Corporation–Leader Suite of tools for Broadcast HDTV studios				
(a) *Compressed Domain Processing of DV Signals* - Sarnoff Corp Software algorithm implemented on general purpose computer to allow splicing and superimposing of multiple HDTV signals in compressed format without decompression	1) Creation of broadcast HDTV signals			
(b) *ATM network command and control system* - IBM		1) Routing, storage and access of HDTV signals within stations		

	Functional uses			
Project, Client Firm, and Innovation	**DV content creation, capture and display**	**DV data storage, access and retrieval**	**Transmission and management of DV data streams and intellectual property**	**End uses of DV data streams.**
(c) *ATM network command and control system* - MCI Software and hardware for routing signals over ATM networks between TV studios			1) Routing, storage and access of HDTV signals between stations	
(d) *Broadcast HDTV transmitter* - Thomcast Transmitter for over the air HDTV broadcasts			1) Transmission of HDTV signals	
(e) *HDTV encoder* - Thomson Electric Hardware encoder for compressing HDTV signals for broadcast			1)Encoding HDTV signals for broadcast	
(f) *Command and control architecture for ATM networks* - IBM, Sun Microsystems, IBM Software and hardware to manage system resources needed to store, access, and transmit HDTV data streams within TV studio		1) access, control and storage of DV signals		
Interoperability Tools for Digital Video Systems - Telcordia (formerly Bellcore) Software reference standards for locating and accessing DV content over networks **				
Compressed Live Object Video Interactive Singular - Physical Optics Object oriented compression algorithm	1)post-production editing–adding special effects or hyperlinks			1) interactive remote monitoring 2) interactive education and training videos

	Functional uses			
Project, Client Firm, and Innovation	**DV content creation, capture and display**	**DV data storage, access and retrieval**	**Transmission and management of DV data streams and intellectual property**	**End uses of DV data streams.**
Integrated Speech, Language, and Image Processing for Real-Time Creation of a Video Conferencing Library System - Mediasite, Inc. Parallel processing approach to automated indexing of video asset content		1) improved access to video assets		1) cataloging and access to corporate video conferencing libraries or other video assets
Integrated Layered Compression System Prototype - DemoGraFX High resolution, high compression ratio algorithm that works in real time and includes encryption and watermarking	1)higher quality image representation in digital editing systems		1) digital delivery of cinema to theaters 2) transmission of live events to theaters	
Improving Digital TV Broadcast Reception– General Electric Corporate Research and Development Analysis of problems with DTV reception and development of transmitters and receives that work together to produce good reception			1) HDTV signal broadcast	1) Home and office viewing of HDTV broadcast signals
** project abandoned -- no commercial products				

APPENDIX 5.1 INTERVIEWS WITH ATP CLIENT FIRMS

This appendix includes detailed reports in a standardized format of interviews with ATP-client firms. Each report is based on interview notes and audiotape recordings from telephone interviews conducted during the Spring of 2000. Draft reports were sent to interviewees who checked them for clarity and accuracy before being finalized at the University of Kansas. In some instances confidential information has been removed or concealed at the request of the interviewees.

The reports are arranged alphabetically by company name as follows:

- Cubic Video Systems
- DemoGraFX
- MediaSite, Inc.
- Physical Optics
- Sarnoff Corporation, Perceptually-Based Video Encoding and Quality Management
- Sarnoff Corporation, HDTV Broadcast Technology
- Sarnoff Corporation, AgileVision
- Thomcast Communications
- Telcordia

REPORT ON ATP-CLIENT INTERVIEW–Cubic Video Systems

0. Interview description

Respondent(s):	Bill Guetz, Chief Technology Officer
Organization:	Cubic Video Systems
Email address:	bguetz@cvideo.com
Telephone:	858-385-2030
FAX:	Not available
Date of interview:	18 April 2000
ID of interviewers:	Patricia Oslund, Joshua Rosenbloom
Referrals to additional interviewees in firm or elsewhere:	None

1. Technology description

Name of ATP project: Adaptive Video Codec for Information Networks

Technology name or description:
A video compression scheme designed to operate over packet switched and/or wireless networks (e.g., the Internet, or other data networks), and a codec implemented in software that can run under the Windows OS on an Intel or compatible microprocessor.

Technology goal(s):
To make it possible to easily distribute and view digital video images over networked desktop computers. Initial motivation was to facilitate corporate video conferencing over intranets or the Internet. As the market has evolved, however, commercialization plans have evolved (see below)/

Technology technique:
When the project started, existing compression schemes (MPEG and H-Dot) were being developed primarily for entertainment industry uses, and were optimized for use over terrestrial broadcast, cable, phone networks, or satellite broadcast. They were designed to reduce random noise or snow in images, and relied heavily on interpolation schemes to fill in missing data. These approaches don't work well in a packet-switched environment. In this context there are no missing bits, but packets can arrive out of order or get lost, causing peculiar artifacts.

Cubic's core technology was an alternative compression scheme based on first transforming a series of images in both space and time dimensions into a domain in which redundant information can be readily identified and then compressing the resulting information to remove this redundancy. The algorithm is programmed in assembly language to run on Intel Pentium Microprocessors. The resulting compression engine is highly efficient: it is able to perform the wavelet transformation in half a dozen clock cycles (while MPEG and other Direct Cosign Transform algorithms require hundreds of clock cycles). Decompression program was written to run on Intel Pentium PCs specifically to avoid lock-in to specific hardware, and can be embedded in the video stream from the server, making it unnecessary for recipients to purchase either specialized hardware or software.

Current developmental status (stage, timeline, risk):
Cubic has completed development of the core technology–the compression engine, has applied for a patent, and expects to receive patent office approval within the next few months. They have embedded this core engine in several commercial products so far, and expect the market for their products to expand rapidly in the next several years.

Related, broader technologies:
Compression algorithms
Video recording, access and control over networks

Related, narrower technologies:
Remote monitoring
Video streaming

Cross-references:

2. Actual/anticipated effects in immediate markets

Intended initial markets:

Commercialization plans have evolved over time. At the moment the primary market is the security industry–remote monitoring systems for distributed assets (for example–self service gas pumps, convenience stores, school buildings, automatic teller machines). The systems include a transmitter that can assemble and stream video from up to 16 cameras, and a recorder that can store and access the video images produced by these cameras. Cameras are connected to a network that allows remote monitoring, and cameras can be controlled to pan or zoom via the network. It is also possible to use wireless networks to give mobile access to video data over relatively short ranges (500 feet or so).

There are sixteen thousand licensed security equipment dealers in the United States who install cameras, monitoring systems, alarm panels, and access control equipment. Cubic markets its software and hardware to these dealers, who combine them with other components and install them for customers.

Other possible markets:

Several other earlier commercialization plans were explored and dropped. These were:

o) A Video streaming website © Video Now). This product was introduced early in the company's history and they made a number of errors in implementation. Microsoft entered the market with a competing product that it made available for free, and Cubic decided to exit this market

p) A system for attaching video clips to e-mail © Video Mail). Software was packaged with a video camera. The user can record and send video clips as attachments to messages, which can be opened by the recipient simply by opening the file. Cubic shipped 70,000 units of this product, but made some commercial errors–for example, despite buying cameras in large quantities it was paying $50 for an item that could be purchased at retail for $40. They lost money on the product, and have largely abandoned this product, though they continue to sell it to business users.

Other potential markets include:

1. Corporate video conferencing
2. TV broadcast over the Internet
3. Hard disk based home video recorders

Planned/actual business model:

The compression engine is combined with application programming and a variety of off-the-shelf hardware to produce useful products relying on video compression to enhance value and improve performance relative to existing technologies.

Existing substitutes (negatively impacted):

Most existing security systems use time lapse analog images which are recorded on video tape.
Digital image systems based on alternative compression schemes

Nature of gain(s) to user (as compared with existing substitutes):
Compared to existing systems:
Streaming video replaces time lapse images
Remote access and camera control is improved
In particular it is possible to have random access to recorded images
Costs of changing video tape or degradation of recording quality can be avoided

Compared to other compression schemes:
Compression engine retains more data than MPEG schemes which rely on interpolation, which is satisfactory for entertainment but not for security or conferencing applications.

Likely limitations of technology in short-term:
Quality of images is substantially lower than conventional broadcast TV

Additional desirable features:
Improved image quality
Automated face recognition

Potential for "inventing around":
Deemed high in principle, but achieving comparable levels of performance in terms of speed of compression appears in practice to be relatively difficult.

Other future substitutes:
New compression algorithms
Increased bandwidth (which will make compression less important)

Other factors on monopolization potential:[14]
Specialized knowledge about software components
Market leadership
Learning through interaction with users will allow systems to be adapted to more closely meet end user needs.

Other factors on intellectual property protection: Patents

3. Actual/anticipated effects in related markets
Complementary products:
Data network components–hubs, routers, switches, fibre optic cable

Potential for forced "tie-ins" of this product: None identified

[14] In addition to those identified inj Section 5 below. Also, nearly all DV products have significant monopolization potential because of IRTS (see footnotes 8 and 9 below).

Potential for forced "tie-ins" to this product:[15]
Embedded software could be tied to specific hardware installations

Upstream products (inputs to production of this product):
Computers and components–microprocessors, hard disks
Video cameras

Downstream products (uses this product as input to production):
Security systems

Antagonistic products: None identified

4. Knowledge spillovers
Potential/actual spill-outs:
Demonstration of market potential for DV based security systems

Potential/actual spill-ins:
Compression technology experience and background in defense related work on coding for jamming resistence provided the knowledge base for product development

5. Network spillovers
Investment coordination problems: None identified

Standards problems:
For law enforcement purposes security systems must be designed to be tamper proof so that image data can be introduced as evidence.

Hardware-software coordination:
Not a major consideration. Windows/Intel systems for which the software is designed are ubiquitous.

Software-software coordination: None identified

Previous installed base (as a barrier):
Existing base of analog remote monitoring systems is a barrier to rapid diffusion of digital systems

Future installed base (as a source of lockin and monopolization): None identified

Other sources of premature lockin: None identified.

Economies of scale in production: None identified

Direct interactions between consumers (economies of consumption): None identified

Synergies with other technologies (and economies of scope): None identified

[15] In addition to those implied by complementary markets.

Need for development of specialized uses: none identified.

Other specialized use networks using this product: none identified.

Specialized use networks to which this product belongs: none identified.

6. Barriers to development or commercialization

Capital availability:

Internal funding for this project would not have been available in the absence of NIST-ATP support because it was deemed too risky

Other special barriers: None identified.

7. Description of this firm

Cubic Video Systems is a spin-off of Cubic Defense Systems. The parent company was the original ATP applicant. It's primary activities are: (1) subway fare collection systems, (2) defense systems for transmission of reconnaissance images from airplanes to the ground. Cubic Video Systems was created to market video applications arising out of this development project. It's largest owner is Cubic Defense Systems which holds 30 percent of the company's stock; employees hold most of the rest. Still looking for major investors to infuse capital.

This project employed 25 people, all are not employed by the derivative business. This project employed 6 people–5 software engineers, and 1 hardware engineer.

8. Effects of ATP

Effect of ATP on this organization's R&D investment (this and other projects):

This project would not have been pursued without ATP funding

Effect of ATP on other organization's R&D investment on competitive projects:

None identified

Other factors on timing of innovation:

None identified

Leading competitors in field (experts, firms, laboratories):

Loronix, Sony, Sensormatic, Vicon, and Integral are all potential competitors in the security system market. Siemens and a Korean company are also apparently working on applications in this area.

Foreign government action: None identified

Likely scenarios absent ATP intervention:

Cubic Defense Systems would not have invested in developing Compression engine. At this point none of the potential competitors has a compression engine that is close to the level of performance that Cubic has achieved.

Progress would likely have been delayed by 1-2 years

Effect of ATP on national location:

Given presence of foreign competitors it is quite possible the innovation would have been developed outside the US.

Effect of ATP on qualitative characteristics of innovation: None identified

Effect of ATP on organization, strategy, partnering, business plan:
ATP was excellent at managing development. Their contributions likely accelerated Cubic's progress by 6 months.

ATP's stamp of approval has made it possible to get initial internal funds, and has made it easier to get external funds.

Effect of ATP on this organization's R&D investment (this and other projects):
Cubic Defense committed $1.24 million during the initial project
An additional 3 million has been spent on R&D since the end of the project

Effect of ATP on other organization's R&D investment on competitive projects:
None identified

Actual/expected dates:

event	point estimate	lower bound	upper bound
Initiation of the project	9/1995		
ATP funding of project	9/1995		
Completion of research laboratory /verification of concept			
Completion of development /demonstration of innovation and product engineering	1/1997		
Commercial introduction/first sales	1/1997* 1/2000**		
Extinction/replacement by next generation technology			

Research has been ongoing throughout the project. Most of this effort (95%) has been focused on "application programming" to integrate systems built around the compression engine.
* The first commercialization effort was the C Video Mail product.
** This date refers to first commercial introduction of security system application, a number of pre-commercial systems were installed prior to this as part of the development phase of the project. The first of these was introduced in early 1998.

Counterfactual dates (point estimate, LB, UB):

event	point estimate	lower bound	upper bound
Initiation of the project			
Stage comparable to ATP funding of project			
Completion of research laboratory /verification of concept			
Completion of development /demonstration of innovation and product engineering			
Commercial introduction/first sales		1/2001	1/2002
Extinction/replacement by next generation technology			

9. Market impacts

Size of potential (market or markets)

Not estimated

Actual/potential sales of products embodying innovation

To date Cubic has sold approximately 1,000 security systems. A typical installation is 4 “boxes” and is prices at $10,000. This is $3,000 to $4,000 below the price of competing systems. Cost of component hardware is about 50% of sales price (or $5,000). These sales to date reflect only a small part of the potential market.

Revenue per unit earned by innovating firm

Not directly estimated, but the demand curve for this product appears to be relatively price inelastic, while component prices are continuing to fall. Company was able to raise prices by about 10% recently with no appreciable impact on sales. The main competition, however, is from analog based systems which are lower in cost than digital systems, so there is an argument for reducing prices enough to become competitive with these systems, which would allow capture of a much larger market.

REPORT ON ATP-CLIENT INTERVIEW–DemoGraFX

0. Interview description

Respondent(s): Allan Peach, Consultant
Phyllies Wreagh, Vice President,

Organization: DemoGraFX
Email address: demografx@earthlink.net
Telephone: 310-452-7587
FAX: 310-314-7066

Date of interview: March 13, 2000
ID of interviewers: David Burress, Pat Oslund, Joshua Rosenbloom
Referrals to additional interviewees in firm or elsewhere: None provided

1. Technology description

Name of ATP project:
Integrated Layered Compression System Prototype

Technology name or description:
A hardware prototype implementation of DemoGraFX's Digital Cinema Layered Compression System.

Technology goal(s):
A real-time decoder and an near real-time encoder prototyped on a Mercury G4 parallel system. Such a system could lead to the following economic goals:
A drastic reduction in cost of storing and transmitting movies.
Improved security against unauthorized copies.
Scalability to match bandwidth.
Eventual replacement of film, a media that can sustain damage and degradation over time.

Technology technique:
Motion imagery is transmitted in two or more layers. First, a Base Layer is used to encode a Standard Resolution version of the imagery. The layer is encoded using DemoGraFX's proprietary compression technology. Second, an Enhancement Layer which contains the difference between the Standard Resolution and High Resolution imagery is also encoded using DemoGraFX's Layered Compression Technology. An encryption scheme is used to protect the two layers from piracy. The Enhancement Layer may or may not be encrypted as it contains only difference information. Massively parallel processing algorithms are used to achieve real-time decompression at very high compression ratios.

Current developmental status (stage, timeline, risk):
DemoGraFX Compression Technology has been demonstrated in software but only in non-real time using very complex and demanding images from actual movies. The current goal is to do decompression in real time and compression in near-real time using a highly parallel processing box designed by Mercury Computer. DemoGraFX will license the technology to firms that will implement the algorithms in silicon, achieving higher speeds and at much lower cost.

Related, broader technologies:
Compression for High Definition TV and Digital TV.
Digital Dailies.

Each step of the current Film Chain.
DVD compression.

Related, narrower technologies:
Digital Archiving.

Cross-references: none identified.

2. Actual/anticipated effects in immediate markets

Intended initial market(s):
The delivery of movies from studios to theaters.
The delivery of live events to movie theaters by satellite.

Other possible markets:
Archival storage of movies.
Non-linear Digital Editing systems such as AVID, could be enhanced to display film-quality images rather than poor quality reference imagery.
Eventually, every physical device that touches a signal in the image chain (pre-production, post production, feed, interconnect) will be modified to be compatible with, and take advantage of, high compression.

Planned/actual business model:
The technology will be licensed, like Dolby sound, to manufacturers who will create encoders and decoders. DemoGraFX feels that this approach is optimal for the Motion Picture industry, because it helps to spread the technology among several manufacturers and therefore keeps the technology from appearing to be controlled by a single source. The industry has expressed a desire to avoid any standardization where there is only a single source for key enabling software/hardware for Digital Cinema.

Existing substitutes (negatively impacted):
Companies involved in the physical delivery of film will be negatively affected by the digital delivery.

Nature of gain(s) to user (as compared with existing substitutes):
Cost saving: ~ $700M/year in duplicating prints
Cost saving: security arrangements simplified
Cost saving: archival costs.
Cost saving and quality improvement: more reliable digital projection equipment replacing mechanical projection devices
Quality improvement: Digital projection avoids unstable image projection, scratches, and image fading.
Potential quality improvement: 72 Hz frame rate reduces objectionable flicker.
Revenue enhancement: increased security against intellectual property theft (an estimated 1 to 4 billion dollars in lost revenue can be attributed to film piracy.

Likely limitations of technology in short-term: none identified.

Additional desirable features:
Super high resolution (in both pixels per frame and frames per second)
Integration of compression and encryption with watermarking.
Site- and date- specific watermarking.
72 Hz image capture and mastering

Backward compatibility as resolution increases

Potential for "inventing around":
In principle, the potential is high. The general idea of a layered compression scheme is not patentable, but DemoGraFX is using a method of layered compression that is unique and patentable. Alternative algorithms are sure to be possible, however, DemoGraFX feels that most other compression techniques are based on a few wrong assumptions, and therefore, it will be difficult for the composition to catch up to the massive amount of research and development that has gone into the DemoGraFX Layered Compression Technology.

Other future substitutes:
A very wide-band/high-speed pipe could be a substitute for real-time compression, but bandwidth is an expensive commodity and the cost currently are prohibitive.

Other factors on monopolization potential:
First mover advantage, standardization, capital lock-in. See below.

Other factors on intellectual property protection: none identified.

3. Actual/anticipated effects in related markets
Complementary products:
1. Movie production and distribution.
2. Movie theaters
3. All physical devices in the image chain: cameras, cinema projectors, recording and storage devices, non-linear editors.
4. Delivering movies to the home for "home theaters"
5. Texas Instruments has a high resolution digital cinema projector
6. Philips has a 720 line 72 Hz. progressive scan digital video camera

Potential for forced "tie-ins" of this product:
Each physical device in the image chain will be tied in to the standard for compatibility reasons and not by market force.

Potential for forced "tie-ins" to this product:
Encryption and watermarking are theoretically separable products that will probably be tied in.

Upstream products (inputs to production of this product):
Chips and hardware used for compression/decompression.

Downstream products (uses this product as input to production):
The image chain.

Antagonistic products:
Alternative compression schemes would lead to incompatible standards. Current alternative compression schemes produce inferior imagery.

4. Knowledge spillovers
Potential/actual spill-outs:

1. If this product creates a standard for cinema rapidly enough, that standard is likely to become a de facto standard for DTV and HDTV as well - because the existing standards are little more than a set of hunting licenses.
2. It could also become a standard for video on the Internet.
3. If both events occur, then convergence of the three media will be greatly accelerated.
4. Applications to image searching seem possible.

Potential/actual spill-ins:
MPEG-2 and MPEG-4
parallel computing
computational graphics

5. Network spillovers
Investment coordination problems:
Chip producers, movie distributors, and theater owners have to make complimentary investments.

Standards problems:
This system constitutes a standard. It is hoped that it will eventually be accepted by most agents in the cinema image chain.

Hardware-software coordination:
Movie content will have to be recorded in ways compatible with the hardware standard.

Software-software coordination: none identified.

Previous installed base (as a barrier):
Theater owners will have to write off much of their existing projection equipment, but should gain additional revenue from pay-per-view events.

Future installed base (as a source of lock-in and monopolization):
Digital equipment builds on computer compatibility. Moore's Law teaches us that CPU's and memory will get faster and cheaper each year, so new equipment is likely to have a short service-life. Film stock prices and services, on the other hand tend to rise in cost each year. Therefore, adoption of digital methods of film production and distribution will become increasingly attractive.

Other sources of premature lock-in: None identified.

Economies of scale in production: None identified.

Direct interactions between consumers (economies of consumption): None identified.

Synergies with other technologies (and economies of scope): None identified.

Need for development of specialized uses: None identified.

Other specialized use networks using this product: none identified.

Specialized use networks to which this product belongs: None identified.

6. Barriers to development or commercialization

Capital availability: No longer viewed as problem for this firm.

Other special barriers: None identified.

7. Description/history of this firm

Personnel:
Staff of six consultants. Gary Demos is President/CEO.
Demos used parallel computing for motion imagery since the 1970's.
DemoGraFX was funded by government agencies to do the basic research - DOD, ARPA , NIST, State of California. This extensive research gave the company a large advantage over other companies during a period when research money was generally scarce.

Company History:
Work on layered compression began in Fall 1995; DemoGraFX filed a patent for layered compression algorithm in January 1996. The system was implemented in software early in 1996. Demonstration to other industry leaders has led to revision and improvement of the compression algorithm. The ATP award was received in January 1999, with the goal of implementing a hardware prototype that could achieve real time decompression and near real time compression. The project is expected to be successfully completed by December 2000. Talks have already begun with potential partners to develop a production version of hardware.

R&D Investments to date:

Time period	Source	Amount
1995-1998	DemoGraFX Funded Research*	$250,000 $2,500,000
1999-2000	DemoGraFX Mercury Computer, Inc. Loaned computer equipment	$250,000 $100,000

*DemoGraFX retained all intellectual property rights.

8. Effects of ATP

Other factors on timing of innovation: None identified.

Leading competitors in field (experts, firms, laboratories):
Sarnoff - optimizing MPEG-4. has achieved bit rates of 45 to 50 Megabits/second. DemoGraFX is working in the 8 to 20 Megabit/second range where lower numbers are better. Even at the high bit rates used by Sarnoff, a significant number of viewers at a recent demonstrations could easily pick the original from the compressed version.
Qualcom - working with MPEG-4, but has had nothing to demo.
GrassValley (out of Northern CA) - a company which made its name in switching devices and titles making hardware is working with MPEG-2 as well as MPEG-4
QuVis - the leading competitor, uses wavelet compression, and has achieved bits rates of only 60 to 90 Megabits/second.

Foreign government action: None identified.

Likely scenarios absent ATP intervention:
DemoGraFX is a small company that would not have attempted an R&D effort of this magnitude without government funding. A venture capital infusion at an earlier point would have led to loss of control and loss of incentive for the principals. Without ATP funding it would have taken DemoGraFX 4-6 years to get to where they will be in 1/2001, as opposed to the 2 years of the ATP award. This suggests an acceleration of from 2 to 4 years. None of the leading competitors seem to be on the right track - MPEG-4 is not layered in the same way as DemoGraFX's Layered Compression and therefore cannot achieve the low bit rates and high compression ratios that DemoGraFX's proprietary compression can achieve.

Effect of ATP on national location:
An unnamed European firm has been examining holes in MPEG-4.
DemoGraFX's research has discovered numerous basic flaws in MPEG-4 compression (an International effort at compression). DemoGraFX's proprietary compression technology does not have these flaws..

Effect of ATP on qualitative characteristics of innovation:
It is possible that a non-layered or non-scalable system would have prevailed, although at a great sacrifice in quality and bit rate.

Effect of ATP on organization, strategy, partnering, and business plan:
ATP encouragement and "sounding board" services were a great help to strategic planning.

Effect of ATP on this organization's R&D investment (this and other projects):
This is the main project of DemoGraFX. ATP helped them continue to invest their own time. They have also received a great deal of in-kind assistance from movie studios - especially feedback and access to difficult to compress footage.

Effect of ATP on other organization's R&D investment on competitive projects:
None identified.

Actual/expected dates:

event	**point estimate**	**lower bound**	**upper bound**
Initiation of the project	1996		
ATP funding of project	1/1999		
Completion of research laboratory /verification of concept	12/2000	12/2000	2/2001
Completion of development /demonstration of innovation and product engineering	12/2001		
Commercial introduction/first sales	6/2002		
Extinction/replacement by next generation technology	?		

Counterfactual dates (point estimate, LB, UB):

event	point estimate	lower bound	upper bound
Initiation of the project	1996		
stage comparable to ATP funding of project	2002	2001	2003
Completion of research laboratory /verification of concept	12/ 2003	12/2002	12/2004
Completion of development /demonstration of innovation and product engineering	2005	2004	2006
Commercial introduction/first sales	2006	2005	2008
Extinction/replacement by next generation technology	?		

9. Market impacts

Size of potential (market or markets)

The current cost of film distribution is around $700 million per year. Digital Cinema has the potential to displace existing distribution channels at lower cost. This will increase profits of film producers, and movie theaters as well as lowering costs to consumers. Estimated losses due to piracy are on the order of several billion dollars per year. Proposed security measures would substantially reduce these costs.

Actual/potential sales of products embodying innovation

None to date

Revenue per unit earned by innovating firm

Not estimated

REPORT ON ATP-CLIENT INTERVIEW–MediaSite, Inc.

0. Interview description

Respondent(s):	Robert Mozenter
Title/occupation:	Vice President of Engineering
Organization:	MediaSite, Inc.
Email address:	mozenter@mediasite.com
Telephone:	412-288-9910
FAX:	NA
Date of interview:	4-27-2000
ID of interviewers:	Joshua L. Rosenbloom Pat Oslund

Referrals to additional interviewees in firm or elsewhere:
Leading competitors in indexing and managing video assets are Virage and Excalibur

1. Technology description

Name of ATP project:
Integrated Speech, Language, and Image Processing for Real-Time Creation of a Videoconferencing Library System

Technology name or description:
Indexing and accessing libraries of audio/video content.

Technology goal(s):
Extend current methods of indexing and accessing video images. Current methods work well on structured video such as newscasts or other broadcast television for which there is supplementary information such as closed captions that allow segmentation of the video, identification of subjects and text of dialogue. It also works well with newscast without cc because of professional speakers and the nature of the broadcast (i.e., speakers don't typically talk over one another). But even in this context indexing can be relatively slow. Other, non-structured video such as documentaries, entertainment content, etc. can take as much as 10 to 12 times as long as "real time.", depending on the types of indexing techniques used. The goals of this project are two-fold:

- Develop a processing architecture that allows for near "real time" indexing
- Extend methods of indexing to unstructured video that lacks supplementary data, such as might be created in a corporate video conferencing context, and that supplementary data..

Technology technique:
Increased speed will be achieved primarily by developing a parallel processing architecture for handling the analysis and indexing of video streams

Automating indexing of unstructured video is based on the simultaneous use of base technologies in speech recognition, image recognition, and language processing. New indexing techniques based on one or more image, language and speech techniques. will be created to enable searching of business meetings. the simultaneous use of all the indexing techniques is another innovation.

Current developmental status (stage, timeline, risk):
MediaSite currently supplies software used to index and manage videotape archives for broadcasters and video production companies. These developed out of basic research conducted at Carnegie Mellon

University. The first commercial sale of this product was made in the Fall of 1997, and the product was subsequently improved.

NIST-ATP funding for the current project was secured in March 1999, and during the first year of the project work has focused on

- benchmarking and improving existing techniques for speech recognition and image analysis (especially face detection);
- developing techniques for identifying and analyzing text images–such as a Powerpoint presentation or other items represented within the frame of the video stream;
- development of parallel processing architecture for indexing engine.

Subsequent iterations will advance these techniques and new techniques will be added. By Spring 2001 the feasibility of project goals will have been established, and by March 2002 (completion of NIST-ATP funding) a commercial product, products or licensing arrangement will be underway. Commercialization of products, technology, etc will begin in year 3 but may not complete in year 3 of the project.

Related, broader technologies:
Interactive television

Related, narrower technologies:
Speech recognition
Language processing
Image recognition
Parallel processing

Cross-references:

2. Actual/anticipated effects in immediate markets
Intended initial markets:
Corporate video conferencing
Broadcast television
Video production studios

Other possible markets:
Education and training providers including universities
Information retrieval on the Internet–visual information search engine
Consumers (for organizing home video, etc.)

Planned/actual business model:
Indexing and archiving can be provided as a service for an ongoing fee or software to implement procedures can be sold to end-users. Indexing methods might also be licensed to equipment manufacturers such as camcorder producers or VCR makers who would embed this in their products.

Current software is sold at a fixed price. For Internet applications, pricing is a function of the number of servers on which the software is installed. When MediaSite performs the indexing it charges a per hour fee. Asset management fees are on a per month basis. This model would be extended with the improved software. But new models would be needed for additional applications envisioned.

Existing substitutes (negatively impacted):
Existing video indexing systems including labor inputs used to produce closed captioning or other supplementary data used to analyze and classify video.

Nature of gain(s) to user (as compared with existing substitutes):
Substantial increase in speed of indexing–would make real time uses possible;
Greatly expanded scope of material that can be indexed.

Likely limitations of technology in short-term:
Capabilities of speech recognition, language processing, and image processing are imperfect

Additional desirable features:
Ability to summarize indexed data. As the volume of indexed video increases, it will become increasingly important to have the ability to analyze and build summaries of large amounts of video, similar to documentaries that are produced today.

Potential for "inventing around":
High in principle. The basic techniques being used are not proprietary with MediaSite. Advantage comes from trade secrets and specialized knowledge based on experience.

Other future substitutes: None identified

Other factors on monopolization potential: None identified

Other factors on intellectual property protection: None identified

3. Actual/anticipated effects in related markets
Complementary products:
Greater access will increase the value of video assets and encourage more interactive uses of video libraries.

Potential for forced "tie-ins" of this product:
Video libraries or collections that use this product will necessarily oblige there users to employ it.

Potential for forced "tie-ins" to this product: None identified

Upstream products (inputs to production of this product):
Speech recognition software
Language processing software
Image recognition software
Computers

Downstream products (uses this product as input to production):
Internet streaming video
Video production activities
Home recording and playback

Antagonistic products: None identified

4. Knowledge spillovers

Potential/actual spill-outs:

Advances in parallel processing architecture

Potential/actual spill-ins:

Improvements in techniques for analyzing speech, language, and images
Improved computation speed

5. Network spillovers

Investment coordination problems: None identified

Standards problems:

Standards for video metadata have not yet been finalized, but they will be in the form of MPEG-7, various other groups like SMPTE are likely to accept these standards. They will facilitate development of indexing applications. But absence of these standards is not a major impediment to development of indexing. The standards will provide an architecture in which to embed the information produced by indexing.

Hardware-software coordination: None identified

Software-software coordination: None identified

Previous installed base (as a barrier):

Previously indexed video will be a minor obstacle to introduction of new techniques. Especially as indexing speed increases it will be easy to convert video libraries to be compatible with new methods. But there will be some costs.

Future installed base (as a source of lock-in and monopolization):

Not seen as a significant factor

Other sources of premature lock-in: None identified

Economies of scale in production: None identified

Direct interactions between consumers (economies of consumption): None identified

Synergies with other technologies (and economies of scope): None identified

Need for development of specialized uses: None identified

Other specialized use networks using this product: None identified

Specialized use networks to which this product belongs: None identified

6. Barriers to development or commercialization Also, commercialization risk is always present; we will not list it unless there are known problems specific to this technology and not identified elsewhere.

Capital availability:

Lead time for this project made it unattractive to private investors. The pay-off is too far in the future, and the size of returns too unpredictable to attract venture capital.

Other special barriers:

7. Description of this firm

MediaSite is a spin-off of Carnegie Mellon University, which acquired rights to a number of patents developed by researchers at the University relating to the analysis and indexing of video. The company now consists of 65 employees most are engaged in managing the existing video indexing and asset management product that the company supplies.

There are 5 full time researchers working on this project, along with occasional contract consultants and developers from Carnegie Mellon.

MediaSite is conducting one other, much smaller research project for the Air Force at this time.

8. Effects of ATP

Effect of ATP on this organization's R&D investment (this and other projects):
Project would not have been undertaken without ATP support. The demands of maintaining and improving the company's existing products would have taken all available R&D resources. Only work on marginal improvements would have been likely to be pursued.

Effect of ATP on qualitative characteristics of innovation:
ATP support has provided the opportunity to conduct research with a longer time frame that has allowed the project to pursue broader and more extensive improvements in techniques than would have been possible otherwise.

Effect of ATP on organization, strategy, partnering, business plan:
ATP involvement has kept researchers more focused on commercial applications than otherwise. With financial support but no organizational assistance goals would have been more diffuse and progress toward commercialization would have been slower (delayed perhaps 6-12 months).

Opportunities to find partners have been enhanced by ATP involvement.

Other factors on timing of innovation: None identified

Effect of ATP on other organization's R&D investment on competitive projects: None identified

Leading competitors in field (experts, firms, laboratories):
Virage
Excalibur

Effect of ATP on national location:
Effects on national location do not appear significant. There is little research on these applications outside the US. Indeed, MediaSite was paid to deliver a Japanese version of their product. They are working on possible partnerships but they are not in place at this time. It has also provided its services to a number of European countries.

Foreign government action: None identified

Likely scenarios absent ATP intervention:
Existing indexing methods would have improved incrementally. Significant advances would be substantially delayed. Delay might be an additional 3 years.

Actual/expected dates:

event	point estimate	lower bound	upper bound
Initiation of the project	3/1999		
ATP funding of project	3/1999		
Completion of research laboratory /verification of concept	NA*		
Completion of development /demonstration of innovation and product engineering	NA*		
Commercial introduction/first sales	3/2002		
Extinction/replacement by next generation technology	3/2005		

*Distinction between Research and Development phases is not precise. Rather there is an iterative process in which techniques are tried, and then incorporated into a potential product, and then further research is conducted.

Counterfactual dates (point estimate, LB, UB):

event	point estimate	lower bound	upper bound
Initiation of the project	A		
Stage comparable to ATP funding of project			
Completion of research laboratory /verification of concept			
Completion of development /demonstration of innovation and product engineering			
Commercial introduction/first sales	A+36		
Extinction/replacement by next generation technology	A+36		

9. Market impacts

Size of potential (market or markets)
Current market for video asset management by studios and broadcasters is around $20 million
The market for services associated with video conferencing is estimated to be worth 20-30% of the total size of this market, but this number is not available

Actual/potential sales of products embodying innovation
Not applicable

Revenue per unit earned by innovating firm
Unable to estimate

Cost saving or monetary benefit to users per unit purchased
Unable to estimate

REPORT ON ATP-CLIENT INTERVIEW–Physical Optics

0. Interview description

Respondent(s):	Freddie Lin, Vice President for Applied Technology Lonnie Lindsey, Director of Marketing
Organization:	Physical Optics
Email address:	Freddielin@aol.com Lonnie@Poc.com
Telephone:	310-530-1416
FAX:	NA

Date of interview:	6 April 2000
ID of interviewers:	Pat Oslund, Joshua Rosenbloom
Referrals to additional interviewees in firm or elsewhere:	None identified

1. Technology description

Name of ATP project: Compressed Live Object Video Interactive Singular (CLOVIS)

Technology name or description:
An object oriented compression algorithm that makes it possible to achieve compression ratios an order of magnitude greater (i.e. 1000-to-1 vs. 100-to-1) than are possible with current MPEG based approaches while retaining information about objects within the image frame that allows manipulation of these objects.

Technology goal(s):
Develop a prototype coder and decoder implemented in hardware and software that would allow for both real-time and non-real-time compression and decompression and provide:
1)Higher compression ratios while preserving good of image quality
2)Interactive object oriented video streams for remote monitoring (e.g., bank security cameras, power plant monitoring, etc.), education and training (e.g., streaming video in which the viewer can click on objects within a frame to view them in more detail, manipulate them, or refer to additional information), and interactive television (e.g., the ability to separate different layers of information such as news, weather, sports, and stock market information now provided simultaneously by CNN)
3)Ability to perform post production editing, addition of special effects, and interactive links to independent objects within an image frame.

Technology technique:
In contrast to existing compression techniques that rely on transformations, this technology makes us of mathematical innovations in catastrophe theory developed by Russian mathematicians in the 1950s that captures all the essential information about three dimensional edges and boundaries of the objects that can be expressed completely in a finite number of terms or “singularities” Each term can be represented by a polynomial of relatively low order. Like MPEG this approach relies on a relatively complicated coder and a simple decoder, so that users can decode using relatively simple software and hardware that can easily be distributed.

Current developmental status (stage, timeline, risk):
$ Project initiated in August 1996
$ ATP grant began January 1999
$ Year 1 (1999) has been spent on initial verification of the applicability of the catastrophe theory as a

mechanism for compression and post compression manipulation

- $ Year 2 (2000) will be spent developing software implementation of the algorithm and building a non-real time demonstration
- $ Year 3 (2001) will be used to develop real time compression and decompression prototype and a demonstration of non-real time application for video image compression and manipulation
- $ With completion of this phase it will be feasible to search for partners to develop commercial implementations.
- $ Non-real time compression algorithm would be commercially available as early as 2003. The latest possible introduction would be 2004/2005
- $ Real time compression algorithm would be commercially available for less demanding applications in 2004 at the earliest and 2006/2007 at the latest

Related, broader technologies:
Compression algorithms
Object oriented representations of images
Object tracking and recognition

Related, narrower technologies: None identified

Cross-references: NA

2. Actual/anticipated effects in immediate markets
Intended initial markets:
Security and remote monitoring applications where low bandwidth currently constrains image quality
Internet video streaming
Interactive training and educational video production

Other possible markets:
Television and film post production activities
Production of digital cinema special effects
Distribution of compressed digital cinema

Planned/actual business model:
Once working prototype is developed POC will seek one or more partners to develop commercial applications embedding the technology. The model envisioned is one in which decoders are given away, but encoders are sold. In addition, POC will seek the integration of its compression software with existing Internet browser or other video communication and manipulation market applications.

Existing substitutes (negatively impacted):
Interactive features of object-oriented compression are novel. At the moment they can be achieved only through very costly image processing and human manipulation in non-real time post production of video streams. The cost of interactivity and object manipulation will fall substantially causing the market to expand substantially.

Existing methods of compressing and streaming video will still be cheaper for non-interactive uses, but this approach will probably reduce the use of such non-interactive video.

Nature of gain(s) to user (as compared with existing substitutes):

Improved image quality for fixed bitstream size
Interactivity
Ease of production of interactive video

Likely limitations of technology in short-term:
Cost of calculations needed to perform real-time compression

Additional desirable features:
Ability to adapt compression algorithm to increase detail in some objects and reduce detail in others to maximize usefulness of compressed image stream. Adjustment could be accomplished by the viewer manipulating the images being viewed (this appears to be what is envisioned) or it could be done automatically on the fly by the coder itself.

Potential for Inventing around@:
Viewed as limited. Basic ideas are not adequate to develop competing alternatives. Expertise in this area of mathematics is limited and unlikely to be available to competitors.

Other future substitutes:
Greater bandwidth, higher density media, and faster processors would reduce the value of compression. But object oriented approach has few obvious substitutes.

Other factors on monopolization potential: None identified

Other factors on intellectual property protection: The algorithm has been patented

3. Actual/anticipated effects in related markets
Complementary products:
Users would not require specialized equipment. Decoder would be simple and relatively inexpensive, as is true with MPEG

Potential for forced "tie-ins" of this product: None identified
Potential for forced "tie-ins" to this product:
Compression algorithm might be embedded in editing and production equipment or in security/surveillance system.

Upstream products (inputs to production of this product): Specialized chip or chipset embedding the compression algorithm

Downstream products (uses this product as input to production):
Television/video production equipment.
Security/surveillance equipment
Digital special effects and editing equipment
Streaming video over the Internet

Antagonistic products:
Other compression algorithms

4. Knowledge spillovers

Potential/actual spill-outs:
Development of non-transformational compression algorithms

Potential/actual spill-ins:
Increased computing power
Greater storage capacity

5. Network spillovers

Investment coordination problems: None identified

Standards problems: None identified

Hardware-software coordination: None identified

Software-software coordination: None identified

Previous installed base (as a barrier): Not likely to be a problem

Future installed base (as a source of lockin and monopolization): None identified

Other sources of premature lockin: None identified

Economies of scale in production: None identified

Direct interactions between consumers (economies of consumption): None identified

Synergies with other technologies (and economies of scope): None identified

Need for development of specialized uses: None identified

Other specialized use networks using this product: None identified

Specialized use networks to which this product belongs: None identified

6. Barriers to development or commercialization

Capital availability:
The approach is unproven and too risky to attract venture capital at this time

Other special barriers: None identified.

7. Description of this firm

POC is a small company. There are 10-12 people working on the project, about 9 of them are R&D personnel, and not all of them are assigned to the project full time. Overall the R&D technical personnel in the company number about 100.

8. Effects of ATP
Other factors on timing of innovation:

There is a strong demand for the capabilities that object oriented compression offers. Currently interactive object based video requires a great deal of human effort to identify objects frame by frame and link these appropriately. Manipulation of independent objects within an image frame can be done but requires expensive ($200,000-$300,000) specialized production equipment. Rendering of object oriented special effects is highly computationally expensive at the moment.

Consequently there is strong demand pressure for solutions. Thus it seems likely that some ensemble of innovations facilitating these activities would emerge.

Leading competitors in field (experts, firms, laboratories):
Most work on solution to these problems is being conducted in other countries, mainly Europe (France, and Italy) and Japan

Foreign government action:
Japanese, French, and Italian governments are sponsoring work in this area.

Likely scenarios absent ATP intervention:
POC would *not* have pursued this line of research without ATP funding because of risks
Other approaches are unlikely to yield as much efficiency. POC is estimated to be 3-4 years ahead of potential competitors.

Effect of ATP on national location:
Shift in likely national location of innovation

Effect of ATP on qualitative characteristics of innovation:
None identified

Effect of ATP on organization, strategy, partnering, business plan:
ATP support has made POC more credible, but has not yet resulted in partners or other external funding sources.

Effect of ATP on this organization's R&D investment (this and other projects):
Increased POC=s investment in post grant phase from estimated value of zero to $1.9 million. This has presumably reduced investment in other activities.

Effect of ATP on other organization's R&D investment on competitive projects:
None identified

Actual/expected dates:

event	point estimate	lower bound	Upper bound
Initiation of the project	8/1996		
ATP funding of project	1/1999		
Completion of research laboratory /verification	1/2001	12/2000	4/2002

of concept			
Completion of development /demonstration of innovation and product engineering	1/2003	7/2002	7/2003
Commercial introduction/first sales*	2004	2003	2005
Extinction/replacement by next generation technology	2012	2010	2015

Counterfactual dates (point estimate, LB, UB):

event	**point estimate**	**lower bound**	**upper bound**
Initiation of the project	1996		
Stage comparable to ATP funding of project	1999		
Completion of research laboratory /verification of concept	2004	2003	2005
Completion of development /demonstration of innovation and product engineering	2007	2006	2008
Commercial introduction/first sales*	2009	2008	2010
Extinction/replacement by next generation technology	2012	2010	2015

9. Market impacts

Size of potential (market or markets)

Primary markets initially are anticipated to be in security/monitoring and in production and distribution of transactive multimedia for training and education. It is estimated that the market for these services is currently around $500-600 million annually. With the additional capabilities that object-oriented compression would provide this market would grow substantially over time. The scope of applications for which the compression algorithm was applicable would also expand with progress down the learning curve.

Actual/potential sales of products embodying innovation

NA

Revenue per unit earned by innovating firm

Not estimated

REPORT ON ATP-CLIENT INTERVIEW–Sarnoff Corporation, Perceptually-Based Video Encoding and Quality Management

0. Interview description

Respondent(s):	Albert Pica, Group Head John Pearson, Technical Director
Organization:	Sarnoff Corporation
Email address:	jpearson@sarnoff.com apica@sarnoff.com
Telephone:	609-734-2859 609-734-2385
FAX:	609-734-3211
Date of interview:	March 31, 2000
ID of interviewers:	David Burress, Pat Oslund, Joshua Rosenbloom
Referrals to additional interviewees in firm or elsewhere:	None

1. Technology description

Name of ATP project:
Perceptual-Based Video Encoding and Quality Measurement

Technology name or description:
Perceptual methods to compress video images and to assess image quality.

Technology goal(s):
To use algorithms based on human vision to improve compression by 10 to 20 percent (for a given number of bits.);
To use human vision concepts to create a video encoder;
To make motion estimation algorithms more efficient;
To put the encoder on a single chip, or possibly a set of a small number of chips.

As background, there does not exist today a technology that can compress video for HDTV using a single chip or even a small chip set.

Technology technique:
Most compression algorithms that compress video for MPEG-2 decoding depend on engineering concepts to find differences between images. The problem is that the measured image differences are poor indicators of visual quality as perceived by humans. Sarnoff's approach is to create a computational model based on human vision and build it into the encoder. The human vision model is based on psycho-physics and is calibrated by actual data. The human vision model can be used for testing the quality of compression algorithms and can also be the basis of a new video encoder. In a sense, the human vision model is used to weight various parts of the image for encoding.

Current developmental status (stage, timeline, risk):
This project is currently on hold. Sarnoff has had a number of partners on the project (LSI Logic, TI, Tektronix, Sun, Bell Atlantic but each partner's business objectives have changed and, consequently, all but Bell Atlantic have stepped out of the project. Sarnoff recently has found a new partner, AgileVision.

The project was constructed so that Sarnoff was the main source of innovation in creating the algorithms, while the partners were more concerned with creating the chips.

Sarnoff has already created algorithms than can reduce the number of bits for a given image quality by 10 to 20 percent. Sarnoff is confident that they have devised the best approach for optimizing bits for compression, and that the approach could lead to improvements on standard MPEG encoders by as much as 35 percent.

Related, broader technologies:
video compression
human vision models

Related, narrower technologies:
none identified.

Cross-references:
none identified.

2. Actual/anticipated effects in immediate markets
Intended initial market(s):
1) Broadcast market. The chip would be used to encode content for transmission by cable, over the air, and by satellite.
2) Camcorders. Most camcorders use a format called DV. This algorithm, coded on a single chip, would allow MPEG-2 type compression.
3) DVD. The chip could be used in DVD recordable devices and for replay TV.

Other possible markets:
Internet video streaming. When work started on the Sarnoff technology, this was not a very important market. But this market is growing and may be an important use of the encoder chip in the future.
Electronic cinema. The algorithms that are developed by this project may have uses in electronic cinema distribution and archival.
Video quality measurement devices. The Sarnoff approach is natural for this application because it is based on human vision criteria.

Planned/actual business model:
At first, Sarnoff will partner with a manufacturer to produce chips. The likely first market is broadcast equipment. Later, Sarnoff will license its algorithms. Licensing will probably NOT be exclusive.

Existing substitutes (negatively impacted):
Existing MPEG encoder algorithms and chips. Existing "DV" chips for camcorders. Alternative (not MPEG) encoders.

Nature of gain(s) to user (as compared with existing substitutes):
Cost saving (for example, in broadcast): 10 to 20 percent less bandwidth needed to transmit an image of a given quality (in comparison with standard MPEG compression). There is a potential to achieve gains up to 35 percent.
Quality improvement (in broadcast): For a given bit rate, 10 to 20 percent quality improvement, as measured by the just noticeable difference (JND) standard.
Quality improvement (in camcorders): Compression will be 10 times better. Cost of chips will be about the

same as current cost: $30 - $50 per chip. The total size of the market for chips for camcorders is >100 million. Other cost considerations: the market for encoder chips is several million dollars per year, and there are about 8 competing firms.

Likely limitations of technology in short-term:
No short-term limitations identified. In the long term, it may be a disadvantage that this approach may not be very adaptable to pattern recognition and computer vision techniques.

Additional desirable features:
Video encoded with this technique could be decoded with standard MPEG-2 decoder. The Sarnoff approach will also work with emerging MPEG-4 standard. Adaptable for real-time applications.

Potential for "inventing around":
In principle, high. The general idea of adapting the compression scheme in light of perceived quality is probably not patentable. Alternative algorithms may be possible. However, the particular standard can be protected though patents and/or proprietary algorithms. Furthermore, experience with human vision gives Sarnoff an important head start.

Other future substitutes:
A very wide-band/high-speed pipe may be a substitute for real-time compression in Internet and broadcast applications. Smaller and cheaper storage devices may be a substitute for compression in camcorder applications.

Other factors on monopolization potential:
Being first in the market is a substantial advantage in this industry. Also, getting products out in the market creates a base for future sales.

Other factors on intellectual property protection:
none identified.

3. Actual/anticipated effects in related markets
Complementary products:
1. Chip production. The algorithm will eventually be used in an encoder chip.
2. Camcorders.
3. DVD players and replay devices.

Potential for forced "tie-ins" of this product:
This product will become part of physical devices such as camcorders, so in buying the camcorder one will buy the encoder as well.

Potential for forced "tie-ins" to this product:
None identified because the product will not require proprietary decoder devices.

Upstream products (inputs to production of this product):
Products used in production of silicon chips.

Downstream products (uses this product as input to production):
See complementary products above.

Antagonistic products:
Alternative compression schemes that would lead to incompatible standards.

4. Knowledge spillovers
Potential/actual spill-outs:
1. The "demonstration effect" of incorporating components of human vision into compression schemes may be useful to anyone trying to develop compression algorithms.
2. The compression algorithm under development may "raise the bar" for compressed video quality, and hence stimulate new research. It could also become a standard for video on the Internet.

Potential/actual spill-ins:
MPEG-2 and MPEG-4
human vision research (some of it done by Sarnoff as early as the 1970s).

5. Network spillovers
Investment coordination problems:
Chip producers will need to make complementary investments.

Standards problems:
This algorithm will work with standard MPEG decoders, and will be usable with MPEG-4. So this algorithm is depends on MPEG decoders being in common usage.

Hardware-software coordination:
Hardware (the chip or chips) will be needed to implement the software algorithm in real or near real time.

Software-software coordination:
none identified.

Previous installed base (as a barrier):
None identified. This approach can make use of existing MPEG decoders.

Future installed base (as a source of lockin and monopolization):
If this algorithm is successfully implemented and embedded into hardware, it may make MPEG standard(s) even more attractive (as opposed to completely different approaches to compression and decompression). This compression algorithm may become a standard for compression of video to be transmitted over the Internet.

Other sources of premature lockin:
None identified.

Economies of scale in production:
As more chips are produced, the up-front costs of designing the chip are spread over a larger base.

Direct interactions between consumers (economies of consumption): None identified.

Synergies with other technologies (and economies of scope): None identified.

Need for development of specialized uses: None identified.

Other specialized use networks using this product: None identified.

Specialized use networks to which this product belongs: None identified.

6. Barriers to development or commercialization Note: commercialization risk is always present; we will not list it unless there are known problems specific to this technology and not identified elsewhere.

Capital availability:
This firm specializes in research, and while it does production for prototyping and small-scale manufacturing, it does not manufacture chips in large quantities. . For the algorithm to be implemented in a chip and actually embedded in products, a partner who is a chipmaker/manufacturer will be needed.

Other special barriers: None identified.

7. Description/history of this firm
Sarnoff has a long history as a research and development laboratory. It was founded in 1942 (as RCA Laboratories). The firm became part of SRI International in 1987. The firm specializes in contract research for government and industry. The firm often hires researchers from universities, and hence takes advantage of developments in academic research.

This particular project involves 8-10 people out of a total Sarnoff employment of about 500 engineering staff.

Sarnoff's research on human perception goes back to the 1970s. This particular project began in October, 1995. Sarnoff has had several partners on this project, including LSI Logic, Texas Instruments, Sun, and Bell Atlantic As of April, 2000, all of the partners have left the project except for Bell Atlantic. However, the basic research on the algorithm is essentially complete, and Sarnoff has recently found a new partner for the project. The project has about one year of NIST funding remaining.

8. Effects of ATP
Other factors on timing of innovation: None identified.

Leading competitors in field (experts, firms, laboratories):
C-Cube Microsystems Inc. is a digital video integrated circuit maker who builds a traditional encoder chip. IBM builds video encoding chips

Foreign government action: None identified.

Likely scenarios absent ATP intervention:
Most of Sarnoff's research is done on contract. For the most part, Sarnoff does not have its own funds to invest. Without the NIST/ATP funding, the firm would almost certainly not have undertaken the project. The firm had tried ~~to~~ unsuccessfully to get funding prior to the NIST program.
The NIST funding also allowed the firm to get partners involved with the project. Various partners have contributed substantial amounts to the research. Including Sarnoff's own investment and funds from partners, about $16 million has been spent exclusive of the NIST funding. It is possible that none of this would have been spent but for the NIST project.

There is a lot of market pressure to get better compression technologies. If Sarnoff had not undertaken this project, other firms (possibly IBM) might have developed similar technologies. However, the pace of research would have been set back three to four years. For example, IBM has the resources to do such a project, but they don't have in place a team of human vision experts.

Effect of ATP on national location:
Presumably, counterfactual success could have been by a non-US firm. However, most non-US firms are working on video quality measures rather than on optimization within the compression scheme. Non-US firms are at least 3-4 years behind Sarnoff in this area.

Effect of ATP on qualitative characteristics of innovation:
Not only did NIST make it easier for Sarnoff to find partners; it also influenced the types of partners chosen. Partners were chosen so that the innovation might make its way into a broad range of products. In this sense, the potential scope of the innovation was broadened.

Effect of ATP on organization, strategy, partnering, business plan:
See above.

Effect of ATP on this organization's R&D investment (this and other projects):
Some of the 8-10 people working on this project were hired specifically for this project. Others would have been working on other Sarnoff projects. No business was turned away because the staff was already engaged in this project.

Effect of ATP on other organizations' R&D investment on competitive projects:
None identified.

Actual/expected dates:

Event	Point estimate	Lower bound	Upper bound
Initiation of the project	1995		
ATP funding of project	10/1995		
Completion of research laboratory /verification of concept A) encoding algorithm B) chips	 12/1/00 2/1/00	 10/1/00 1/1/01	 2/1/01 3/1/01
Completion of development /demonstration of innovation and product engineering (chip prototype)	6/2001	3/2001	9/2001
Commercial introduction/first sales (chip production)	10/2001	6/2001	2/2002
Extinction/replacement by next generation technology	1/1/08	1/1/07	1/1/10

Counterfactual dates (point estimate, LB, UB):
Note: without ATP funding, everything is assumed to happen three to four years later. A+36 means 36 months (3 years) later. A+48 means 4 years later.

Event	point estimate	lower bound	upper bound

Initiation of the project (by Sarnoff or another firm)	A+42	A+36	A+48
stage comparable to ATP funding of project	A+42	A+36	A+48
Completion of research laboratory /verification of concept	A+42	A+36	A+48
Completion of development /demonstration of innovation and product engineering	A+42	A+36	A+48
Commercial introduction/first sales	A+42	A+36	A+48
Extinction/replacement by next generation technology	?	?	?

9. Market impacts

Size of potential (market or markets)

Current market for chips for video cameras is around 100 million. The cost of each chip currently used in video cameras is $30 to $50.

The market for encoder chips is several million per year, shared by about 8 firms. Sarnoff expects that its innovations will also impact non-chip-based encoding markets, such as digital cinema, but no market estimates for these have been made.

Actual/potential sales of products embodying innovation

Not known from this source.

Revenue per unit earned by innovating firm

Not available

Cost saving or monetary benefit to users per unit purchased

Not yet identified.

Cost saving or monetary benefit to users per unit purchased

Not yet identified.

REPORT ON ATP-CLIENT INTERVIEW–Sarnoff Corporation, HDTV Broadcast Technology

0. Interview description

Respondent(s):	Frank Marlowe
Title/occupation:	Program Manager
Organization:	Sarnoff Corporation
Email address:	fmarlowe@sarnoff.com
Telephone:	609-734-3179
FAX:	Not available
Date of interview:	5-9-2000
ID of interviewers:	Joshua Rosenbloom, Patricia Oslund

Referrals to additional interviewees in firm or elsewhere:
IBM—Jim Janniello (914-784-7819)
Sun Microsystems—Tom Jacobs (605-786-6375)
Thomson—Jean Chatel (011-33-2-99-273052 – located in France)
Thomcast, previously Comark—Brett Jenkins (413-569-0116, extension 231)
New Jersey Network, NJN—William Schnorbus (609-777-5163)
MCI—Paul Donaldson (972-729-4908)

1. Technology description

Name of ATP project: HDTV Broadcast Technology

Technology name or description:
Suite of software and hardware applications necessary to perform functions needed to operate an HDTV broadcast station.

Technology goal(s):
Develop tools to edit, distribute, store, access and broadcast HDTV content for broadcast television studios. The initial goal was to develop a tightly integrated set of tools that could be bundled together to equip television broadcasters making the transition to HDTV. As it turned out, however, joint venture participants were reluctant to tie their individual projects together too tightly. There was overall coordination, but individual projects were pursued independently and each partner has taken responsibility for commercializing their own innovations.

The key tools involved and their developers are:

- Software and hardware for routing signals over ATM (i.e., telephone-like) networks. This involves treating DTV as a data stream, along with other similar data streams for audio, equipment status, communication etc. The key challenge is in developing techniques to deal with latency—delays in the arrival of packets in the video data stream, so that images are displayed continuously and without interruption. Two independent sets of tools have been developed: (1) for transmission within the studio, by IBM; and (2) for transmissions between the studio and other locations, by MCI. Currently television data streams are sent mainly by satellite, which is essentially a one-way broadcast medium. Use of ATM telephone networks makes possible two-way, interactive applications, and creates the potential for “studios without walls.”
- Software for archiving and accessing HDTV content. This involves mechanisms of cataloging and accessing video content. IBM has been working on developing techniques to automate the cataloging and retrieval of data.

- Command and Control system for ATM network. This is software and hardware to manage all of the system resources needed to store, access, and transmit HDTV data streams within the studio. This project was managed by Sun Microsystems. With Sarnoff Corp. and IBM, Sun developed a data architecture for command and control that has been submitted to SMPTE, and will soon form the basis for an industry set of standards.
- Broadcast transmitters. These have been developed by Thomcast.
- Encoders for converting video signals to compressed digital data streams. Thomson has developed an encoder that is implemented in hardware. Sarnoff has begun work on a software encoder implementation. Both approaches are compliant with industry standard MPEG-4.
- Compressed domain processing. These tools allow multiple video data streams to be combined and manipulated while in the compressed domain. This would be used for example to insert a television station ID over a network supplied signal, to superimpose emergency information or other layers on an image, or to splice together multiple streams of data to create a single broadcast. This has been developed by Sarnoff.
- Integration of system components. NJN, the New Jersey Public Television network, provided a test bed for technologies being developed as part of this project.

Technology technique:
Sarnoff has served as system integrator. It has coordinated actions of other players, and has developed some key tools such as the compressed domain processing application. It has also picked up some tasks that were originally assigned to partners, but have not been delivered by those partners.

Current developmental status (stage, timeline, risk):
Sarnoff has completed initial work on its compressed domain processor and the production and marketing of the compressed domain processing tools has been spun off into an independent company AgileVision. AgileVision has begun selling this product as of March 2000, when it was introduced at the National Association of Broadcasters convention. It will continue to extend the capabilities of its product (see the accompanying report on this technology for additional details).

A number of other commercial technologies are being commercialized. Thomcast is producing and marketing HDTV transmitters. But respondent could not comment on commercialization plans or status of projects conducted by all the other companies.

Related, broader technologies:
Network command and control software and hardware
Digital signal processing
Compression
Image recognition and analysis

Related, narrower technologies:
None identified

Cross-references:

2. Actual/anticipated effects in immediate markets
Intended initial markets:
The 1500 or so television broadcast stations in the United States.

Other possible markets:
Television broadcast stations in other countries.

Planned/actual business model:
Sarnoff has created a separate spin-off, AgileVision, to produce and market this product (see accompanying report for additional details). Respondent could not comment on other companies' commercialization plans.

Existing substitutes (negatively impacted):
See accompanying reports for product specific details.

Nature of gain(s) to user (as compared with existing substitutes):
Availability of integrated suite of tools for HDTV broadcast will simplify and lower the cost to broadcasters of making the transition to HDTV that has been mandated by the FCC.

Likely limitations of technology in short-term:
Functionality of components may be limited initially.

Additional desirable features:
See accompanying reports for specific details.

Potential for inventing around:
See accompanying reports for specific details.

Other future substitutes: None identified

Other factors on monopolization potential:
See accompanying reports for specific details.

Other factors on intellectual property protection: None identified.

3. Actual/anticipated effects in related markets
Complementary products:
HDTV broadcast content to be used with this product.

Potential for forced tie-ins of this product: None identified

Potential for forced tie-ins to this product: None identified

Upstream products (inputs to production of this product):
Computers, general purpose processors

Downstream products (uses this product as input to production):
Television broadcasts

Antagonistic products:
Individual components that perform specific functions.

4. Knowledge spillovers

Potential/actual spill-outs: None identified

Potential/actual spill-ins: None identified

5. Network spillovers

Investment coordination problems:

Not directly. But the need for skilled personnel to work with and maintain systems will encourage the industry to standardize so that investments in human capital will be coordinated.

Standards problems:

Two types of standardization problems are relevant:

1) Networks will make decisions about the format in which they provide content to affiliates that may influence equipment purchases of affiliates;

2) Local stations are often owned by companies that own several stations. For purposes of purchasing, maintenance, etc., station owners may choose to standardize their purchasing decisions across individual stations.

Hardware-software coordination: None identified

Software-software coordination: None identified

Previous installed base (as a barrier):

Not relevant here. Adoption of HDTV means that stations will be obliged to make this transition. None of them presently have equipment.

Future installed base (as a source of lockin and monopolization):

Possibly important, since major initial investments will be required that will lock stations in to particular solutions.

Other sources of premature lockin: None identified

Economies of scale in production: None identified

Direct interactions between consumers (economies of consumption): Not applicable

Synergies with other technologies (and economies of scope):

Diffusion of HDTV receiving and viewing equipment will be an important factor stimulating broadcasters to make the transition to producing and providing more HDTV content. Improvements especially in display technology are crucial for this to occur.

Need for development of specialized uses: None identified

Other specialized use networks using this product: None identified

Specialized use networks to which this product belongs: None identified

6. Barriers to development or commercialization

Capital availability:

Project was too speculative to attract private financing or private sector partners.

Other special barriers: None identified.

7. Description of this firm

Sarnoff Corporation is a contract research laboratory. They do not produce products themselves. To produce and market the compressed domain editing system they developed they have created a new company, AgileVision. This project has involved approximately 10-20 full time scientific personnel

8. Effects of ATP

Effect of ATP on this organization=s R&D investment (this and other projects):

This innovation would not have been pursued without ATP's support. Sarnoff believed this research had potential uses, but the distance to commercialization made it impractical to seek private partners to develop the technology.

Effect of ATP on qualitative characteristics of innovation:

Effect of ATP on organization, strategy, partnering, business plan:

ATP support has facilitated finding partners. On the other hand, the long lead time involved in making proposals to ATP has made it difficult to involve partners involved in commercial production. Projects with commercial potential are too time sensitive to be able to wait for ATP support.

Other factors on timing of innovation:

Increases in computing power will make it easier to achieve the type of software solutions Sarnoff has developed for these innovations. As computers become more powerful it will be simpler and less costly to develop software applications for HDTV that will run on general purpose hardware.

Effect of ATP on other organization=s R&D investment on competitive projects:

None identified

Leading competitors in field (experts, firms, laboratories):

Sony, Panasonic, Mitsubishi, Philips, Thomson

Effect of ATP on national location:

Most of the major competitors in production of broadcast equipment for HDTV are foreign (see above). ATP has created domestic competition that would not otherwise exist.

Foreign government action: None identified

Likely scenarios absent ATP intervention:

Alternative solutions would have been developed. Instead of offering flexible, general purpose designs, they might have been more specialized to specific uses, and hence less easily upgraded in the future. Their cost would also be higher.

Actual/expected dates:

event	point estimate	lower bound	upper bound
Initiation of the project	10/1995		
ATP funding of project	10/1995		
Completion of research laboratory /verification of concept	9/30/2000		
Completion of development /demonstration of innovation and product engineering	Varies by company		
Commercial introduction/first sales	Varies by company		
Extinction/replacement by next generation technology	????		

Counterfactual dates (point estimate, LB, UB):

event	point estimate	lower bound	upper bound
Initiation of the project	???		
Stage comparable to ATP funding of project			
Completion of research laboratory /verification of concept			
Completion of development /demonstration of innovation and product engineering			
Commercial introduction/first sales			
Extinction/replacement by next generation technology			

9. Market impacts

Size of potential (market or markets)

There are 1,500 TV broadcasters.

Actual/potential sales of products embodying innovation

Estimated equipment purchases for basic HDTV broadcast readiness are around $1 million for each. This implies a market size of about $1.5 billion

Revenue per unit earned by innovating firm

Not able to estimate.

Cost saving or monetary benefit to users per unit purchased
See accompanying reports for specific innovations.

REPORT ON ATP-CLIENT INTERVIEW– Sarnoff Corporation–AgileVision

0. Interview description

Respondent(s):	Frank Marlowe**,**
Title/occupation:	Program Manager
Organization:	Sarnoff Corporation
Email address:	fmarlowe@sarnoff.com
Telephone:	609-734-3179
FAX:	

Date of interview:	5-9-2000 and 6-2-2000
ID of interviewers:	Joshua Rosenbloom, Patricia Oslund
Referrals to additional interviewees in firm or elsewhere:	None

1. Technology description

Name of ATP project:
HDTV Broadcast Technology

Technology name or description:
Compressed domain video processing

Technology goal(s):
An integrated device that enables broadcasters to combine and manipulate multiple video data streams that have already been compressed while maintaining signal quality and bit-rate. This would be used for example to insert a television station ID over a network supplied signal, to superimpose emergency information or other layers on an image, or to splice together multiple streams of data to create a single broadcast.

Technology technique:
This rests on a signal processing algorithm that enables the addition of information to the compressed signal without either degrading image quality or increasing the bit rate required to transmit the video data stream. The algorithm is implemented using software designed to run on a commercially available high performance computer. The computer is built by Mercury Computer Systems and makes use of a massively parallel hardware design that has a distributed interconnect fabric and distributed memory. These features make the hardware scalable so that it is relatively simple to add additional capabilities or improve system performance.

Current developmental status (stage, timeline, risk):
Sarnoff created an independent company, AgileVision, in fall 1999 to commercialize this innovation. It introduced its product in March 2000 and is marketing and selling it to broadcasters.

Related, broader technologies:
Digital signal processing
Compression
DTV editing

Related, narrower technologies:
None identified

Cross-references:

2. Actual/anticipated effects in immediate markets

Intended initial markets:
The 1500 or so television broadcast stations in the United States.

Other possible markets:
Television broadcast stations in other countries, cable TV, Internet

Planned/actual business model:
Hardware and software necessary to implement compressed domain processing are sold as a bundle to broadcasters.

Existing substitutes (negatively impacted):
There are no other existing tools for editing HDTV signals in the compressed domain. The alternative is to first decompress network feeds, process them and recompress them. In addition to the additional steps that this involves, it requires the assembly of a large number of special purpose pieces of equipment, and solution of significant engineering problems to interconnect and manage them.

Nature of gain(s) to user (as compared with existing substitutes):
Compressed domain editing lowers the cost of operation, especially for smaller stations that primarily pass through network feeds. With this innovation they will be able in a simple way to combine an HDTV broadcast from a network with overlays of information—station logo, weather or emergency alerts—and combine local advertising with network broadcasts.

AgileVision estimates that the up-front cost saving of performing these tasks using its product is approximately 50%, reducing the cost from about $500 thousand to $250 thousand for a basic installation.

Likely limitations of technology in short-term:
The kinds of editing operations that can be performed are limited

Additional desirable features:

- More sophisticated editing tools including: creation of graphics such as graphs and maps; tools to artistically combine several different images such as one sees in a newscasts from separate feeds; control room mixing functions; color and resolution enhancement.
- Play control systems that would allow control of sequence of video sources for broadcast
- Encoding software that allow the system to work with uncompressed video inputs
- Integration of video and data streams that would allow viewers to access supplementary information related to a broadcast image

Potential for inventing around:
Solving the algorithmic problems involved in compressed domain processing is difficult. There is no evidence that any one else has come close to achieving Sarnoff's expertise. Patents will provide reasonably strong intellectual property protection.

Other future substitutes: None identified
Other factors on monopolization potential: None identified

Other factors on intellectual property protection: None identified

3. Actual/anticipated effects in related markets

Complementary products:
HDTV broadcast content to be used with this product.

Potential for forced "tie-ins" of this product:
Network decisions about the form in which they will provide content to affiliates will affect the usefulness of the system. PBS has adopted a standard of providing compressed data in a format that AgileVision is well suited to work with. While some networks plan distribution at higher bit rates, they are examining the potential benefits to them of AgileVision's approach.

Potential for forced "tie-ins" to this product: None identified

Upstream products (inputs to production of this product):
Computers, general purpose processors

Downstream products (uses this product as input to production):
Television broadcasts

Antagonistic products:
Other editing systems

4. Knowledge spillovers

Potential/actual spill-outs:
Proof of concept will demonstrate that compressed domain editing is possible. This may stimulate alternative solutions.

Potential/actual spill-ins:
Sarnoff was not originally planning to develop this tool. But another partner in the project was initially working on solutions to allow splicing of compressed data streams. They failed, but in working with them engineers at Sarnoff developed ideas about how to solve the problem that formed the genesis of this project.

5. Network spillovers

Investment coordination problems:
Not directly. But the need for skilled personnel to work with and maintain systems will encourage the industry to standardize so that investments in human capital will be coordinated.

Standards problems:
Network choices of compression standards
Broadcast station owners' decisions to standardize purchases across multiple stations
Cable operators' choices of signal standard and rate of conversion to DTV

Hardware-software coordination:
Applicability of AgileVision is dependent to some degree on network's choices of how to provide content to affiliates.

There are linkages between AgileVision and other broadcast station tools such as choices of compression for internal storage and handling of video streams.

Software-software coordination: None identified

Previous installed base (as a barrier):
Not relevant here. Adoption of HDTV means that stations will be obliged to make this transition. None of them presently have equipment.

Future installed base (as a source of lockin and monopolization):
This could be a problem. Stations once they have adopted a particular set of editing tools are likely to stick with them.

Other sources of premature lockin: None identified

Economies of scale in production: None identified

Direct interactions between consumers (economies of consumption): Not applicable

Synergies with other technologies (and economies of scope):
Diffusion of HDTV receiving and viewing equipment will be an important factor stimulating broadcasters to make the transition to producing and providing more HDTV content. Improvements especially in display technology are crucial for this to occur.

Need for development of specialized uses: None identified
Other specialized use networks using this product: None identified
Specialized use networks to which this product belongs: None identified

6. Barriers to development or commercialization
Capital availability:
In the research phase this project was too speculative to attract private financing or private sector partners without ATP matching funds. After feasibility was demonstrated AgileVision was formed with financing from Mercury Computing Systems. Second round financing is being pursued. .

Other special barriers: None identified.

7. Description of this firm
Sarnoff Corporation is a contract research laboratory. They do not produce products themselves. To produce and market the compressed domain editing system they developed they have created a new company, AgileVision. This project has involved approximately 12 full time scientific personnel

8. Effects of ATP
Effect of ATP on this organization=s R&D investment (this and other projects):
This innovation would not have been pursued without ATP’s support. Sarnoff believed this research had potential uses, but the distance to commercialization made it impractical to seek private partners to develop the technology.

Effect of ATP on qualitative characteristics of innovation: None identified

Effect of ATP on organization, strategy, partnering, business plan: None identified

Other factors on timing of innovation:
Increases in computing power will make it easier to achieve the type of software solutions Sarnoff has developed for these innovations. As computers become more powerful it will be simpler and less costly to develop software applications for HDTV that will run on general purpose hardware.

Effect of ATP on other organization's R&D investment on competitive projects:
None identified

Leading competitors in field (experts, firms, laboratories):
None identified

Effect of ATP on national location:
None identified

Foreign government action: None identified

Likely scenarios absent ATP intervention:
Alternative solutions would have been developed. Instead of offering flexible, general purpose designs, they might have been more specialized to specific uses, and hence less easily upgraded in the future. Their cost would also be higher.

Actual/expected dates:

event	**point estimate**	**lower bound**	**upper bound**
Initiation of the project	1998*		
ATP funding of project	10/1995		
Completion of research laboratory /verification of concept			
Completion of development /demonstration of innovation and product engineering			
Commercial introduction/first sales	3/2000		
Extinction/replacement by next generation technology			

This date refers to origination of AgileVision project, which began after ATP funding of larger project.

Counterfactual dates (point estimate, LB, UB):

Respondent could not identify a counterfactual date at which a comparable technology would have emerged without ATP support. Sarnoff would not have pursued this technology, and it is not apparent that anyone else has been working on this approach.

9. Market impacts

Size of potential (market or markets)

There are 1,500 TV broadcasters. Not all networks will adopt a distribution format that is directly compatible with AgileVision. PBS has adopted compatible distribution format. In total there are about 350 PBS stations that are the primary initial market for AgileVision.

Actual/potential sales of products embodying innovation

Estimated equipment purchases for basic HDTV broadcast readiness are around $1 million for each. This implies a market size of about $1.5 billion

Revenue per unit earned by innovating firm

Not available

Cost saving or monetary benefit to users per unit purchased

$250,000 per unit cost saving for adopters. Saving will grow as AgileVision adds capabilities. There are likely to be operating cost savings as well but these are harder to estimate at the moment.

REPORT ON ATP-CLIENT INTERVIEW–Thomcast Communications

0. Interview description

Respondent(s): Brett Jenkins
Title/occupation: Senior Director of Engineering
Organization: Thomcast Communications
Email address: Bjenkins@thomcastcom.com
Telephone: 413-569-0116, ext. 231
FAX:
Date of interview: 13 July 2000
ID of interviewers: Joshua L. Rosenbloom
Referrals to additional interviewees in firm or elsewhere:

1. Technology description

Name of ATP project: HDTV Broadcast Technology

Technology name or description:
Transmitter technology for HDTV terrestrial broadcast.

Technology goal(s):
To develop transmitter technologies that would allow broadcasters to meet tighter FCC regulations on out-of-band emissions with a given level of signal power at lower cost than is possible with existing technologies.

Technology technique:
This approach makes use of advances in computational power, specifically the availability of Digital Signal Processor and Programable Logic Devices.

Current developmental status (stage, timeline, risk):
Research is completed. Project was begun in early 1996, and the first commercial prototype was available in early 1998. As of July 2000, they have sold 100-150 transmitters embodying the technology. Since then the product has been available commercially. Thomcast is continuing R&D efforts aimed at making incremental improvements in the technology–improving compliance to allow greater power levels.

Related, broader technologies:
Radio frequency transmissions
Terrestrial broadcasting
Satellite transmission

Related, narrower technologies:
Digital signal processing

Cross-references:

2. Actual/anticipated effects in immediate markets

Intended initial markets:
Television broadcast stations in the United States
Television broadcast stations in other countries–especially Europe

Other possible markets:
In theory the technology could be used in other terrestrial and satellite transmissions, but the cost is prohibitively large for these uses at the moment. But the rising value of radio frequency bandwidth, and falling costs of implementing the company's technology will make it competitive at some point in the future.

Planned/actual business model:
Thomcast will retain proprietary technology which is embedded in the transmitters that it sells.

Existing substitutes (negatively impacted):
Conventional transmitters

Nature of gain(s) to user (as compared with existing substitutes):
Achieving any level of compliance with FCC regulations regarding out-of-band emissions involves a trade-off. By reducing the power of a transmitter and increasing the number of amplifiers in the system it is possible to lower these emissions. This involves increased costs, however.

Each transmitter installation is unique, so the cost savings vary, but they estimate that the cost saving to users of their transmitters will be $100,000 to $200,000 per transmitter.

Thomcast's transmitter is fully automated. In contrast other transmitters require monitoring and adjustment by skilled personnel. There is an operating cost saving as a result. But the size of this cannot be estimated.

Likely limitations of technology in short-term: None identified

Additional desirable features:
Better compliance at any given power level.

Potential for "inventing around":
Thomcast is relying on trade secrets to protect its intellectual property. Imitation is regarded as unlikely. There is no evidence of research by competitors along these lines. Reverse engineering is not possible because the solutions are implemented in programmable logic devices that cannot be interrogated.

Other future substitutes:

None identified. Unless there are significant regulatory changes implemented the technological paradigm is unlikely to shift very quickly. This general approach seems likely to be dominant for a long time to come.

Other factors on monopolization potential: None identified

Other factors on intellectual property protection: None identified.

3. Actual/anticipated effects in related markets
Complementary products: None identified

Potential for forced "tie-ins" of this product: None identified

Potential for forced "tie-ins" to this product: None identified

Upstream products (inputs to production of this product):
Digital Signal Processing Chips
Programable Logic Devices

Downstream products (uses this product as input to production):
HDTV terrestrial broadcasts

Antagonistic products:
Existing HDTV transmitters

4. Knowledge spillovers
Potential/actual spill-outs: None identified

Potential/actual spill-ins: None identified

5. Network spillovers
Investment coordination problems: None identified

Standards problems: None identified

Hardware-software coordination: None identified

Software-software coordination: None identified

Previous installed base (as a barrier):
This is not an issue as broadcasters must install new transmitters to meet the FCC mandated transition to HDTV broadcasts.

Future installed base (as a source of lockin and monopolization):
Transmitters have a lifetime of about 10 years, but well maintained ones can be used for perhaps 20 years.

Other sources of premature lockin: None identified

Economies of scale in production: None identified

Direct interactions between consumers (economies of consumption): None identified

Synergies with other technologies (and economies of scope): None identified

Need for development of specialized uses: None identified

Other specialized use networks using this product: None identified

Specialized use networks to which this product belongs: None identified

6. Barriers to development or commercialization
Capital availability:

Other special barriers:
Industry is highly competitive and does not have a history of high levels of investment in R&D. Profit margins have been small, and firms would not invest in developing new technologies.

7. Description of this firm

Thomcast's R&D staff is about 30 people, including support (management, administration, technicians and drafting). Of these about 16 are engaged in transmitter design and development. Two FTE employers were added at the beginning of the NIST-ATP funded project, and have now been absorbed into other activities. One or two employees were shifted from other projects to work on the NIST-ATP project, but the opportunity cost of this shift is regarded as negligible.

8. Effects of ATP
Effect of ATP on this organization's R&D investment (this and other projects):
Thomcast would not have pursued R&D in this area without ATP support.

Effect of ATP on qualitative characteristics of innovation:
Participation in the Sarnoff led joint venture was crucial to development of this technology. Thomcast subcontracted important parts of the development work for this technology to Sarnoff, and would not have been successful in its efforts without Sarnoff's engineering expertise.

Effect of ATP on organization, strategy, partnering, business plan:
Invitation from Sarnoff to participate in the joint venture was crucial in putting Thomcast in contact with Sarnoff and other firms in the project. Without these contacts the development of this technology would not have been initiated.

Other factors on timing of innovation:
FCC regulations tightening restrictions on out-of-band emissions and the transition to HDTV were important conditioning factors encouraging research and development along these lines.

Similarly progress in microprocessors was important in making the project feasible. Thomcast was using state of the art chips to implement early versions of its technology.

Effect of ATP on other organization's R&D investment on competitive projects:
No effects identified.

Leading competitors in field (experts, firms, laboratories):
In the US
- Harris Corporation
- ADC
- Acrodyne
- Larcan
- MCBM

In Japan: NEC
In Germany: Rhode & Schwartz (?)

Effect of ATP on national location:
It is quite likely that without ATP support this technology would have been developed in Japan or Germany

Foreign government action: None identified

Likely scenarios absent ATP intervention:
It seems likely that investment in developing this technology would have been substantially delayed. Thomcast has been marketing their transmitters for over 2 years now, and they are not aware of significant efforts by any of their competitors to develop a comparable technology. But there are growing market pressures that might push for such development. Some of the products available today may not be in compliance with FCC regulations, but the FCC has not been strictly enforcing its rules because of the workload involved in rolling out HDTV broadcast. Tighter enforcement in the future would also encourage research.

Best guess is that implementation of the technology has been delayed between 3 and 4 years.

Actual/expected dates:

event	point estimate	lower bound	upper bound
Initiation of the project	1996		
ATP funding of project	1996		
Completion of research laboratory /verification of concept	late 1997		
Completion of development /demonstration of innovation and product engineering	early 1998		
Commercial introduction/first sales	1998		
Extinction/replacement by next generation technology	not in foreseeable future		

Counterfactual dates (point estimate, LB, UB):

event	point estimate	lower bound	upper bound
Initiation of the project	A+42	A+36	A+48
Stage comparable to ATP funding of project	A+42	A+36	A+48
Completion of research laboratory /verification of concept	A+42	A+36	A+48
Completion of development /demonstration of innovation and product engineering	A+42	A+36	A+48
Commercial introduction/first sales	A+42	A+36	A+48
Extinction/replacement by next generation technology			

9. Market impacts

Size of potential (market or markets)
US market has about 1500 broadcast TV stations. Each will need to purchase from 1 to 2 transmitters. European market, served by sister company.

Actual/potential sales of products embodying innovation
Thomcast has about 40% of existing adopters of HDTV transmitters. Adoptions to date account for about 10% of the total market. Most of the early adopters are stations in the VHF range who previously purchased transmitters from Harris. Thomcast in the past has only produced UHF transmitters. As the rollout of HDTV proceeds, Thomcast expects to reach 50-60% market share.

Pace of diffusion of HDTV–FCC mandates that transition be complete by 2003, but Thomcast thinks that this is not likely to be met.

They forecast that diffusion of HDTV transmitters will be as follows

2000	10% of stations installed
2002	50% of stations
2003	70% of stations
2005	100% of stations

Revenue per unit earned by innovating firm
Not available

Cost saving or monetary benefit to users per unit purchased
$100,000 to 200,000 per transmitter. Most stations will purchase two transmitters.

REPORT ON ATP-CLIENT INTERVIEW–Telcordia

0. Interview description

Respondent(s):	David Waring, Director
Title/occupation:	
Organization:	Telcordia (formerly Bellcore)
Email address:	DLW@research.Telcordia.com
Telephone:	973-829-4850
FAX:	
Date of interview:	11 April 2000
ID of interviewers:	Joshua Rosenbloom
Referrals to additional interviewees in firm or elsewhere:	None identified

1. Technology description

Name of ATP project: Interoperability Tools for Digital Video Systems

Technology name or description:
Software reference implementations of standards for DV access and distribution across ATM based networks.

Technology goal(s):
The project was tightly coupled to the process of standards development undertaken by DAVIC (Digital Audio Video International Council) in the mid-1990s. International discussions within DAVIC were focused on developing standards for Digital Storage Media Command and Control (DSMCC) for the interchange of DV content across networks. These standards would specify for example how file servers would be located, and accessed remotely. The project's goal was to develop a set of software implementations of these standards that would be licensed to two groups: (1) network operators–i.e., telecom firms; and (2) equipment producers –e.g., makers of file servers, ATM switches, set-top box manufacturers.

The DAVIC standards setting process, which was focused on ATM based networks was essentially derailed in late 1997, however, by the emergence of a competing network architecture centered around IP-based networks. The growth of the Internet substantially undermined interest in ATM based networks, as did the abandonment at this time by several phone companies of pilot projects distributing DV content over ATM networks.

ATM networks are better for quality of service but much more expensive alternative to IP based networks.

Technology technique:
Develop software tools in conjunction with participation in international standards setting body.

Current developmental status (stage, timeline, risk):
Project has terminated due to collapse of standards setting process and the loss of interest in ATM networks as a mechanism of distributing DV content.

Related, broader technologies:
Information Network protocols

Related, narrower technologies:

Cross-references:

2. Actual/anticipated effects in immediate markets

Intended initial markets:

1) telecommunications companies in major advanced economies (approximately 20 of these world wide, all are well known), and
2) suppliers of components for these networks (approximately 200-300 companies are in these markets)

Other possible markets:

Corporate intranets

Planned/actual business model:

Software would be licensed to user who would implement it on their networks or embed it in their components. Licenses would typically involve an up-front fee, and a negotiated payment presumably reflecting the volume of business that different clients did.

Existing substitutes (negatively impacted):

None identified. The alternative is for users to write their own implementation of the standards.

Nature of gain(s) to user (as compared with existing substitutes):

Up front cost savings from not having to create their own implementations

Likely limitations of technology in short-term: None identified

Additional desirable features: None identified

Potential for "inventing around":

Large, once standards are adopted they are readily known to all. Being the first to market and establishing market share is the primary source of competitive advantage in this market.

Other future substitutes:

Revised standards could lead to the replacement of existing protocols.

Other factors on monopolization potential: None identified

Other factors on intellectual property protection: None identified.

3. Actual/anticipated effects in related markets

Complementary products:

DV content
Display devices for viewing DV content
Broadband networks connecting final consumers to fiber backbones

Potential for forced "tie-ins" of this product:

Software tools would be integrated into a variety of products, including relays, file servers, switches, and set top boxes.

Potential for forced "tie-ins" to this product:

Upstream products (inputs to production of this product):
Standards

Downstream products (uses this product as input to production):
Delivery of DV content of all sorts to consumers
Distribution of Broadcast or other DV content between producers
Video conferencing

Antagonistic products:

4. Knowledge spillovers
Potential/actual spill-outs:
Knowledge about ATM networks
Additional skills developed by team working on the project. Now diffused to other electronics companies working in the DV field

Potential/actual spill-ins:
Knowledge of telephone system networks
Knowledge of ATM networks
Knowledge about DV uses and distribution
Bellcore had prior experience developing reference standard software tools for signaling and control of voice switching on broadband networks.

5. Network spillovers
Investment coordination problems:
Industry adoption of standards was crucial (in this case the failure to adopt standards aligned with the product brought the project to an end).

Standards problems:
Establishing standards was essential

Hardware-software coordination:
Important

Software-software coordination:
Important

Previous installed base (as a barrier): Not a significant problem

Future installed base (as a source of lockin and monopolization):
Possibly important as a means of capturing the market.

Other sources of premature lockin: None identified.

Economies of scale in production:
Significant, since most of the costs of producing software are up-front costs.

Direct interactions between consumers (economies of consumption): None identified

Synergies with other technologies (and economies of scope): None identified

Need for development of specialized uses: none identified.

Other specialized use networks using this product: none identified.

Specialized use networks to which this product belongs: none identified.

6. Barriers to development or commercialization

Capital availability:

Problems of financing the project were important. The project was viewed as too risky to gain internal financing without ATP support.

Other special barriers: None identified.

7. Description of this firm

8. Effects of ATP

Other factors on timing of innovation:

The standards setting process determined the timing. The project was undertaken in conjunction with DAVIC sponsored discussion of standards

Leading competitors in field (experts, firms, laboratories):

Lucent, Alcatel, Erickson, other major telecom

Columbia University was engaged in research in related fields, but was not judged likely to develop a commercially viable product.

Foreign government action: None identified

Likely scenarios absent ATP intervention:

Bellcore would not have undertaken to develop these software tools in the absence of ATP funding.

If standards had been established, Lucent or another major telecommunications company would probably have developed software implementing the standards. These might have been used internally without ever being marketed more widely. Thus there were potential cost savings/efficiency gains from a project committed to widespread licensing of the resulting software tools.

Effect of ATP on national location:

Small, Lucent judged the most likely competitor to develop this technology

Effect of ATP on qualitative characteristics of innovation: None identified

Effect of ATP on organization, strategy, partnering, business plan:

Access to NIST labs was helpful in developing project, and would have helped in commercialization.

Effect of ATP on this organization's R&D investment (this and other projects):

Organization would not have devoted resources to this project absent ATP fund

Effect of ATP on other organization's R&D investment on competitive projects:
Lucent's investments in this area appear to have been unaffected by ATP

Actual/expected dates:

event	point estimate	lower bound	upper bound
Initiation of the project	1995		
ATP funding of project	1995		
Completion of research laboratory /verification of concept	1997		
Completion of development /demonstration of innovation and product engineering	NA		
Commercial introduction/first sales	NA		
Extinction/replacement by next generation technology	NA		

Counterfactual dates (point estimate, LB, UB):
Discussion suggests that ATP funding did not substantially accelerate potential introduction of software tools

event	point estimate	lower bound	upper bound
Initiation of the project			
Stage comparable to ATP funding of project			
Completion of research laboratory /verification of concept			
Completion of development /demonstration of innovation and product engineering			
Commercial introduction/first sales			
Extinction/replacement by next generation technology			

9. Market impacts

Size of potential (market or markets) Not applicable

Actual/potential sales of products embodying innovation Not applicable

Revenue per unit earned by innovating firm Not applicable

Cost saving or monetary benefit to users per unit purchased

6. PARTIAL EQUILIBRIUM BASELINE IMPACT ESTIMATES

Introduction

Most of the ATP funded DV projects have not yet resulted in commercial products, so it is too early to attempt to quantify their economic impacts. However, three projects studied have produced innovations that have resulted in commercial products. Two of these products reached the market during the Spring of 2000, close to the time we were conducting our interviews. The third has been available commercially since 1998. Based on data gathered as part of our interviews it is possible to construct at least partial estimates of the economic impacts of the innovations arising from these projects that have been realized to date and make projections about their potential future impacts.

Theoretical framework for measuring economic impacts

The economic impact of an innovation may be equated with the increase in profits that the innovator receives as a result of the innovation plus the net value of the spillovers attributable to the innovation. The increase in profits and spillovers must be evaluated relative to a counterfactual situation in which the innovation did not occur.

All three of the innovations that have resulted in commercial products are in effect process innovations that will be licensed or sold by the innovators to other companies that will use them to produce final goods and services. The effect of these innovations is to lower the cost to consumers of purchasing final goods and services of a fixed quality (alternatively they allow suppliers to increase quality holding price constant). Figure 6.1 illustrates the impact of such a cost reducing innovation[1]. We assume that the industry using the innovation is competitive, so the market supply curve can be represented as horizontal. The innovation shifts the supply curve downward by an amount C, and causes a movement down along the demand curve from Q1 to Q2. The innovator is assumed to earn additional profits of R per unit of final goods and services sold.

Increased profits (say, π) are equal to R*Q2, while the increase in consumer surplus (say, σ) is equal to Q2*C - (1/2)*(Q2-Q1)*C. In practice the second term in this expression is usually quite small (see Mansfield et al 1977), and as a first approximation we can take σ = Q2*C. Hence total direct effects of the innovation are approximated by

(1) $\pi + \sigma = R*Q2 + C*Q2.$

In addition to the increased benefits realized by consumers and higher profits earned by the innovator, it is possible that the innovation may have an effect (generally negative) on the profits of producers of competing products that are displaced by the innovation, as well as an effect on profits of suppliers of the production process that uses the innovation. The net effect of increased consumer surplus and

[1]This diagram, and the subsequent analysis closely follow the framework laid out by Mansfield et al (1977).

changes in the profits of directly affected suppliers and competitors comprise what Jaffe (1996) has termed the "market spillovers" resulting from an innovation.

In addition to market spillovers and innovators profits, a complete accounting of the economic impacts of an innovation should include effects known as knowledge, network, material, and fiscal spillovers. Knowledge spillovers are the result of information flows generated by the innovation–these include increased profits earned by imitators of the original innovation, as well as those of firms whose innovations benefit from knowledge generated and disseminated through the new product. Network spillovers refer to benefits realized because of interactions between different goods and services that cannot be readily internalized by any of the economic agents (see Burress *et al.* 1999b, p. 28). Material spillovers refer to the value of any environmental effects that an innovation might have. Fiscal spillovers refer to the impact on government revenues resulting from the innovation.

In theory at least, the impacts of knowledge and network spillovers can be measured using a framework comparable to that sketched above to quantify market spillovers. That is, the benefits result either in increased profits or in higher consumer surplus for purchasers of products affected by these spillovers. The biggest challenge in making these measurements resides in tracing these pathways of influence. Measurement of material spillovers can be more problematic because of the "public good" nature of many environmental resources - that is, it is hard to place a defined value on goods that are freely available and not marketed. However, judging from interview responses and other data, there is no indication that material spillovers are likely to be important for any of the DV innovations sponsored by ATP, and we will not concern ourselves further with this issue. Fiscal spillovers will be difficult to track in a partial equilibrium framework, but should be easier to measure in a general equilibrium model.

Theoretical framework for measuring attribution effects

The previous section sketches a theoretical framework for measuring the economic impacts of an *innovation*, as opposed to the impacts of ATP's *intervention*. Only some fraction of the benefits arising from the innovations studied should be attributed to ATP's support. Measuring the ATP "attribution effect" requires us to compare the realized benefits of an innovation with the benefits that would have been realized in a counterfactual situation in which ATP had not supported the project in question.

Our starting assumption is that ATP's impact on innovations can be modeled in terms of an acceleration effect. That is, ATP's funding helps to move forward the date at which an innovation is realized. In the extreme of course, ATP's support might move the arrival date of an innovation forward by so much that the counterfactual would be equivalent to the innovation never having occurred.

Consequently, formula (1) must be modified in two additional ways. First, the observed profits and consumer surplus may be caused in part or whole by pre-existing conditions rather than by ATP intervention; therefore these terms should be multiplied by a factor (say, α) that represents the causal share of the innovation that is attributed to ATP. Second, the analysis has to be repeated for each unit of time and a present value function calculated. (We will indicate the present value function as PV(.), with the assumed social discount rate being suppressed.) The present value analysis begins with the date when the innovation is first introduced. It ends with the earlier of two possible dates when ATP's intervention would cease to constitute a net contribution to the economy, either:

- the date when the innovation would have occurred in the absence of the intervention, or
- the date when the innovation would have been replaced by a successor innovation.

We can summarize these considerations by stating that the direct market impacts of ATP intervention, say I, is given by:

(2) $I = \alpha * PV(\pi + \sigma)$.

To obtain the net social benefit from the innovation, it is still necessary to subtract off the present value of R&D and marketing costs. Moreover, we need to make assumptions about the opportunity cost of those funds - which is same as making counterfactual assumptions about where those funds would have gone in the absence of ATP intervention. In the following we will assume that there is no particular scarcity of R&D funds, so that R&D funds can be viewed as being withdrawn directly from consumption; or in other words, that a dollar of R&D costs exactly a dollar in welfare terms.

Note that this assumption could understate the social cost (and overstate the net benefits) of the innovation. In particular, if R&D funds are withdrawn from other R&D that would have had positive net benefits, then more than a dollar's worth of welfare is lost per R&D dollar spent. It is reasonable to assume that the share of R&D dollars provided by ATP would (in the absence of the ATP program) have either been spent by the government on other government consumption, or returned to the taxpayers and spent on private consumption. However, the share of R&D dollars provided by the private investor is more problematical. In particular, ATP is intervening in the R&D investment market, *exactly because policy makers believe that R&D is being underprovided* - that is, they believe there is a market failure which makes private R&D dollars. in some sense relatively scarce. That being the case, it is important to understand the precise nature of the market failure.

Our maintained hypothesis will be that the *only* R&D market failure consists in various spillovers that may drive a wedge between private and social returns to R&D. In particular, we will assume:

- The private discount rate equals the social discount rate, and
- private market investors fully fund any known R&D opportunity for which the expected private returns to R&D exceed the private costs.
- Consequently, private investors fully fund any project with no spillovers for which the expected social returns exceed the expected social costs, and they withdraw that funding from consumption.
- Moreover, if ATP funding causes a new R&D project to take place, it does so exactly because it reduces the private costs sufficiently so that expected private returns now exceed private costs, resulting in additional funding being withdrawn from consumption (or at worst, from an R&D project with a marginal payoff).

Under these assumptions, each dollar of R&D funding (whether from private or public sources) has a welfare cost of exactly one dollar.

Our interviews with ATP clients do provide some limited support for this model. In particular, interviewees generally report that they would not have made this particular R&D investment in the absence of ATP funding. While interviewees do sometimes report that private funding for this project was withdrawn from other R&D projects, it remains possible either that the defunded projects have only marginal expected net benefits, or that equivalent projects are being undertaken by other organizations.

Partial equilibrium estimates of baseline economic impacts

The discussion above makes it clear that a comprehensive measure of economic impacts is a data-intensive exercise. The baseline data that we have collected are not sufficient to construct comprehensive economic impact measures of ATP sponsored DV projects, in part because the major part of those impacts is expected to occur in the future. In particular, neither knowledge nor network spillovers can be clearly identified at this point, and accurate measurements of these effects will likely be possible only with the collection of retrospective data. However, we have gathered data which can be used to estimate the market spillovers of the three innovations that have already resulted in commercial products, and also to estimate the ATP attribution effects.

This section uses the available data to construct partial equilibrium estimates of the market spillovers and innovators profits that have resulted and/or are likely to result in the near future from ATP funded DV projects, as of the time that the baseline data were collected. As noted earlier, three projects have so far resulted in commercial products. We discuss each project in turn. We also discuss the social costs of the research that produced these impacts.

Transmitter technology for HDTV terrestrial broadcast

This project was carried out by Thomcast Corporation as part of the HDTV Broadcast Technology project that was coordinated by Sarnoff Corporation. As a result of the ATP funded project Thomcast developed new technologies for broadcasting HDTV signals that make it possible for broadcasters to meet tighter FCC regulations on out-of-band emissions with a given level of signal power at lower cost than is possible with existing technologies. The new technology has been commercially available since 1998.

Based on our interview we estimate that without NIST-ATP funding development of a comparable technology would have been delayed by about 4 years. Thus, our counterfactual analysis assumes that R&D expenditures and benefits would all be pushed back by four years relative to the actual dates.

Effects on innovators profits. Thomcast's development of a superior transmitter seems likely to increase its sales at the expense of other transmitter manufacturers. We did not obtain information on Thomcast's per unit profits, or the reduction in profits per unit of other manufacturers. As a first approximation we assume that Thomcast's increased profits are exactly offset by the reduction in profits (that is a negative market spillover) of other transmitter manufacturers. To the extent that

Thomcast is able to use its possession of superior technology to increase its profits, this assumption will result in an understatement of total economic benefits from the technology.

Effects on market spillovers. Market spillovers comprise negative spillovers due to the loss of profits of competitors, plus cost savings of customers. As noted above we assume that the loss of profits of competitors is offset by increased profits earned by Thomcast.

Holding other transmitter characteristics constant, the new transmitter technology is estimated to reduce costs by between $100,000 and $200,000 per installation. Because each transmitter installation is unique, however, it is not possible to specify cost savings more precisely. Thomcast estimated that as of mid-2000 between 100 and 150 of their transmitters have already been installed.

Assuming that the average savings to stations installing the new technology are equal to $150,000 (the midpoint of the estimated range of benefits), it is possible to calculate the realized gains in consumer surplus from this innovation. The top panel of Table 6.1 summarizes R&D expenditures and increases in consumer surplus for each year between 1996 and 2000.

Combining expenditures and revenues from different years requires that we discount them to reflect the opportunity cost of funds. The table summarizes the net benefits to consumer surplus from this project for a variety of different social discount rates. As is apparent the net benefits to purchasers already substantially exceed the R&D costs of developing the technology, ranging from $5.5 million to $9.75 depending on the rate of discount used.

Projected Future Effects. Based on the information we gathered it is also possible to construct a forecast of future benefits as well, and to compare them with the a counterfactual situation in which this project did not receive NIST-ATP funds. Such a forecast rests on a projection of future sales. To construct such an estimate we begin by noting that there are currently about 1,500 television broadcast stations in the United States which will eventually make the transition to broadcasting HDTV signals. Since some stations require multiple transmitters, we assume that the total market size for HDTV transmitters is 2,250 (an average of one and one-half transmitters per station). Further we assume, based on data collected in our interview, that Thomcast will capture a 50 percent share of the market.

The FCC has mandated that all broadcast stations begin broadcasting HDTV signals by 2003, but there is evidence that some stations are unlikely to meet this timeline. Instead, we assume that the transition will be only 70 percent complete by 2003, and that a complete transition will take until 2005[1].

Our specific assumptions about the diffusion path of transmitters are summarized in the first column of Table 6.2. Column 2 reproduces our estimates of R&D expenditures while Column 3 extrapolates

[1]Assuming a more rapid transition would have the effect of magnifying the forecast net present value of benefits arising from this project. The benefits are also understated by focusing exclusively on the US market. Thomcast believes that significant foreign markets for its innovation may also exist.

the estimated benefits due to market spillovers through 2005. As the bottom panel illustrates the gains substantially outweigh the costs. Without discounting the difference by 2005 reaches nearly $160 million. Even applying a 15 percent rate of discount the difference is still over $100 million.

Counterfactual effects. These figures, however, overstate the benefits of the project to the extent that the technology would eventually have been developed even without ATP support. To account for this we must compare our forecasts to a counterfactual alternative. In the counterfactual we assume that development of the technology is delayed by 4 years. Columns 4 and 5 of Table 6.2 show R&D expenditures and market spillovers under this alternative assumption. As the bottom panel of the table shows, the benefits derived in the counterfactual world are still substantial, but are well below the projected actual world benefits.

After subtracting these counterfactual gains, the net benefits that we can attribute to the acceleration of this technology's development due to ATP-funding ranges from a high of $84 million (with a social discount rate of 0%) to a low of $65 million (with a discount rate of 15%).

Compressed domain Processing of DV Signals

Like the transmitter innovation considered above, the compressed domain processing innovation is a product of the project to develop a package of HDTV Broadcast Technologies, led by Sarnoff Corporation. In addition to coordinating partner efforts, Sarnoff Corporation undertook development of a product designed to enable broadcast stations to perform a variety of editing functions, such as overlaying station identification information on DV signals in the compressed domain. To carry out commercialization of this product, Sarnoff has created a spin-off company called AgileVision. The AgileVision product has only recently been introduced commercially. Consequently there are no realized benefits. However, it is possible to forecast the likely impacts of this innovation over the next five years, as the transition to HDTV broadcasting takes place.

There are approximately 1,500 broadcast stations in the United States that constitute the primary market for this product. Of these, 350 PBS affiliates are considered highly likely to adopt the AgileVision product, because PBS has opted to distribute its network feed in a format compatible with this product. The existing market does provide a combination of hardware and software that could perform the same signal processing functions as AgileVision product. However it is estimated that acquiring these products would require a capital investment of approximately $500,000 per station. The AgileVision product costs $250,000, so each user will realize a saving of some $250,000.[1]

Based on our interviews, there is no evidence that any competitors have been developing comparable technologies. Sarnoff corporation estimated that it was unlikely that a functional equivalent would

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[1]It is possible, of course, that some PBS stations may not have the funds to complete the transition to HDTV broadcasting and will simply exit the industry. On the other hand, some will purchase more than one AgileVision unit, and there are likely to be other, non-PBS affiliates, that purchase this product. So the assumption of a total market size of 350 units appears more likely to understate than overstate potential sales.

be developed before the transition to HDTV broadcasting was completed. Once the transition had occurred, future purchases would be small. Consequently we assume that without ATP funding this innovation would not have occurred any time within the next five years.

Effects on future profits. Once again, we lack information on AgileVision's profits, or those of competing suppliers of alternative editing equipment. Because the need for HDTV signal processing is a new one, and stations would either purchase the AgileVision product or a competing product, we assume that the reduction in profits of competing products will be approximately equal to the increased profits realized by AgileVision.

Effects on future market spillovers. With this assumption the benefits of the AgileVision technology can be equated to the projected market spillovers resulting from the lower cost of this product in comparison to alternative technologies. From our interview this cost saving is estimated conservatively to be $250,000 per unit. In addition, because of its greater simplicity users of the AgileVision product are likely to realize additional operating cost savings that cannot be quantified at this time.

Table 6.3 contains the data needed to forecast the likely benefits attributable to ATP support of this innovation. The first column reproduces our estimates of the rate of diffusion of HDTV broadcasting under the same assumptions used before. The second column reports R&D expenditures, while the third column calculates market spillover benefits accruing under the assumption that a total market size for the AgileVision product is likely to be 350 units. The bottom panel of the table reports net benefits as of 2000 for a variety of different social discount rates.

Once again, it is apparent that ATP support is likely to be responsible for substantial net economic benefits. As the lower panel of the table shows the net present value of the actual and forecast benefits ranges from a little more than $81 million dollars without discounting to nearly $50 million assuming 15% annual rate of discount

Attribution Effects. Our interviews indicate that Sarnoff Corporation would not have pursued this innovation without ATP support, and they were not aware of other companies working on comparable products. Because the transition to HDTV broadcast standards must be accomplished within a finite window, purchase decisions must be made within the next few years. Consequently our counterfactual assumes that this technology would not have been developed prior to 2005 in the absence of ATP support. Thus the net benefits above are assumed 100% attributable to ATP support.

Adaptive video codec for information networks

Cubic Video Systems began in March 2000 to provide components for remote monitoring security systems based on their codec. As of the time of our interview they had sold 1,000 systems, priced at around $10,000. By their estimate analog-based systems with fewer capabilities would cost purchasers between $3,000 and $4,000 more. Using the midpoint of this range implies an increase in consumer surplus of $3.5 million to date. (This is understatement because it does not include unmeasured benefits from having additional capabilities). Sales to date are estimated to be only a small fraction of the potential market, however, so this figure is likely to expand considerably.

Effects on innovator's profits. Cubic Video Systems estimates its earnings on each unit at around $5,000, so earnings to date are about $5 million. Since Cubic Video would not be in this market without this innovation this figure represents their increased profits. At this point we have not been able to measure the negative impact on profits of producers of existing analog-based security systems, but we assume that these are no larger than the increase in Cubic Video System's profits.

Actual and Counterfactual Effects. Table 6.4 summarizes the R&D expenditure and increased consumer surplus data to date for this innovation, along with a counterfactual. As the lower panel shows, without discounting the realized returns to date exceed R&D expenditures. With discounting, however, the project's net benefit is approximately zero or slightly negative. We are unable to forecast future sales, but it appears that there is a substantial potential market for this product which should result in further increases in consumer surplus in the future.

Cubic Video Systems estimated that without ATP support introduction of the innovations developed by this project would have been delayed by between 12 and 24 months. The counterfactual data assume a 12 month delay in the onset and completion of R&D, and assume that sales begin one year later than in the actual case. Given the relatively short delay in development of this technology the difference between actual and counterfactual benefits is relatively small unless a very high rate of discount is assumed.

Conclusion

Baseline data gathered at this time do not permit an exhaustive measurement of the economic impacts of ATP's Digital Video Focused Program. Moreover, most of the projects funded by this program are still in a pre-commercial stage of development. Nonetheless, the partial data that are available provide the basis for a rough estimate of the economic impact of several projects. One of these projects, development of new HDTV transmitter technology has already produced substantial spillovers well in excess of the R&D investments in this project. And forecast benefits over the next five years attributable to ATP's intervention are substantially larger, amounting to a minimum of nearly $65 million current dollars. Forecast benefits from a second project, development of compressed domain digital video editing technology, are of a comparable order of magnitude.

It is of interest to compare current and expected net benefits documented so far with the entire cost of the ATP digital video focused area program. That program has an undiscounted cost to the government of $60 million dollars. Allocating these expenditures over the life of the program–assuming the first expenditures began in 1996 and the final expenditures will be made in late 2001–the Present Value of this cost ranges from $65 million (at a 5% rate of discounting) to $78 million (at a 15% rate of discounting)[1]. Private investments in R&D on these projects have a present value of between $68 million (0% rate of discounting) to $90 million (15% rate of discounting).

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[1]These calculations assume that projects funded in 1995 incur equal expenditures in each year from 1996 through 2000, and that projects funded in 1999 incur equal expenditures in each year from 1999 through 2001.

Based on the projected benefits for the small number of projects that can currently be assessed the program can already be described as highly successful in the sense that the present value of the anticipated net benefits of these projects (from $175 million without discounting to $120 million at a discount rate of 15%) already substantially exceeds the government's investment in the program, and are close to the combined public and private costs to date. If even a few additional projects result in substantial pay-offs the program's success will be considerably greater.

Table 6.1
Actual and Forecast Expenditures and Benefits of
Thomcast Corporation's Development of New HDTV Transmitter Technology

Panel A: Actual Expenditures and Increased Consumer Surplus, 1996-2000

Year	Cumulative number of transmitters sold to date	R&D Expenditures (millions of current $)	Increase in Consumer Surplus (millions of current $)
1996		3	
1997		3	
1998		3	
1999	25		3.75
2000	125		15

Panel B: Net Present Value in 2000 of Expenditures and Increased Consumer Surplus

Social Discount Rate	Net Present Value (millions of $)
0%	9.75
5%	8.51
10%	7.11
15%	5.54

Notes: Cumulative number of transmitters are from interview, R&D expenditures on this project were $3 million from ATP and $6 million private (from interview). Increased consumer surplus is equal to the number of units sold times the mid-point of the estimated cost savings ($150,000).

Table 6.2
Forecast Expenditures and Benefits of
Thomcast Corporation's Development of New HDTV Transmitter Technology
Actual and Counterfactual Cases

Panel A: Actual and Forecast Expenditures and Increased Consumer Surplus, 1996-2000

		Actual		Counterfactual	
Year	Diffusion of HDTV Broadcast (Share of All Stations Broadcasting HDTV Signals)	R&D Expenditures (millions of current $)	Increase in Consumer Surplus (millions of current $)	R&D Expenditures (millions of current $)	Increase in Consumer Surplus (millions of current $)
1996		3			
1997		3			
1998		3			
1999	0.02		3.8		
2000	0.11		15.0	3	
2001	0.30		31.9	3	
2002	0.50		33.8	3	
2003	0.70		33.8		33.8
2004	0.85		25.3		25.3
2005	1.00		25.3		25.3

Panel B: Net Present Value in 2000 of Actual and Forecast Expenditures and Increased Consumer Surplus

Social Discount Rate	Actual and Forecast	Counterfactual	Actual and Forecast minus Counterfactual
0%	159.8	75.4	84.4
5%	138.4	60.6	77.8
10%	119.3	48.0	71.3
15%	102.2	37.5	64.7

Notes: Diffusion shows the cumulative fraction of TV stations broadcasting HDTV signals. For 1999 and 2000 this is based on Thomcast's sales for these years divided by its estimate of its market share for transmitters. The forecast diffusion for 2001 through 2005 is based on interview data. R&D expenditures are from interview. Increased consumer surplus is equal to the cost saving per unit times the number of units Thomcast is forecast to sell each year. The latter number is estimated as the implied number of HDTV adopters each year (the change in diffusion times 1500 total stations) times Thomcast's forecast market share. The counterfactual assumes that R&D and innovation are delayed by 4 years, but that once developed the new technology achieves the same level of sales as forecast in the "actual" scenario.

Table 6.3
Forecast Benefits of Sarnoff Corporation's Development of Compressed Domain DV Processing Technology

Panel A: Data and Forecasts

Year	Diffusion (Share of potential adopters Using Technology)	R&D Expenditures (millions of current $)	Increase in Consumer Surplus (millions of current $)
1996	0	1.25	
1997	0	1.25	
1998	0	1.25	
1999	0	1.25	
2000	0	1.25	
2001	0.30		26.25
2002	0.50		17.50
2003	0.70		17.50
2004	0.85		13.13
2005	1.00		13.13

Panel B: Net Present Value in 2000 of Actual and Forecast Expenditures and Revenue

Rate of Discount	Net Present Value (millions of $)
0%	81.25
5%	69.68
10%	59.29
15%	49.95

Notes: We have assumed the same diffusion path as in Table 6.2; R&D expenditures on this project were ATP $3.1 million, private $3.2 million. Increased consumer surplus is equal to the increase in numbers of adopters each year times the estimated cost saving of $250,000 per unit based on interview data. The number of adopters is based on the increased diffusion of HDTV broadcasters multiplied by AgileVision's assumed share of the total market.

Table 6.4
Actual Expenditures and Benefits of Cubic Video Corporation's Development of An Adaptive Video Codec for Information Networks

Panel A: Data

	Actual			Counterfactual		
Year	Units Sold	R&D Expenditures (millions of current $)	Increase in Consumer Surplus (millions of current $)	Units Sold	R&D Expenditures (millions of current $)	Increase in Consumer Surplus (millions of current $)
1996		1.3			0.0	
1997		1.3			1.3	
1998		0.3			1.3	
1999		0			0.3	
2000	1000	0	3.5		0	
2001				1000	0	3.5

Panel B: Net Present Value of Benefits less R&D Expenditures as of 2000 in Millions of Dollars

Social discount rate	Actual	Counterfactual	Actual minus Counterfactual
0%	0.5	0.5	0
5%	-0.0	-0.0	0
10%	-0.6	-0.6	0
15%	-1.3	-1.2	-0.1

Figure 6.1
Impacts of Innovation

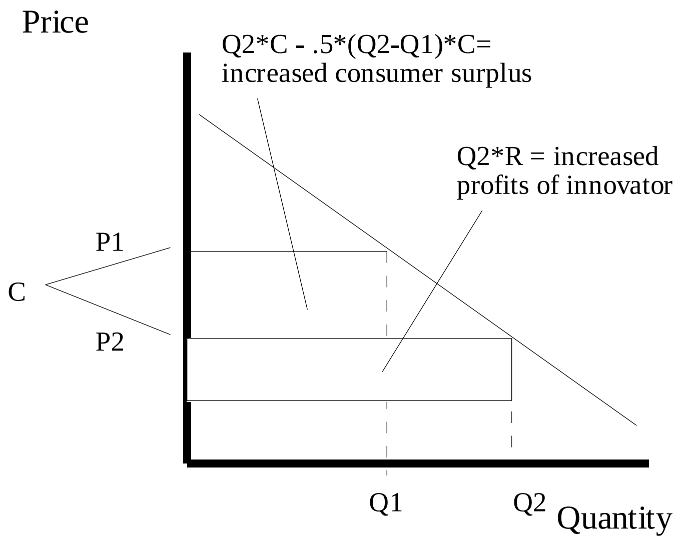

Figure 6

7. CGE MODEL OF ATP INTERVENTIONS

Introduction

Chapter 6 described the impacts of ATP's DV program using conventional partial equilibrium language. This chapter is primarily technical and sets up a more complex Computable General Equilibrium (CGE) framework. In Chapter 8 this model will be applied to our DV data. Some of the added advantages of this more complex CGE framework are:

- A comprehensive accounting framework that identifies all needed assumptions and all needed empirical observations or estimates.
- A comprehensive aggregative framework that makes clear how various impact effects can be added up, and how they may interfere with each other.
- A multiplier model that traces all indirect market spillover effects resulting from any identified direct spillovers.
- A Monte Carlo model that leads to combined error estimate for effects of all uncertainties.
- In a forecasting version, a portfolio model that shows how the riskiness of a program decreases with the number of independent R&D investments that are included.

However, this framework has disadvantages as well.

- Setting up the model is a significant added cost.
- Multiplier values are sensitive to assumptions.
- The model is less transparent than a partial equilibrium approach.

In the present application, we present a stripped-down version of the model developed in Burress *et al.*, (1999a). In particular, we omit important features that are not empirically relevant at this stage of the research, by assuming that:

- Investment in R&D is exogenous, and has an opportunity cost equal to that of forgone consumption.
- As in a conventional transactions matrix, consumption of broadcast TV by households does not appear in the Social Accounting Matrix, because it is an unpaid, non-market "public" good. (In a full analysis the effects of public goods on utility should be represented. We omit this feature because ATP innovations have not yet measurably affected the quantity or quality of broadcast TV.)
- Technology and preferences do not change over time, and can be estimated from the most recent historic data (which are mainly from the 1996 US national income accounts). (In an *ex post* study, data would eventually be available that showed year by year changes in US production functions. Even if preferences didn't change, preferences for new goods would be revealed over time.)

Also, since our goal is a demonstration of feasibility rather than an exhaustive analysis, we consider only one particular "state of the universe." In particular, we assume slack capacity or perfectly elastic factor supplies, leading to a sectoral Keynesian multiplier model. This model would arguably be appropriate during phases of the business cycle involving recession or slow growth, but would not be appropriate during periods of maximum sustainable growth.[1]

The social accounting framework

The starting point for the general equilibrium model is a transactions matrix showing dollar flows to and from various sectors of the economy. The transactions matrix for the DV project was developed with the following goals in mind:

- Products and services that have already been affected directly by the outcomes of ATP projects should appear as separate sectors in the transactions matrix.
- Other goods and services can be grouped into aggregate sectors such as "manufacturing."
- Households should be treated as a sector that supplies labor and purchases other goods and services.

We will assume an economy with 10-15 sectors, broken out as follows.

<u>endogenous supplies and demands</u>

B broadcasting & advertising
Eq electronic components for DV
R&D DV-related R&D (with two subsectors for broadcast equipment and electronic components)
C households/government consumption (column only)
R resources, energy and raw materials
Mn manufactures (with two subsectors for construction and other)
Ser services (with two subsectors for transportation/utilities and other)

<u>input factors</u> (row only)

L labor
K capital
M imports
Sv savings less aggregate exports

<u>final demands</u> (column only)

I investment + inventory change + R&D less aggregate imports
includes HDTV R&D
E exports

[1] According to some economists who favor New Classical Real Business Cycle models, a Keynesian model would *never* be appropriate. We are not persuaded by that view.

Table 7.1
SAM Format

	B	Eq	R&D	R	Mn	Ser	C	E	I	total
B	U_{BB}	. . .				U_{BS}	C_B	$F_{E\text{-}B}$	0	X_B
Eq	U_{EQB}	.				.	C_{EQ}	$F_{E\text{-}EQ}$	$F_{I\text{-}EQ}$	X_{EQ}
R&D			.			.	$C_{R\&D}$	0	$F_{I\text{-}R\&D}$	$X_{R\&D}$
R	.			etc.		.	C_R	$F_{E\text{-}R}$	$F_{I\text{-}R}$	X_R
Mn	.						C_{MN}	$F_{E\text{-}MN}$	$F_{I\text{-}MN}$	X_{MN}
Ser	.	. . .				U_{SS}	C_S	$F_{E\text{-}S}$	$F_{I\text{-}S}$	X_S
L	U_{LB}	. . .					C_L	0	0	Y_L
K	U_{KB}			etc.			C_K	0	0	Y_K
M	U_{MB}	. . .				U_{MS}	C_M	0	-M	0
Sv	0	0	0	0	0	0	S	-E	0	S-E
total	X_B	X_{EQ}	$X_{R\&D}$	X_R	X_{MN}	X_S	Y	0	I-M	XX

s.t. $Y = Y_L + Y_K$ and
$S - E = I - M$.

Note that the row totals equal the transposed column totals (except that the income row is broken out between labor and capital).

Data sources

The foundations of the transactions matrix are the input-output tables for the United States (U.S. Bureau of Economic Analysis, 2000, 1997). Data are available for 1996 at the 2-digit industry level. However, data that decompose value added into labor and capital components are available for 1992 only. Hence we relied on the 1996 data for most of our work, supplemented by 1992 data where necessary. We used data from additional sources to help us break out and scale the digital video sectors. Data must be adjusted in various ways; for example, the transactions matrix must balance in that expenditures = income.

The transactions were constructed in several steps:

- Translate U.S. input-output transactions data into “commodity-by-commodity” space. (The U.S. input-output data consists of two tables, one showing the use of commodities by industries, and one showing the production of commodities by industry. We transform the data to estimate commodity-specific production technologies. The approach is explained in Miller and Blair (1985, Ch. 5)).

- Decompose value added into labor and capital components, using data from the 1992 U.S. input-output tables.
- Break out digital video industries. For our model, we define four digital video-related industries: TV broadcasting, broadcast equipment, chip-making for digital video equipment, research and development for the broadcast equipment sector, and research and development for the chip-making sector. (see Appendix 7.1 for details on how the sectors are broken out).
- Aggregate remaining sectors into broad categories.
- Check matrix balance (expenditures = income) and adjust if necessary. The process of converting to commodity-by-commodity space can introduce very small imbalances in the matrix. Where necessary, we used the investment-inventory category to adjust the matrix. Necessary adjustments were almost always less than 1 percent of output.

The estimated 1996 SAM table is given in Appendix 7.1.

Overview of the CGE model

The exogenous prices are:

ω = wage rate
ξ = capital rental rate
ι = import price.

All other prices, say **P**, are endogenous.
The final demand cash flows are assumed to be functions of prices:

I(P)	investment + inventory change + R&D	
	R&D	includes HDTV R&D
E(P)	exports	

The elastic or slack supplies at fixed prices are:

capital goods
labor
imports

The solution algorithm is:

1. Solve for equilibrium prices **P = P**(ω, κ, ι). Because of constant returns to scale, these prices are independent of all quantities and cash flows. This is the heart of the model and uses an iterative algorithm. It is driven by technical coefficients estimated from the transactions matrix, plus demand price elasticities estimated from other sources.

2. Solve for demands Q = Q(I, R&D, X) at those prices.

3. Solve for outputs (B, EQ, R&D, R, S, MN, L, K, M) given those prices and final demands.

Application of the CGE model involves solving the model twice (for the "actual" and "counterfactual" worlds) in each time period. The two worlds can differ in final demands and/or in technical coefficients.

Main equations of the model

We define technical coefficients for production and consumption:

(1) $A_{ij} = U_{ij}/X_j$,

(2) $A_{iC} = C_i/X_C$

where i runs over factors and sectoral outputs, j runs over industrial sectors, and C is the household/government sector. These coefficients are determined by technology and preferences and are assumed to depend only on prices; i.e. $\mathbf{A} = \mathbf{A(P)}$. We define quantity units such that all prices are unitary at the equilibrium described by the SAM matrix above; then (1) and (2) can be used to estimate $\mathbf{A(\ell)}$ (where ℓ denotes a column vectors of 1's). We define submatrices of **A** by

(3) $a_{ij} = A_{ij}$ industry coefficient;

(4) $\varsigma_i^* = A_{iC}$ consumption (and saving) coefficients;

(5) $\lambda_j, \lambda_C = A_{Lj}, A_{LC}$ labor coefficients:

(6) $\kappa_j, \kappa_C = A_{Kj}, A_{KC}$ capital coefficients; and

(7) $\mu_j, \mu_C = A_{Mj}, A_{MC}$ import coefficients,

where i and j run over industries. Or in other words, $\mathbf{A = ((a\ \varsigma^*)'\ \lambda\ \kappa\ \mu)'}$.

The quantity flow solution

The SAM matrix identity for row totals states that, in dollar flow terms, output equals intermediate demands plus consumption plus exports plus investment, or

(6) $\mathbf{X = U\ell + C + E + I}$.

Substituting in definitions for the submatrices of **A** yields the basic equation for conservation of material flow, weighted by prices:

(7) $\mathbf{X = a\ X + \varsigma^*}Y + \mathbf{E + I}$.

We will assume that the dollar flow of savings, S, is exogenous. It follows that we will need to redefine the consumption coefficients to eliminate savings from the denominator:

(8) $\varsigma = \varsigma^{*}Y/(Y\text{-}S)$, leading to

(8') $\mathbf{X} = \mathbf{a}\,\mathbf{X} + \varsigma(Y\text{-}S) + \mathbf{E} + \mathbf{I}$.

From the SAM row totals we derive the total income dollar flow:

(10) $Y = \boldsymbol{\lambda}'\mathbf{X} + \boldsymbol{\kappa}'\mathbf{X}$

which leads to a conditional multiplier solution for the dollar flows:

(11) $\mathbf{X} = (\mathbf{I} - \mathbf{a} - \varsigma\boldsymbol{\lambda}' - \varsigma\boldsymbol{\kappa}')^{-1}(\mathbf{E} + \mathbf{I} - \varsigma S)$.

Adopting the convention that lower case characters stand for quantity flows and pre-multiplying by $\boldsymbol{\pi}^{-1} = \mathbf{diag}(\mathbf{P}^{-1})$ we have the same result stated in quantity flow terms:

(11') $\mathbf{x} = (\mathbf{I} - \boldsymbol{\pi}^{-1}\mathbf{a}\,\boldsymbol{\pi} - (1/\omega)\boldsymbol{\pi}^{-1}\varsigma\boldsymbol{\lambda}'\boldsymbol{\pi} - (1/\xi)\boldsymbol{\pi}^{-1}\varsigma\boldsymbol{\kappa}'\boldsymbol{\pi})^{-1}(\mathbf{e} + \mathbf{i} - \boldsymbol{\pi}^{-1}\varsigma S)$.

(It can be shown that the indicated inverse always exists and is nonnegative, using a dominant diagonal theorem.) In the above, ω, ξ, and S are exogenous; but final demand quantity flows **e** and **i** or cash flows **E** and **I**, and coefficients **a**, ς, $\boldsymbol{\lambda}$ and $\boldsymbol{\kappa}$, all depend on the endogenous prices, **P**. Therefore this solution is conditional on first solving the price model.

The price solution

The price model starts with the SAM matrix identity for column totals:

(12) $(\mathbf{X}'\ Y) = (\mathbf{U}\ \mathbf{C})'\ell = (\mathbf{A}.\mathbf{diag}(\mathbf{X}'\ Y_L\ Y_K)')'\ell$, leading to

(13) $\mathbf{diag}(\mathbf{x})\mathbf{P}' = \mathbf{diag}(\mathbf{x})(\mathbf{P}'\mathbf{a} + (\boldsymbol{\lambda}\omega + \boldsymbol{\kappa}\xi + \boldsymbol{\mu}\iota))$.

After some algebra, we can derive

(14) $\mathbf{P} = (\mathbf{I} - \boldsymbol{\pi}\mathbf{a}'\boldsymbol{\pi}^{-1})^{-1}(\boldsymbol{\lambda}\omega + \boldsymbol{\kappa}\xi + \boldsymbol{\mu}\iota)$.

The indicated inverse exists at least in a local price region near unit prices because the norm of **a** is less than 1. Note that (14) is not a price solution, because **a** depends on **P**. However, (13) does provide the basis for a computationally efficient iterative solution:

(14a) $\mathbf{P}_0 = \ell$

(14b) $\mathbf{P}_n = (\mathbf{I} - \boldsymbol{\pi}_{n-1}\mathbf{a}'(\mathbf{P}_{n-1})\boldsymbol{\pi}_{n-1}^{-1})^{-1}(\boldsymbol{\lambda}\omega + \boldsymbol{\kappa}\xi + \boldsymbol{\mu}\iota)$, n>0.

Convergence of this algorithm depends of course on the properties of **a(P)**. While it is straight forward to develop sufficient conditions for convergence, we will omit them; as a practical matter the algorithm did converge in the applications developed below.

Model parameters

The input-output coefficients are function of prices that depend on the production functions and consumption functions. Appendix 7.2 gives consistent augmented Cobb-Douglas models that derive these functions from cost functions and indirect utility. The Appendix then establishes formulas for estimating all parameters from measurements of **A(ℓ)** and the various own price elasticities. These formulas were then used to implement the CGE model.

APPENDIX 7.1 THE SAM MATRIX

Breaking out digital video sectors in the transactions matrix

1. Broadcasting. A broadcast sector including both radio and TV is already broken out in the U.S. input-output tables. We did not disaggregate this sector further.

2. Broadcast equipment. Broadcast equipment appears in the U.S. input-output within the more general electronic equipment sector. We used data from U.S. Bureau of the Census (2000b) to determine the output total for broadcast equipment ($39 billion in 1997). Broadcast equipment was assumed to use the same technology as general electronic equipment.

3. Chips for digital video equipment, in particular, CODECS. Chip-making is part of the electronic components and parts industry in the U.S. input-output tables. Data from the U.S. Bureau of the Census (2000b) were *not* sufficiently detailed to let us break out video chips from other kinds of chips. We decided to take a different approach, adding up the units of consumer products that might (at least in the future) use CODECs. We included TVs, video cameras, and home security systems. We multiplied the number of units sold (in 1998) by $50, a chip price suggested to us by one of the firms that we interviewed earlier in the project.

4. Research and development for broadcast equipment and for chip-making. The National Science Foundation (2000) provides data on research and development expenditures and on R&D scientists and engineers, broken out by board industry group. Both broadcast equipment and chips are part of the "electrical equipment" group. The same data set provides sales figures, so we can compute crude ratios of R&D dollars and employees to sales. The employment numbers can be converted to expenditures using an average salary for scientists and engineers (National Science Board, 2000). We assume a very crude production technology for R&D - R&D is produced using scientists and engineers, and manufactured goods. Broadcast equipment R&D is a column in the transactions matrix with a labor entry equal to (ratio of R&D to sales)* (ratio of R&D salaries to total R&D)* broadcast equipment sales. The R&D-chip-making column is constructed in a similar manner.

Table 7A1.1
US Social Accounting Matrix, 1996
($M)

	1 natural resources	2 construction	3 manufacturing	4 transportation and utilities	5 services	6 broad-casting	7 broad-cast equipment
1 natural resources	81631	9261	219434	53498	16823	30	22
2 construction	6565	781	24003	62230	102582	863	285
3 manufacturing	46837	207170	1024116	65826	303589	5812	12288
4 transportation and utilities	23766	23032	168235	199435	260702	4807	858
5 services	73441	167849	441495	177766	1372145	66989	5575
6 broadcasting	143	603	47220	9357	109411	5765	264
7 broadcast equipment	0	615	754	938	79	19	592
8 electronic components for DV	0	0	1372	83	283	7	161
9 R&D-broadcast equipment	0	0	0	0	0	0	0
10 R&D-DV electronic components	0	0	0	0	0	0	0
11 compensation to labor	60437	309236	805579	344649	2970194	59725	7478
12 other value added plus indirect taxes	126619	88850	493307	317588	2187426	33000	7080
14 imports by sector	30702	60268	325805	34784	107904	2679	4397
15 gross saving less exports	0	0	0	0	0	0	0
TOTAL	450140	867665	3551320	1266154	7431139	179695	39000

	8	9	10	14	17	15	18
	electronic compon-ents for DV	R&D-broadcast equipment	R&D-DV electronic compon-ents	personal and govt. consump-tion	exports	investment plus inventories less aggregate imports	TOTAL
1 natural resources	2	0	0	29238	35189	5011	450140
2 construction	47	0	0	189135	97	481078	867666
3 manufacturing	748	1362	90	922503	456494	504484	3551320
4 transportation and utilities	85	0	0	502370	66430	16433	1266154
5 services	407	0	0	4666465	246869	212137	7431139
6 broadcasting	34	0	0	6074	826	0	179696
7 broadcast equipment	1	0	0	6985	8216	20801	39000
8 electronic components for DV	8	0	0	22	647	5	2589
9 R&D-broadcast equipment	0	0	0	0	0	2730	2730
10 R&D-DV electronic components	0	0	0	0	0	181	181
11 compensation to labor	653	1010	67	0	0	0	4559028
12 other value added plus indirect taxes	395	285	19	0	0	0	3254570
14 imports by sector	208	73	5	336966	0	-903790	0
15 gross saving less exports	0	0	0	1153838	-814768	0	339070
TOTAL	2589	2730	181	7813598	0	339070	21943282

Source:
Calculated by PRI

APPENDIX 7.2 PRICE ELASTICITY PARAMETERS

This appendix explains our models and methods for estimate price elasticities. In general, these elasticities are estimated using data from two sources:

- estimates taken from the literature on own-price elasticities of demand
- the **A** matrix described above.

To understand why the **A** matrix is relevant, note that e.g. in a Cobb-Douglas case, the own price elasticity of an input demand is equal to - 1, plus its budget share; i.e., $\eta_{ij} = -1 + A_{ij}$. In the following, we will assume production and consumption functions that somewhat generalize the Cobb-Douglas case; as a result, while A_{ij} data are relevant, other data are relevant as well.

Production functions

We assume perfect competition, so that price equals unit cost. We assume the unit cost function for sector "j" is given locally by an augmented Cobb-Douglas form:

(1) $P_j(\mathbf{P}) = \exp\{ \Sigma_i \alpha_{ij} \log P_i + \Sigma_i \beta_{ij} P_i\}$, subject to

(2a) $\Sigma_i \alpha_{ij} = 1$ and

(3a) $\Sigma_i \beta_{ij} = 0 \; \forall \; i$ (homogeneity of degree 1);

(4a) $0 \leq (\alpha_{ij} + \beta_{ij})^2 \leq \alpha_{ij}$ (convexity of cost); and

(5) $0 \leq \alpha_{ij} + \beta_{ij} \; \forall \; i,j$ (cost increasing in prices; positive demands).

and where all prices have been normalized to 1 in an initial equilibrium. α and β are constants which we can estimate from own-price elasticities of input demand (say, η_{ij}) and from input budget shares. (Input budget shares are just the input-output technical coefficients A_{ij}, defined to include labor, capital, and all other inputs). In particular, we calculate unit input demands from Shepard's lemma as

(6) $x_{ij}(\mathbf{P}) = \partial P_j(\mathbf{P})/\partial P_i = P_j\{\alpha_{ij}/P_i + \beta_{ij} \}$. Then we have

(7) $A_{ij}(\mathbf{P}) = x_{ij}P_i / P_j = \alpha_{ij} + \beta_{ij}P_i$

(8) $\eta_{ij}(\mathbf{P}) = \partial(\log x_{ij}(\mathbf{P}))/\partial(\log P_i)$

$$= \alpha_{ij} + \beta_{ij}P_i - (\alpha_{ij}/P_i) /(\alpha_{ij}/P_i + \beta_{ij})$$

At an initial equilibrium with unit prices, we have

(9) $A_{ij}(\ell) = \alpha_{ij} + \beta_{ij}$, and

(10) $\eta_{ij}(\ell) = \alpha_{ij} + \beta_{ij} - \alpha_{ij}/(\alpha_{ij} + \beta_{ij})$.

The solution to this system is

(11) $\alpha_{ij} = - \eta_{ij}A_{ij}(\ell) + A_{ij}(\ell)^2$, and

(12) $\beta_{ij} = A_{ij}(\ell) + \eta_{ij}A_{ij}(\ell) - A_{ij}(\ell)^2$.

Note that, if we are given particular estimates of η_{ij} and $A_{ij}(\ell)$ that are subject only to the input-output accounting conditions

(13) $0 \leq A_{ij} \leq 1$ and

(14) $\Sigma_i A_{ij} = 1$,

then solutions (11-12) need not, and usually will not, obey conditions (2a-4a) and (5). However note that (5) follows from (9) and (13). Therefore fitting this model in practice requires finding the α_{ij} and β_{ij} that are the "closest" to the observed η_{ij} and A_{ij}, while still conforming to conditions (2a-4a). Since in most applications the input-output coefficient A_{ij} is known much more accurately than the price elasticity η_{ij}, the "closest conforming" solution would ordinarily be found by adjusting the η_{ij} but not the A_{ij}. The implied conditions on η_{ij} are:

(2b) $\Sigma_i - \eta_{ij}(\ell)A_{ij} + A_{ij}(\ell)^2 = 1$;

(3b) $\Sigma_i A_{ij}(\ell) + \eta_{ij}A_{ij}(\ell) - A_{ij}(\ell)^2 = 0$; and

(4b) $0 \leq A_{ij}(\ell)^2 \leq - \eta_{ij}A_{ij}(\ell) + A_{ij}(\ell)^2$.

Because of (14), (3b) holds whenever (2b) holds. Therefore our problem is: given estimates for the η_{ij}, say $\eta_{ij}*$, find the "best" values (say $\eta_{ij}**$) that satisfy (2b) and (4b). Note we can restate (4b) as:

(4c) $\eta_{ij} \leq 0$.

Note that solutions always do exist; for example, $\eta_{ij}** = -1 + A_{ij}(\ell)$ is one possible solution. The "closest" solution (i.e. nearest to $\eta_{ij}*$ in a least squares sense) can be roughly described verbally as: for each given j, add a constant amount to each $\eta_{ij}*$. Then set any $\eta_{ij}**$ that exceed the bound of (4c) to 0. Adjust the constant until (3b) is satisfied. Or in other words:

(15) $\eta_{ij}** = \text{MIN} (\eta_{ij}* + \xi_j , 0)$

where ξ is a set of parameters chosen so as to satisfy (2b) for each j.

Consumption functions

Generally in parallel to the production case, we will assume an augmented Cobb-Douglas indirect utility function (at least in a neighborhood of $\mathbf{P} = \ell$):

(1') $V(\mathbf{P}, Y) = Y\exp\text{-}\{ \Sigma_i \gamma_i \log P_i + \Sigma_i \delta_i P_i\}$, subject to

(2a') $\Sigma_i \gamma_i = 1$ and

(3a') $\Sigma_i \delta_i = 0$ (homogeneity of degree 1);

(4a') $0 \leq \gamma_i + \delta_i \;\forall\; i$ (quasi-convexity of utility); and

(5a') $0 \leq \gamma_i + \delta_i \;\forall\; i$ (utility decreasing in prices; positive demands).

Once again, all prices have been normalized to 1 in an initial equilibrium. From Roy's identity we derive consumption demands, input-output coefficients, and own-price elasticities:

(6') $X_{iC}(\mathbf{P},Y) = - \partial V(\mathbf{P}, Y)/\partial P_i \;/\; \partial V(\mathbf{P}, Y)/\partial Y = Y\{\gamma_i/P_i + \delta_i \}$;

(7') $A_{iC}(\mathbf{P}) = X_{iC}P_i \;/\; Y = \gamma_i + \delta_i P_i$; and

(8') $\eta_{iC}(\mathbf{P}) = \partial(\log X_{iC}(\mathbf{P}))/\partial(\log P_i) = - (\gamma_i/P_i)/(\gamma_i/P_i + \delta_i)$.

At an initial equilibrium with unit prices, we have

(9') $A_{iC}(\ell) = \gamma_j + \delta_i$, and

(10') $\eta_{iC}(\ell) = - \gamma_i /(\gamma_i + \delta_i)$.

The solution to this system is

(11') $\gamma_i = - \eta_{iC}(\ell)A_{iC}(\ell)$, and

(12') $\delta_i = A_{iC}(\ell) + \eta_{iC}A_{iC}(\ell)$.

Assume we are given predetermined η_{iC}* and $A_{iC}(\ell)$, subject to the input-output conditions

(13') $0 \leq A_{ij} \leq 1$ and

(14') $\Sigma_i A_{ij} = 1$.

Then condition (5') holds because of (14') and (4') is identical to (5'). Therefore a solution η_{iC}** should be subject only to conditions (2'-3'):

(2b’) $\Sigma_i - \eta_{iC}^{**}A_{iC}(\ell) = 1$, and

(3b’) $\Sigma_i \eta_{iC}^{**}A_{iC}(\ell) + A_{iC}(\ell) = 0$.

Because of (14'), (3b’) holds whenever (2b’) holds. Therefore our problem is: find the "best" values η_{iC}^{**} that satisfies (2b’). Note that solutions always do exist; $\eta_{iC}^{**} = -1$ is one possible solution. The best solution in a least squares sense is:

(15') $\eta_{iC}^{**} = \eta_{iC}^{*} + \nu$

where ν is a parameter chosen so as to satisfy (2b’); namely,

(16') $\nu = -1 - \Sigma_i \eta_{iC}^{*}A_{iC}(\ell)$.

Table 7A2.1
alpha

	1 natural resources	2 construc-tion	3 manufac-turing	4 transport-ation and utilities	5 services	6 broad-casting	7 broad-cast equipment
1 natural resources	0.2080	0.0099	0.0651	0.0411	0.0019	0.0001	0.0006
2 construction	0.0128	0.0007	0.0061	0.0432	0.0102	0.0035	0.0066
3 manufacturing	0.1009	0.2524	0.3404	0.0458	0.0313	0.0245	0.3837
4 transportation and utilities	0.0485	0.0224	0.0445	0.1554	0.0267	0.0201	0.0203
5 services	0.1679	0.1957	0.1263	0.1362	0.1682	0.4091	0.1494
6 broadcasting	0.0003	0.0006	0.0120	0.0062	0.0109	0.0243	0.0062
7 broadcast equipment	0.0000	0.0006	0.0002	0.0006	0.0000	0.0001	0.0139
8 electronic components for DV	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
9 R&D-broadcast equipment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 R&D-DV electronic components	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11 compensation to labor	0.1343	0.4186	0.2538	0.2998	0.4501	0.3513	0.2098
12 other value added plus indirect taxes	0.3227	0.0943	0.1432	0.2709	0.3004	0.1668	0.1968
14 imports by sector	0.0047	0.0048	0.0084	0.0008	0.0002	0.0002	0.0127
15 gross saving less exports	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	8 electronic compon-ents for DV	9 R&D-broadcast equipment	10 R&D-DV electronic compon-ents	14 personal and govt. consump-tion
1 natural resources	0.0009	0.0000	0.0000	0.0042
2 construction	0.0161	0.0000	0.0000	0.0248
3 manufacturing	0.3348	0.5577	0.5567	0.1209
4 transportation and utilities	0.0297	0.0000	0.0000	0.0658
5 services	0.1613	0.0000	0.0000	0.6114
6 broadcasting	0.0115	0.0000	0.0000	0.0008
7 broadcast equipment	0.0003	0.0000	0.0000	0.0009
8 electronic components for DV	0.0000	0.0000	0.0000	0.0000
9 R&D-broadcast equipment	0.0000	0.0000	0.0000	0.0000
10 R&D-DV electronic components	0.0000	0.0000	0.0000	0.0000
11 compensation to labor	0.2829	0.3660	0.3659	0.0000
12 other value added plus indirect taxes	0.1561	0.0757	0.0767	0.0000
14 imports by sector	0.0064	0.0007	0.0007	0.0053
15 gross saving less exports	0.0000	0.0000	0.0000	0.1659

Source: Calculated by PRI

Table 7A2.2
beta

	1 natural resources	2 construction	3 manufacturing	4 transportation and utilities	5 services	6 broadcasting	7 broad-cast equipment
1 natural resources	-0.0267	0.0008	-0.0033	0.0012	0.0004	0.0000	0.0000
2 construction	0.0017	0.0002	0.0007	0.0060	0.0036	0.0013	0.0007
3 manufacturing	0.0031	-0.0136	-0.0520	0.0062	0.0095	0.0079	-0.0686
4 transportation and utilities	0.0043	0.0041	0.0029	0.0021	0.0084	0.0067	0.0017
5 services	-0.0047	-0.0022	-0.0020	0.0042	0.0164	-0.0363	-0.0065
6 broadcasting	0.0000	0.0001	0.0013	0.0012	0.0038	0.0078	0.0006
7 broadcast equipment	0.0000	0.0001	0.0000	0.0001	0.0000	0.0000	0.0013
8 electronic components for DV	0.0000	0.0000	0.0004	0.0001	0.0000	0.0000	0.0041
9 R&D-broadcast equipment	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
10 R&D-DV electronic components	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
11 compensation to labor	0.0000	-0.0622	-0.0269	-0.0276	-0.0504	-0.0189	-0.0180
12 other value added plus indirect taxes	-0.0414	0.0081	-0.0043	-0.0201	-0.0061	0.0168	-0.0152
14 imports by sector	0.0636	0.0646	0.0833	0.0267	0.0143	0.0147	0.1000
15 gross saving less exports	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

	8 electronic compon- ents for DV	9 R&D- broadcast equipment	10 R&D-DV electronic compon- ents	14 personal and govt. consump- tion
1 natural resources	0.0000	0.0000	0.0000	-0.0005
2 construction	0.0020	0.0000	0.0000	-0.0006
3 manufacturing	-0.0457	-0.0588	-0.0588	-0.0028
4 transportation and utilities	0.0032	0.0000	0.0000	-0.0015
5 services	-0.0041	0.0000	0.0000	-0.0141
6 broadcasting	0.0015	0.0000	0.0000	0.0000
7 broadcast equipment	0.0000	0.0000	0.0000	0.0000
8 electronic components for DV	0.0032	0.0000	0.0000	0.0000
9 R&D-broadcast equipment	0.0000	0.0000	0.0000	0.0000
10 R&D-DV electronic components	0.0000	0.0000	0.0000	0.0000
11 compensation to labor	-0.0307	0.0040	0.0038	0.0000
12 other value added plus indirect taxes	-0.0034	0.0289	0.0290	0.0000
14 imports by sector	0.0738	0.0259	0.0260	0.0378
15 gross saving less exports	0.0000	0.0000	0.0000	-0.0183

Source: Calculated by PRI

8. GENERAL EQUILIBRIUM BASELINE IMPACT ESTIMATES

Introduction

Chapter 7 described a Computable General Equilibrium (CGE) framework, together with a Monte Carlo method for aggregating various uncertainties. In this chapter the model will be applied to the three innovations that have reached the market, as described in Chapter 6. These innovations are:

- Transmitter technology for HDTV terrestrial broadcast;
- Compressed domain processing of DV signals;
- Adaptive video codec for information networks.

Analysis of contact points

Burress *et al.* (1999, Chapter 3) categorizes all possible types of connections or "contact points" between a technological innovation and a CGE model similar to that given in Chapter 7. Consideration of these categories will help us insure that all identified economic impacts of each innovation have been fully accounted for, without any double counting. In this section we list and categorize all of the contact points that were implied by the three DV innovations now coming onto the market.

<u>The effects of successful innovation</u>

(T1) demands: the input demand functions for production or consumption.
The following sectors are affected by cost reductions:
production of broadcasting
production of video and codec equipment
In the model, cost reductions are assumed to appear as across-the-board, pro-rated reductions in all input demands.

(T2) goods: the vector of available market goods (which affects both production input demands and household consumption demands).
None identified. We assume conservatively that qualitative improvements due to the new technologies can be ignored; the only changes which will be modeled are R&D and cost reductions.

(T3) technology rents: the prices of technology knowledge services.
None identified. This can be identified with the quasi-rents received as supercompetitive profits by the innovators. In Chapter 6 we made the relatively conservative assumption that new profits received by innovators were equal to old profits lost by owners of existing technologies. We will make the same assumption here.[1]

[1] The event study method developed in chapter 4 might eventually provide an estimate to replace this assumption, but the work reported there is not yet sufficiently developed to provide a reliable estimate.

(T4) terms of trade: the prices of foreign import goods.

None identified. We assume conservatively that no change in the national location of production took place.

(T5) exports: the export demand function.

None identified. We assume conservatively that neither sales volume nor profits on exports are affected, because the innovative goods simply replace pre-existing goods. The resulting cost savings are enjoyed entirely by foreigners.

<u>The effects of R&D and commercialization activities</u>

(T6) investments: the vector composition of investment decisions (including physical capital as well as R&D); and perhaps to some extent the aggregate level of saving and investment and the real interest rate as well.

As in Chapter 6, we assume that the ATP-supported DV R&D constitutes a net addition to social savings and to investment, which is deducted directly from consumption, without impelling any change in the rate of interest.[1]

(T7) fiscal flows: tax cost and expenditure vector of the ATP program being evaluated (other than any R&D expenditures included under contact type T3).

None were identified. As in Chapter 6, fiscal flows have been aggregated with household factor rents, and do not show up as an independent contact point.

Summary of contact points

The following kinds of exogenous changes can occur in the basic CGE model, depending on the year and on whether the simulation refers to the actual world or the counterfactual world:

- production costs may be reduced in the broadcasting sector.
- production costs may be reduced in the video equipment sector.
- R&D may be increased in the broadcasting R&D sector, offset by a reduction in consumption.
- R&D may be increased in the video equipment R&D sector, offset by a reduction in consumption.

Calibration and sources of error

One could formally describe a CGE model as a simulation based on economic theory which translates direct effects of economic impacts into total effects on an economy. A CGE impact estimate has three major sources of error:

- the direct effects may be mis-measured – for example, estimates of cost saving or other spillovers might be awry; or some spillovers might fail to be identified at all.

[1] As discussed below, we will assume further that there are no multiplier effects from transferring dollars from consumption into R&D.

- the parameters of the CGE model may be mis-measured.
- the structure of the CGE model itself may be mis-specified.

Possible errors in measurements of the direct effects of ATP Intervention on research costs, profits, and market spillovers are discussed in Chapter 6. In the Monte Carlo results described below we will consider the aggregate impact of all those errors. We are not aware of any knowledge or network spillovers that have been actualized from the ATP DV program; while they might occur in the future, this baseline report will not address them.

Errors resulting from mis-specification of the CGE model are especially hard to evaluate. The best approach would be to compare estimated results across CGE models constructed by competing researchers. In most applications, however, there are no estimates from CGE models which are comparable. In cases where such comparison have been performed, estimated impacts tended to vary widely, sometimes even wildly, across models, but for many applications most or all of models agreed on the net direction of the impact. In the present case, no comparable CGE estimates are available, but it is reasonable to assume there is a large amount of specification error.

Even given a particular specification, the CGE model could be sensitive to parameters of the economy that are hard to measure accurately. In the present case, the key parameters are the cash flows between US sectors, and the demand elasticities for the corresponding intersectoral quantity flows. The model also contains parameters for the own-price elasticity of exports and final demands. Most of the cash flows are known reasonably well or can be inferred from published data. Import demands by sector, however, are very poorly measured, and models which like this one have Keynesian multipliers are especially sensitive to imports. Sectoral elasticities are even harder to measure (see Appendix 8.1 for examples based on energy demands).

Unlike structural errors, the effects of parameter errors can estimated using sensitivity analysis. In our particular model, we found that changes in parameters that are small enough to stay within bounds set by empirical measurements, are still large enough to make big differences in the Keynesian multipliers. The multipliers are especially sensitive to import measurements. The model is *not* especially sensitive to any of the price elasticities.

These results are closely related to the modeled assumption of slack capacity, so that changes in final demands have positive multiplier effects on industrial output. In future research it would be useful to repeat this sensitivity analysis under assumptions of full employment.

The finding of excessive sensitivity is disappointing. It suggests that the model as specified is not very useful in translating direct effects into total effects. However the model does have other implications, as discussed below.

Given the sensitivity of the multipliers, we decided to calibrate the model in a fashion which, so far as possible, removed all multiplier effects from the kinds of scenarios we wanted to study. (Calibration means adjusting the model parameters to achieve a desired outcome in the baseline equilibrium. It is usually done to reproduce the historic equilibrium that the baseline version of the model is intended to simulate.) In particular, we attempted to adjust the model so that:

- Transferring x real dollars from household consumption into exogenous saving, while spending the same x dollars on R&D, has the net effect of reducing domestic real consumption by approximately x dollars. In other words, the real consumption multiplier approximates the R&D multiplier.
- Reducing the total cost of production in a sector by y real dollars would have the net effect of increasing domestic real consumption by approximately y dollars. In other words, intersectoral price multipliers from cost reductions would be approximately canceled out by leakages of the cost reduction to foreigners who purchase exports.

This calibration was mainly accomplished by changing the sectoral imports and demand elasticities of the DV-related sectors. (The SAM matrix shown in Appendix 7.1 refers to the economy so calibrated.)

It became apparent in the course of the calibrations that the condition on cost saving was much harder to achieve than the condition on R&D expenditures. The model has a strong tendency to predict that cost savings lead to total general equilibrium effects that are smaller than the measured direct effects. With some combinations of import coefficients, it is even possible for the general equilibrium effects to completely overpower the direct effect, with the result that cost savings lead to a net decline in real income.

The mechanism behind this effect follows from the slack economy assumption, interacting with the factor-saving nature of a reduction in costs. In particular, reduced labor or capital costs lead to reduced nominal income, which has a negative multiplier effect on equilibrium flows. At the same time, initial price reductions also have price multiplier effects leading to other price reductions, and the lower price level tends to raise the level of real consumption. In practice however the negative nominal income multipliers can be greater than the positive price-reducing effects.

Once identified, the negative multiplier effect from cost savings appears to be an accurate description of what really should be predicted by a consistent Keynesian model. Unfortunately, sectoral imports are not measured with sufficient accuracy to support realistic estimates of the size of this effect. However, we do believe it is realistic to expect the net indirect effects to be at least somewhat negative. For these reasons, we calibrated the model in such a way that real income gains are somewhat less than the cost savings that drive them.[1]

Linearity of CGE effects

One interesting theoretical question is whether CGE effects are linear or non-linear. If they are linear, then the aggregate impact of N simultaneous projects is simply the sum of the impacts that would occur individually. The CGE model could however be either subadditive or superadditive-that is, the whole could add up to either less or more than the sum of the parts. This question is not likely to be operationally relevant in the case of projects that are small relatively to major sectors of the economy, because the CGE model is differentiable and therefore linear under sufficiently

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[1] The exact amount of reduced gain is irrelevant to the following results, because, as explained below, we have standardized results in such a way as to essentially remove this effect.

small changes in exogenous variables. However, the issue could conceivably be relevant in the eventuality that ATP scored a large-scale success.[1]

With respect to changes in savings and R&D, this model yields an unambiguous answer: the model is strictly linear. In this model, endogenous cash flows and quantity flows are determined by linear multipliers that operate on the exogenous flows. These multipliers do depend on the particular price equilibrium, but the underlying price equilibria do not depend on quantities and hence are predetermined. Because savings and R&D are modeled as exogenous flows, all of the endogenous flows are linear in savings and R&D.

Linearity of flow multipliers is not a finding; it is simply an assumption of this model. Or rather, it is a characteristic that follows mathematically from assumptions of constant returns to scale for industry, homothetic preferences for households, and slack capacity.

The price model, on the other hand, is formally nonlinear. Moreover, changes in the form of cost savings do not connect with the model through exogenous variables, but rather through changes in parameters. Nevertheless, changes in costs in the amounts we considered are essentially linear in their effects (though not in their calculation). To see why, it may be helpful to examine an actual set of equilibrium prices. Table 8.1 provides the model solution for an exogenous reduction in the cost of broadcasting by a total of $1B. Solving this model to 6 place accuracy required successive iterations using15 minutes of time on a 400 MHZ Pentium 3 PC. Note that the equilibrium prices are only a tiny distance from the base prices, which were set at 1. Because the price changes are so small, we expect the model is likely to be approximately linear in the cost reduction. And in fact, once the solution for a $1B reduction had been found, the solution for a $.5B reduction was easy to find: to 6 place accuracy, the equilibrium prices are exactly halfway between the base price and the previous equilibrium price.

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[1] There is a related question of non-linearity that is implied by ATP's mission, or at least aspiration, to create synergistic innovations that achieve a "critical mass" of network externalities. That question might conceivably be addressed by a CGE model, but we do not know how to construct such a model without first having an actual case study that can be modeled. (Thus far, our interviews have not led to such a case.) The present question has to do with non-linear effects that are completely outside the realm of the initiating technology innovation.

Table 8.1
Price equilibrium for $1B reduction in broadcasting costs

sector		prices		
		equilibrium	base	difference
1	natural resources	0.999973	1	2.74902E-05
2	construction	0.999966	1	3.37163E-05
3	manufacturing	0.999928	1	7.22715E-05
4	transportation and utilities	0.999953	1	4.72828E-05
5	services	0.999932	1	6.75554E-05
6	broadcasting	0.997081	1	0.002918849
7	broadcast equipment	0.999947	1	5.30476E-05
8	electronic components for DV	0.999927	1	7.26404E-05
9	R&D-broadcast equipment	0.999966	1	3.40544E-05
10	R&D-DV electronic components	0.999966	1	3.39896E-05
Source: calculations by PRI				

Monte Carlo modeling

The purpose of the Monte Carlo simulation is to estimate the overall accuracy of the impact estimate. The method involves repeated simulations of the entire model using parameters that vary randomly to reflect the underlying error structure of the measurements. As we have seen, it was not possible to say very much about the accuracy of the CGE effects (because those effects are sensitive to ill-determined import coefficients, we essentially calibrated them out of the model). For that reason, the following analysis focuses mainly on uncertainties in the original partial equilibrium measurements. Accordingly, we have normalized the mean value of each measured distribution to equal the corresponding partial equilibrium point estimate used in Chapter 6.

This analysis can be viewed as solving a portfolio problem. That is, we have a portfolio of (in this case, 3) ATP projects; within each project, we have a portfolio of sources of error. Our problem is estimate the aggregate distribution of expected returns to ATP intervention, conditional on the available information, where the distribution reflects the random errors.

Error structure

Detailed assumptions on the error structure are as follows:

- Cost saving estimates (as measured in Chapter 6) are assumed to have a log-normal distribution with a mean value equal to the estimated cost and a standard deviation equal to about 15% of the estimated cost saving. This leads to a 95% confidence interval ranging from around 50% to 200% of the estimated cost. We believe this is a conservative interpretation of the accuracy our informants intended to imply when they estimated the cost savings with 1 to 2 significant figures.

- Rates of error in the cost saving measurement are assumed constant for a given innovation, but uncorrelated across innovations.

- Estimated timing of the innovation in the counterfactual world could be off by 1 year. In particular, in the absence of ATP intervention, the HDTV transmitter project was estimated by respondents to be likely to have occurred about 4 years later than it did occur. However, we will assume that it could have been as short a delay as 3 years (with 30% probability) or as long as 5 years (with another 30% probability). Similarly, the counterfactual video codec project was expected to take place one year later, but we will assume that, with 30% probability, it could have occurred 2 years later. (It could not have occurred with a lag of 0 years, since no competitor has been observed in the actual market place.)

The assumed lognormal distribution of outcomes is based on a belief that the true cost savings in these particular projects are very unlikely to be negative-- first, because the products are being sold as cost saving devices and would not survive in the market place if they actually were counterproductive; and second, because the interview data supported strong positive cost savings. The lognormal distribution is the simplest distribution that is bounded above zero, has an indefinitely long tail, and is asymptotically normal.

The lognormal distribution is skewed right, but that is consistent with our informants' beliefs that their estimates were conservative, and that the true value of the innovation could be substantially larger that estimated. A consequence is that large upside errors are viewed as quite possible.

This error structure is not so complex that is absolutely requires a Monte Carlo approach. That is, given the quasi-linearity of the CGE model and the limitation to only five sources of error, it would certainly be feasible to perform an exact integration to estimate the mean, variance, and other parameters of the aggregate distribution. Our point here however is partly to demonstrate a proof of concept, showing that a Monte Carlo estimator would be straight forward in cases where exact integration would be impractical.

Monte Carlo results

We ran 10 replications of the entire model with randomly chosen errors, with each replication covering all 10 years (1996 to 2005 and with all three innovations in place), with separate simulations in each year for the "actual" world (with ATP intervention) and the "counterfactual" world (without ATP intervention). As is usual in Monte Carlo calculations, randomness was approximated by using a pseudo-random number generator. The economic impact of an innovation on a given variable is defined as the difference between values of that variable in the actual and counterfactual worlds. Table 8.2 shows results for the estimated simultaneous impacts of all three innovations on real consumption, in Net Present Value (NPV) terms (with base year = 2000), broken out by the assumed social discount rate.

Table 8.2
Uncertainties in the aggregate impacts of three DV innovations

	Impacts (NPV $M, base year = 2000)			
Social discount rate	Mean	Standard Deviation	lower 95% confid. interval	upper 95% confid. interval
0%	$166	$98	$48	$572
5%	$148	$87	$43	$512
10%	$133	$79	$39	$460
15%	$120	$72	$35	$413
Source: PRI				

In the absence of any discounting, net benefits of the three projects had a mean estimate that was normalized to $166M (based on Chapter 6 results), with a relatively large standard deviation of about $80M. The distribution is bounded above zero by assumption and appears to be at least roughly lognormal. Assuming lognormality, a 95% confidence interval would range between around $50M and $600M[1] As is usually the case for investment projects, net benefits decline with the social discount rate. However, the estimated NPVs are fairly substantial for all reported discount rates, even at the bottom ends of the 95% confidence intervals.

These findings imply a much wider range of uncertainty than a casual reader of Chapter 6 might have expected. The upper end of the confidence intervals may seem especially astonishing; it varies between $400M and $600M, depending on the discount rate. To some extent, its high value may be an artifact resulting from our generally conservative assumptions -- conservatism on the lower bound with a fixed mean logically leads to a high upper bound.

To put these results in context, the undiscounted public plus private R&D costs planned for the entire ATP Digital Video program were around $133M. However, $18M those costs have already been included in the NPV calculations for the three marketed innovations given above. That leaves about $115M in social costs incurred by all other planned DV projects. A major part of that cost was incurred prior to the year 2000, so for comparability costs should be (inversely) discounted to 2000. But even at the highest assumed discount rates, the year 2000 NPV would be under $160M. The lower bound estimate for net benefits of the three innovations amounts to between a third and a fifth of this amount, while the upper bound estimates exceed twice this amount. If the discount rate is under 10%, then there is at least a 50% probability that the identified returns exceed the social costs of the entire DV program. (These statements are based on partial equilibrium considerations only, and ignore additional uncertainties due to the general equilibrium.)

[1] Using a maximum likelihood estimator; see Kendall and Stuart (1979, p.77).

Conclusions

Multiplier effects

Under slack capacity, the CGE multipliers are too sensitive to hard-to-measure import parameters to support statements about the general equilibrium effects of DV projects that go much beyond the direct (partial equilibrium) effects. That is, it is possible that general equilibrium effects could either augment or reduce the partial equilibrium effects measured in Chapter 6. On the other hand, under reasonable parameter values the estimated total effects in general equilibrium would be would be unlikely to reverse the major partial equilibrium findings of chapter 6. In other words, the three projects that have reached market are likely to have strongly positive net present values under general equilibrium conditions. We suspect that these findings would generalize to other CGE models that assume slack capacity.

In addition, these results may have some real empirical implications, though of a negative kind. In particular, our model suggests there are real limits on the ability of economists to measure national slack-economy sectoral multipliers using presently available data. These limits would prevent us from knowing reliably whether general equilibrium effects either augment or reduce the measurable partial equilibrium effects of R&D projects, under the kinds of scenarios assumed here. (However, no implications should necessarily be drawn for multipliers under full employment conditions, or under forms of finance other than lump sum taxation of households.)

Aggregate uncertainty

According to our model, the uncertainties associated with the partial equilibrium estimates are substantial -- a 95% confidence interval would extend from ⅓ of the estimated value to 3½ times the estimated value. Our model shows that general equilibrium effects have the potential to increase this uncertainty still further.

We believe that similar uncertainties would apply to other direct estimates of technology impacts based on interview data. Similar general equilibrium uncertainties would apply to technology impact estimates of any type. An implication is that, unless social returns to a technology program are extremely high, it may be fundamentally hard to justify the project with a high degree of statistical confidence.

Baseline results

The approach used both here and in Chapter 6 is partly predictive rather than *ex post*, but it is reasonably conservative. We have focused only on benefits that can be predicted with reasonable assurance based on actual sales and with a time horizon of 5 years or less into the future. We have used either moderate or lower bound estimates at each step. We have not attempted to measure any non-market spillovers, and we have made no projections for a number of potential DV innovations that are still in the pipeline. Based on this limited information, it is more probable than not that the DV program will, in a social sense, more than pay for itself.

Explicitness

One major benefit of constructing a CGE model is that the process of specifying, solving, and interpreting the model requires great explicitness about the underlying assumptions. The particular assumptions we used are analyzed in this and the previous chapter. It may well be the case that none of our assumptions are unchallengeable. Nevertheless, we believe it is a real contribution to simply have a concrete example showing all the kinds of assumptions that must be made in order to fully determine the actual impact of a R&D intervention by ATP. At a bare minimum, the process of building a full CGE model substantially reduces the possibilities for either double counting or omitting significant pathways of effect. No similar level of explicitness can be achieved using partial equilibrium methods.

APPENDIX 8.1
UNRELIABILITY OF DEMAND PRICE ELASTICITY MEASUREMENTS: THE CASE OF ENERGY

Table 8A1.1 summarizes the distribution of results for various independent efforts to measure long run energy input demand elasticities for various industrial sectors. (The underlying examples were collected by Bohi,1981). The measured results vary widely across particular measurement efforts, as shown in the column for standard deviations. Moreover no sectoral elasticity varies significantly from -1 (not even with a highly permissive p of .3! On the other hand, nearly all results are significantly different from 0.) Yet, a majority of the underlying estimates *were* significantly different from 1, according to their own regression statistics (not shown).

As it happens, -1 approximates the own-price input elasticity that would be expected under Cobb-Douglas assumptions. In the case of energy, at least, there would be no demonstrable gain in accuracy from using the formally estimated input elasticities summarized here, as opposed to simply assuming Cobb-Douglas production functions.

Table 8A1.1
Distribution of independent measurements of demand elasticities for energy

				t*		
demanding sector	N	mean observed elasticity	standard dev. of elasticities	non-central t, centered on -1	signifi-cance of t*	$(t^*)^2$
food and kindred	5	-0.55	0.39	1.14	0.30	1.31
textiles	7	-1.02	0.64	-0.03	0.98	0.00
pulp and paper	7	-1.15	0.82	-0.18	0.86	0.03
chemicals & petroleum	6	-1.71	0.76	-0.94	0.38	0.89
stone, clay, glass	6	-1.23	0.69	-0.33	0.75	0.11
primary metal	7	-1.36	0.48	-0.74	0.49	0.54
fabricated metal	4	-0.62	0.33	1.16	0.31	1.36
machinery except electrical	6	-0.96	0.25	0.16	0.88	0.03
electrical machinery	6	-1.00	0.64	0.01	1.00	0.00
transport equipment	5	-0.33	0.62	1.08	0.33	1.17
column average		-0.99	0.56	0.13	0.63	
column sum (assumed χ^2)						5.43
significance of χ^2 (10 DF)						0.86
Source: Calculated from Bohi (1981)						

9. CONCLUSIONS

This report focuses on a single question: how can we measure the *ex post* (or retrospective) economic impacts of the ATP Digital Video program, either now or in the future? Within that question, it addresses four topics that employ relatively discrete research methods:

- survey and analysis of consumer demands for video-related goods;
- an event study of the effects of digital video patents on market values of firms;
- a survey and analysis of the activities of client firms assisted by the ATP DV program;
- a computable general equilibrium (CGE) model, showing how activities of client firms have effects that trickle through the US economy, together with a Monte Carlo model that shows the interaction of various measurement errors.

Within each topic, this report provides baseline data, gives concrete examples of the empirical successes that can be achieved using that methodology, analyzes empirical problems in the methodology, and makes suggestions for further research. Performing a complete *ex post* evaluation of the DV program was *not* a major goal of this report, because insufficient time has passed for much meaningful impact to have occurred (many of the projects are still in the R&D stage). However we did arrive at a number of substantive findings. These findings are based either on *ex post* data, or on reasonably well founded short run expectations for three DV innovations that have actually reached the market.

The consumer survey

Data from a telephone survey of US consumers show a coherent pattern in which video-related market goods act like necessities. That is, even the poorest household purchase them to some extent and the budget share declines with income. Expenditure amounts probably increase rather than declining when prices increase. Purchases increase with number of family members, though often at a low rate which suggests there are economies of scale in consumption. (More technically, estimated income elasticities are around .1 to .5; price elasticities are around -.5 to -.9; family size elasticities vary more widely, between .1 and .9.) The coherency of this pattern suggests that it can be extrapolated to demands for new DV-related goods.

When measured in terms of economic value, households make a vastly larger commitment of time than of dollars to the consumption of video goods. It follows that efforts to evaluate new video goods are likely to be seriously mis-specified if they ignore time usage. However, relatively subtle modeling of time seems to be needed. We found for example that video time use falls with factors that make time more scarce, such as work and family commitments, while expenditures on DV goods tend to rise with these same factors, even after controlling for income. Evidently, people whose time is scare tend to substitute quality of viewing for quantity.

We constructed an aggregate video goods consumption index, which takes into account qualitative as well as quantitative characteristics. Its demand properties are entirely similar to those of disaggregated goods. We have estimated a utility system that incorporates both time usage and the consumption index. This or a similar construct could be used in evaluations of consumer goods influenced by ATP's DV programs.

We had originally planned to use the consumer survey data in the CGE model described below. As it turned out, none of the ATP-supported DV innovations have reached the stage of actually affecting consumer goods or consumer benefits provided in the marketplace. Accordingly, simulations of the CGE model could not be influenced by the consumer survey data. Therefore we left these results out of our CGE model.

The event study of patent announcements

There is some evidence from the event study that digital video patenting has a positive effect on market value of the patenting firm and a negative effect on the value of competing firms. This evidence is important because it is the *only* method we are aware of that attempts to measure the aggregate impact of *all* spillovers from an innovation. (However it does so only with respect to selected competitors, and does not evaluate effects on other actors.) It does so in an *ex ante* (predictive) sense, but according to rational market theories accepted by many economists, those implicit market predictions are based on efficient use of knowledge about historic market relationships that is widely distributed among market actors. Consequently, with a sufficiently large sample those *ex ante* measurements would (arguably) provide an unbiased and reasonably accurate measurement of average spillover effects.

To make the evidence more persuasive, a larger sample that includes a longer time series of relatively small DV-related firms will need to be constructed. Also, a citation study of patents was used to select out "important" patents for the event study, and to select an appropriate set of competing firms. This citation study needs to be sharpened.

Most importantly, the event study needs to be respecified to focus on the actual dollar value rather than on the percentage for changes in market value induced by DV innovations. With such a measurement, we may be able to estimate an average ratio between direct effects on the innovating firm (which is relatively easy to measure), and aggregate spillover effects (which is otherwise very hard to measure).

Interviews with client firms

A partial equilibrium approach is developed in Chapters 5 and 6. Baseline data for the approach was gathered through interviews with research staff members at ATP client firms. The interview process was designed to gather information about spillover effects and other project outcomes.

ATP intervention has stimulated the development of a number of potentially beneficial technologies. These technologies will directly affect all aspects of the creation, storage, distribution, and use of DV data. Three technologies have already resulted in marketable products.

We constructed partial equilibrium estimates of the economic impacts of the innovations arising from these projects that have been realized to date, and we made projections about their potential future impacts over a limited horizon. The combined present value of past and anticipated benefits of these projects is estimated between $175M and $120M (for base year 2000), depending on the discount rate. This substantially exceeds the government's investment in the program, and is approximately equal to the combined public and private costs to date. If even a few additional projects result in substantial pay-offs the program's net social benefit will be strongly positive.

Our interview method was similar to that employed by Mansfield *et al.* (1977). However, our approach was especially careful to distinguish between impacts of an *innovation* and impacts of an *intervention* such as ATP funding. For the most part, we found that research staff had a clear idea of what would likely have happened in the absence of ATP funding. They were able to formulate impacts in terms how much their research programs were accelerated. We also found that the researchers were able to identify potential network and knowledge spillovers, although they were not, for the most part, able either to quantify them, or to identify spillovers that had already occurred.

These data gathering and analysis methods would be directly applicable to estimating impacts of ATP programs in later years. Data would need to be updated through further interviews to establish a) whether and what new products have come on line; and b) whether the anticipated impacts of the products already in the market place have been borne out. In addition, network and knowledge spillovers can be verified and perhaps quantified by interviewing researchers at firms in related industries.

The CGE and Monte Carlo models

Technology impact studies are supposed to tell stories about changes in the economy that follow from innovation. Partial equilibrium studies tell only the first part of the story -- what the innovation does to the immediate industry in which it is embedded. To complete the picture, we built a Computable General Equilibrium (CGE) intersectoral model of the US economy and simulated the overall effects of the three successful DV innovations.

Our model described a static, slack-economy version of the US, based on 1996 data broken out into some 15 sectors. We solved the model separately for each year during 1996-2005, and separately for the actual world (including ATP interventions) and the counterfactual world (without ATP). Impacts of ATP are defined as differences between the two worlds. Different states of the world have differing R&D commitments and differing amounts of production cost savings induced by ATP-backed innovations.

We found that solutions of the model are highly sensitive to certain parameters, especially the amount of imported goods used by various industries. Import data of this kind are not measured directly in the US, so we had to infer them from import data by type of commodity demanded, aggregated across user industries. Moreover, the source data are themselves known to be relatively inaccurate. In consequence, the model is most sensitive to the parameters that are least well known. Therefore we were able to draw only qualitative conclusions from the model, not quantitative ones. These conclusions are discussed further below.

We believe that this problem is not specific to our particular specification, but rather general to intersectoral Keynesian models. All such models are sensitive to import data. Until better data become available, it will be hard to make predictions about slack economy multipliers.

We also built up a Monte Carlo model that made detailed but conservative assumptions about measurement uncertainties in the direct effects, and then aggregated them to determine overall effects on the portfolio of three established innovations. We found a surprisingly high rate of uncertainty. According to the model, the undiscounted net present value (NPV) of effects on real income has a 95% confidence interval ranging from $50M to some $600M. (Of course, the relative size of the confidence interval would tend to be reduced if the portfolio of successful innovations grew to include more innovations.)

Implications for ATP's Digital Video Program

The basis of evaluation of government programs is usually restricted to partial equilibrium data - that is, to data on the relatively direct and easily measured effects of the program. Applying that standard, we believe the probabilities are substantially greater than 50% that the ATP program on net will produce a positive social profit. In other words, the real income of Americans will be greater (in a net present value sense) with the program than it would have been without it. This conclusion holds for a reasonably wide range of social discount rates.

We based this conclusion on conservative data. We asked our interviewees to give lower bound estimates of benefits. We included social gains only from three innovations that have actually reached the market, omitting many R&D projects still in the pipeline. We projected no more than 5 years into the future. We omitted any profits received by the innovators, since that might be offset by unmeasured losses to competitors. We omitted any gains that households may eventually derive from, for example, greater access to high definition TV. And we made conservative assumptions about the accuracy of our interview data.

This finding does *not* by itself imply that the ATP DV program is socially justified (or even that it is justified with a probability of 50%). First, merely having a positive social net present value (NPV) does not pass a high enough hurdle to justify a government program. In a perfect world with lump sum taxes and with fully rational trade-offs being made in all choices between public and private consumption and investment, then it is true that every program with a positive NPV should and would be implemented. But in our world, the taxes used to finance programs always induce distortions and external costs on the economy, and these costs need to be covered by the social profits of the program. (These costs conventionally are not included in NPV calculations.) Also, there exist political limitations on the size of the government budget. This raises the hurdle by putting each government program into direct competition with other programs that also have high NPVs.

Second, much of this report is concerned with overcoming the limitations of the partial equilibrium approach. In a complex and interconnected economy, many things happen which can either augment or reduce the measured direct effects of an innovation. Our event study produced at least limited evidence that innovations do in fact reduce the profits of competing firms (but measuring the amount of lost profits will have to await further research). And our CGE model produced strong evidence that the unmeasured indirect effects of an innovation can be quite large, and can be of either sign.

What then can we say about the reliability of our partial equilibrium result when it is extended into a general equilibrium world? This report addresses only a limited situation, namely that of an economy in disequilibrium leading to a period of recession or slow growth. We assumed that the economy responds in a Keynesian fashion (there being no other coherent and operational approach to modeling disequilibrium). Under those conditions we found that indirect effects of a cost reduction are quite likely to be negative-- that is, the total effect of an innovation on the economy is less than would be predicted from partial equilibrium data. The indirect effects from diverting consumption dollars into R&D are indeterminate - that is, the lost consumption may on net be either greater or lesser than the amount of income that is diverted to R&D. Because of innate uncertainties in the CGE model, we are unable to quantify these various indirect effects with any precision. The uncertainties result from ill-measured data on imported goods by sector of use, and are unlikely to be resolved until better data can be gathered at the national level.

In future work it would be desirable to address CGE effects under conditions of full employment of factor resources. In the particular case of cost reductions, we anticipate that indirect effects will be positive rather than negative, for reasons explained in Chapter 8. We also anticipate that multipliers will be much less sensitive to import data, hopefully leading to an acceptable level of precision. And, while the sign of the indirect effect of a transfer from consumption to R&D cannot be predicted in advance, we anticipate that it will be relatively small.

Based on these initial findings, we will propose a tentative and limited general equilibrium interpretation of our partial equilibrium results. The ATP DV program started in 1996. During 1996-2000 the US economy has experienced a period of generally full employment, while the DV program was mainly engaged in R&D. We anticipate that indirect general equilibrium effects for that period of time will be found to be small.

At the time of this writing, there are signs that the US economy may be entering a period of slow growth or recession. If so, then the indirect effects of cost reductions are likely to be negative, though they would probably not completely reverse the positive direct effects. In consequence, conservative data would no longer be able to predict whether or not the DV program will turn a social profit. That is, a full general equilibrium justification of the DV program will have to await future research that can documents strong *ex post* gains.

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INDEX

access 12, 32, 33, 52, 56, 58-60, 64-66, 69, 70, 81, 85, 103, 104, 111, 122, 125, 176
accuracy 26, 67, 165-167, 172, 176
adaptive 4, 54, 59, 62-64, 68, 134, 142, 162
Advanced Technology Program (ATP) . . . . . i-iii, 1, 3-7, 25, 56-59, 61-64, 67, 68, 72-74, 76, 80-84, 87, 88, 90, 94-96, 100-103, 107, 108, 110, 113-116, 119, 120, 122, 125, 126, 128-135, 137, 140, 144, 145, 163, 164, 166-169, 171, 173-179
advertising 111, 145
aggregate 4, 25, 27, 31, 34, 39, 42, 44, 45, 56, 145, 147, 153, 163-165, 167-170, 173, 174
aggregation 1
aircraft 54
airplanes 72
analog 70, 71, 75, 134, 135
archiving 77, 83, 84, 97, 103
art 119
artifacts 48, 68
asynchronous transmission 52
audio 52, 54, 55, 83, 103, 122
Austin, David H. 48, 49, 51, 178
automated 66, 70, 117
bandwidth 70, 76, 78, 91, 92, 97, 117
baseline data . . . . . i, iii, 1-5, 56, 57, 59, 128, 131, 135, 162, 164, 170, 173, 174
Beardsley, George 179
Belinfante, Alexander 9, 178
benchmark 180
bitstream 92
Blair, Peter D. 146, 179
Bohi, Douglas R. 172, 178
books 178
broadcasting 4, 60-70, 83, 84, 88, 97, 98, 103-108, 110-113, 115, 116, 118, 120, 121, 124, 131-134, 138, 139, 141, 144, 145, 147, 151-153, 158-163, 166, 167
Brown, Stephen J. 51, 178
budget 43, 154, 173, 176
buildings 6, 47, 69, 91, 171
Bureau of Labor Statistics 10, 11, 180
Burress, David . . . . . i, ii, 1, 3-5, 7, 42, 43, 48, 49, 56, 58, 59, 76, 96, 129, 144, 162, 178
cable 12, 15, 21, 24, 36, 37, 44, 52, 53, 68, 70, 97, 111, 112
calibration 163-165
camcorders 64, 97, 98
cameras 54, 69-71, 78, 90, 102, 151
capabilities 52, 62, 85, 94, 95, 104, 110, 115, 134
capacity 59, 93, 144, 164, 166, 170
cataloging 66, 103
census 9-11, 151, 179, 180
channels 1, 12-14, 21, 32-34, 54, 82

chemicals . . . 172
chips . . . 78, 79, 92, 96-102, 118, 119, 147, 151
cinema . . . 61, 66, 76-79, 82, 91, 97, 102
classified . . . 61
closed captioning . . . 85
CNN . . . 90
CODECs . . . 4, 59, 62-64, 68, 134, 142, 151, 162, 168
color . . . 12, 14, 15, 24, 32, 36, 111
color TV . . . 12, 14, 15, 24, 32, 36
common carrier . . . 178
compatibility . . . 78, 79
competitiveness . . . 3, 72, 73, 75, 81, 87, 94, 101, 107, 114, 117, 119, 123, 126, 128
compliance . . . 116, 117, 120
components . . . 27, 31, 32, 56, 57, 69, 70, 75, 99, 104, 105, 123, 134, 145-147, 151-153, 158-161, 167
compression . . . 4, 53, 54, 59-61, 63-66, 68-72, 74, 76-78, 80, 81, 90-101, 104, 107, 110-113, 133, 135, 140, 162
computable general equilibrium (CGE) models . . . iii, 1, 5, 6, 144, 147, 148, 150, 162-168, 170, 171, 173-175, 177
computation . . . 79, 96, 116
computer vision . . . 98
conferencing . . . 60, 66, 68-70, 83, 84, 88, 124
construction . . . 4-6, 56, 145, 152, 153, 158-161, 167
consultants . . . ii, 54, 76, 80, 87
consumers . . . iii, 1-5, 7, 9-21, 23-26, 39, 40, 43, 59-61, 71, 79, 82, 84, 86, 93, 99, 106, 113, 118, 123, 124, 128, 129, 132, 134, 135, 137-140, 142, 151, 173, 174, 179
content creation . . . 58, 64
contrast . . . 8, 9, 15, 37, 40, 90, 117
controller . . . 52
convention . . . 104, 149
cost reductions . . . 162, 165, 177
costs . . . 1, 4, 13, 18, 20, 30, 37, 38, 43, 44, 47, 59-61, 70, 75-79, 82, 86, 89, 91, 92, 97-99, 102, 105, 107, 109, 111, 114-117, 119, 121, 123-125, 127, 128, 130-137, 139, 140, 144, 150, 154, 162-169, 175-177, 179
Cowan Research . . . 50, 178
data storage . . . 58, 59, 64
database . . . 49, 56
decoding . . . 52, 76, 77, 90-92, 96, 98, 99
decompression . . . 54, 64, 68, 76, 78, 80, 90, 91, 99
defense . . . 71-73
desktop . . . 68
digital cinema . . . 76-78, 82, 91, 102
digital video . . . i-iii, 1-3, 5, 7, 25, 48-50, 52, 53, 56, 58, 60, 63, 65, 68, 78, 100, 122, 135, 146, 147, 151, 169, 173, 174, 176, 178
disks . . . 53, 69, 71
display . . . 52, 54, 55, 58, 64, 77, 106, 113, 123
distributing . . . 52, 55, 122

distribution 8-11, 46, 52-55, 59, 60, 62, 63, 78, 79, 82, 91, 95, 97, 112, 115, 122, 124, 167-169, 172, 174
DTV 61, 66, 79, 103, 110, 112
DVD 12, 13, 15, 18, 20, 21, 24, 26, 29, 30, 32, 33, 36, 77, 97, 98
economics . . . . i, ii, 1, 4, 5, 47, 48, 56-59, 62, 64, 76, 128, 129, 131, 132, 134, 135, 146, 162, 163, 168, 173, 174, 178-180
economies of scale 57, 71, 79, 86, 93, 99, 106, 113, 118, 123-125, 173
economists . . . . i, ii, 145, 170, 174
edit 103
editing 58, 60, 61, 63, 66, 77, 90, 92, 107, 110-113, 133-135
education 65, 84, 90, 95
elasticities . . . . iii, 26, 27, 31-33, 38, 39, 46, 47, 147, 150, 154-156, 158, 164, 165, 172, 173, 178
Electronic Industries Alliance Market Research Group 178
electronics 54, 55, 60, 61, 63, 124
email 68, 76, 83, 90, 96, 103, 110, 116, 122
encoding 59, 63-65, 67, 76, 96, 98, 100-102, 111
encryption 60, 66, 76-78
energy . . . . iii, 145, 164, 172, 178
enforcement 71, 120
entertainment 2, 7, 12, 15, 23, 25, 45, 52, 60, 68, 70, 83
environment 53, 68, 129
errors 41, 45, 69, 164, 167, 168, 173
event window 48, 50, 51
exhaustiveness 135, 144
exports 145, 147, 148, 152, 153, 158-161, 163-165
FAX 68, 76, 83, 90, 96, 103, 110, 116, 122
feedback 81
fiber 123
film 60, 76, 77, 79, 82, 91
finance 87, 178
fiscal spillovers 59, 129, 163
food 172
forecasts 133, 140
foreign 57, 62, 72, 73, 81, 88, 94, 100, 107, 114, 120, 125, 132, 163
foreign markets 132
frame rate 77
games 54
Gauch, Susan 178
general equilibrium . . . . iii, 1, 2, 4-6, 25, 26, 39, 56, 128, 129, 131, 144, 145, 147, 148, 154, 156, 162, 164-167, 169-171, 173-177
geographical 55
glass 172, 178
graphics 54, 79, 111
Hall, Bronwyn H. 179
Harris, Brian 63, 119, 121, 178
HDTV 4, 12, 13, 18, 32, 60-67, 79, 96, 103-108, 110-116, 118-121, 131-135, 137-139, 141, 145, 147, 162, 168
health 55

Hermreck, David . . . ii
high resolution . . . 66, 76-78
highway . . . 52
homes . . . 8, 55
hospitals . . . 55
households . . . 7-13, 21, 24, 26, 44, 59, 144, 145, 166, 170, 173, 176, 180
housing . . . 179, 180
hunting . . . 79
hyperlinks . . . 65
IBM . . . 52, 63-65, 100, 101, 103, 104
ID . . . 68, 76, 83, 90, 96, 103, 104, 110, 116, 122, 180
image . . . 14, 15, 18, 19, 60, 63, 64, 66, 70, 71, 77-79, 83-85, 90-92, 94, 96, 97, 104, 110, 111
image processing . . . 60, 63, 66, 83, 85, 91
implementations . . . 91, 122, 123
imports . . . 145, 147, 152, 153, 158-161, 164, 165
indexing . . . iii, 46, 66, 83-88, 173, 174, 181
infrastructure . . . 63
Institute for Public Policy and Business Research (IPPBR) . . . ii, 178
instruments . . . 78, 100
Intel . . . 64, 68, 71
intellectual property (IP) . . . 54, 58, 60, 64, 70, 77, 78, 80, 85, 92, 98, 105, 111, 112, 117, 122, 123
intellectual property rights . . . 80
intensity . . . 15, 17
interactivity . . . 53, 60, 63, 65, 84, 85, 90-92, 94, 103
international . . . 52-55, 81, 100, 122
Internet . . . 12, 23, 32, 33, 37, 68, 69, 79, 84, 85, 91, 92, 97-99, 111, 122
interoperability . . . 60, 63, 65, 122
inventories . . . 145, 147, 153
investment . . . 61, 71-73, 79, 81, 86, 87, 93, 94, 99-101, 106, 107, 112-114, 118-120, 124-126, 130, 131, 133, 136, 144, 145, 147, 148, 153, 163, 169, 175, 176
isochronous . . . 53, 55
Jaffe, Adam . . . 57, 129, 179
just noticeable difference (JND) . . . 97
Kansas . . . i, ii, 1, 7, 67, 178
Kendall, Maurice . . . 169, 179
keyboard . . . 57
knowledge . . . 3, 4, 48, 51, 59-62, 70, 71, 78, 85, 86, 93, 99, 106, 112, 118, 124, 129, 131, 162, 164, 174, 175
knowledge spillovers . . . 3, 4, 59-62, 71, 78, 86, 93, 99, 106, 112, 118, 124, 129, 175
laboratories . . . 72, 80, 87, 94, 100, 107, 114, 119, 125
Lancaster, K. J. . . . 179
law . . . 71, 79
learning . . . 25, 70, 95
letter . . . 15
libraries . . . 18, 60, 63, 66, 83, 85, 86
Link, Albert N. . . . 94
links . . . 90

location . . . 57, 61, 62, 72, 81, 87, 94, 101, 107, 114, 119, 125, 163
Lucent . . . 52, 125
machinery . . . 172
maintenance . . . 106
Mansfield, Edwin . . . 5, 57, 128, 175, 179
manufacturing . . . 77, 84, 97, 100, 122, 131, 145, 152, 153, 158-161, 167
market spillovers . . . 2-6, 62, 129, 131-134, 144, 164, 170
markets . . . 1-7, 12, 17, 24, 38, 39, 42, 47, 48, 50, 51, 59, 62, 68-72, 74, 75, 77, 78, 82, 84, 85, 88, 90-92, 95, 97, 98, 100, 102, 104, 105, 107, 108, 111-113, 115-117, 120, 121, 123, 124, 126, 128-135, 139, 141, 144, 162, 164, 168, 170, 173-176, 178
material spillovers . . . 59, 129
materials . . . 145
media . . . 52, 53, 55, 76, 79, 92, 122
memory . . . 79, 110
Mercer, Susan . . . 178
metadata . . . 86
metal . . . 172
Microsoft . . . 69
Miller, Ronald E. . . . 146, 179
Mishan, E. J. . . . 39, 179
mobile . . . 69
monitor . . . 37
monitoring . . . 60, 64, 65, 69, 71, 90, 91, 95, 117, 134
Monte Carlo model . . . 5, 144, 162, 164, 167, 168, 173, 175, 176
movies . . . 12, 15-19, 21, 24, 26, 27, 29, 32, 33, 35, 37, 40, 41, 76-79, 81, 82
MPEG . . . 54, 64, 68, 70, 79-81, 86, 90, 92, 96-99, 104
multichannel . . . 54
multimedia . . . 52, 54, 63, 95
NAICS . . . 179
National Institute of Standards and technology (NIST) . . . i, ii, 1, 58, 62, 72, 80, 84, 100, 101, 119, 125, 131, 132, 178, 179
National Science Board . . . 151, 179
National Science Foundation . . . 151, 179
natural resources . . . 152, 153, 158-161, 167
net . . . 3, 37, 76, 128, 130-138, 140, 142, 163-165, 168-170, 175-177
network spillovers . . . 3, 59-61, 71, 79, 86, 93, 99, 106, 112, 118, 124, 129, 131, 164
networks . . . 3, 4, 52-56, 58-65, 68-72, 79, 86, 93, 99, 100, 103, 104, 106, 107, 110-113, 115, 118, 122-125, 129, 131, 133, 134, 142, 162, 164, 166, 175
news . . . 54, 90
noise . . . 3, 68
object tracking . . . 91
optic . . . 70
Oslund, Patricia . . . i, ii, 68, 76, 83, 90, 96, 103, 110, 178
ownership . . . 8-10, 12, 23, 33, 34, 38
paper . . . 172, 178
parent . . . 72
patents . . . iii, 3, 48-52, 55, 68, 70, 80, 87, 98, 111, 173, 174, 178, 180
pathways . . . 6, 56, 58, 129, 171, 178

pattern recognition . . . 98
patterns . . . 26, 33, 38, 47, 48, 98, 173
payment . . . 123
pay-per-view . . . 79
PBS . . . 112, 115, 133
PCs . . . 54, 59, 64, 68, 166
phone . . . 9, 68, 122
picture . . . 2, 15, 18, 19, 21, 26, 27, 29, 40, 41, 47, 77, 175
pipeline . . . 170, 176
pixels . . . 77
playback . . . 53, 54, 59, 64, 85
Policy Research Institute (PRI) . . . i, ii, 1, 2, 7, 9-17, 19, 23, 30-32, 35, 37, 39, 42, 47, 51, 153, 159, 161, 167, 169, 178
portfolios . . . 50
post production . . . 61, 77, 90, 91
predictions . . . 174, 176
press . . . 179
prices . . . iii, 2-4, 12, 13, 18-20, 23, 25-33, 35, 39, 42-48, 50, 59, 75, 79, 84, 128, 147-151, 154-156, 158, 162-167, 172, 173
pricing . . . 23, 84
private . . . 58, 61, 86, 107, 113, 130, 131, 135-137, 140, 169, 175, 176, 179
production . . . 1, 60, 61, 65, 71, 77-80, 83-86, 90-95, 98-101, 104-107, 112, 113, 118, 124, 128, 144, 146, 148, 150, 151, 154, 156, 162, 163, 165, 172, 175
programs . . . i, ii, 1, 6, 15, 24, 52-54, 56, 58, 63, 68, 100, 103, 110, 130, 135, 136, 144, 163, 164, 169, 170, 173-179
property . . . 54, 58, 60, 64, 70, 77, 78, 80, 85, 92, 98, 105, 111, 112, 117, 123
property rights . . . 80
protocols . . . 1, 4, 58, 122, 123, 178
publications . . . 54
publishers . . . 179
qualitativeness . . . 57, 59, 73, 81, 87, 94, 101, 107, 114, 119, 125, 162, 173, 175
quality . . . 2, 13, 18, 19, 21, 26, 27, 29, 31, 32, 38, 40, 41, 45, 47, 52, 59, 60, 63, 64, 66, 67, 70, 77, 81, 90-92, 96-99, 101, 110, 122, 128, 144, 173
R&D . . . 3, 6, 25, 63, 72, 73, 80, 81, 87, 93, 94, 101, 107, 113, 114, 116, 119, 125, 126, 130-135, 137-140, 142, 144-148, 151-153, 158-163, 165-167, 169-171, 173, 175-177
radio . . . 116, 117, 151
range . . . 33, 48, 56, 59-62, 80, 101, 121, 132, 134, 169, 176
Rapaport, John . . . 179
realm . . . 166
real-time . . . 60, 66, 76, 78, 83, 90, 92, 98
recorders . . . 69
recording . . . 20, 54, 59, 69, 70, 78, 85
recording and playback . . . 85
redundancy . . . 68
relays . . . 123
reliability . . . 15, 177
remote . . . 53, 60, 64, 65, 69-71, 90, 91, 134
rental . . . 18, 20, 24, 37, 44, 45, 147

resolution . . . 66, 76-78, 111
resources . . . 65, 87, 101, 104, 126, 129, 145, 152, 153, 158-161, 167, 177, 178
retail . . . 69
retrieval . . . 58, 60, 64, 84, 103, 178
rights . . . 53, 80, 87
Romeo, Anthony . . . 179
Rosenbloom, Joshua . . . i, ii, 68, 76, 83, 90, 96, 103, 110, 116, 122, 178
sales . . . 59, 74, 75, 81, 82, 88, 89, 95, 98, 101, 102, 108, 114, 115, 120, 121, 126, 127, 131-135, 139, 151, 163, 170
satellite . . . 12, 21, 24, 32, 37, 68, 77, 97, 103, 116, 117
scalability . . . 52, 54, 76, 81, 110
school . . . 69
screens . . . 13-15, 17, 18, 21, 32, 34, 40, 41, 55
script . . . 58
searching . . . 53, 54, 79, 83, 84, 91
security . . . 59, 60, 64, 69-72, 74-77, 82, 90-92, 95, 134, 135, 151
segmentation . . . 83
Sienkiewicz, Robert . . . ii
sign . . . 38, 47, 50, 177
site . . . 77
SMPTE . . . 86, 104
software . . . 50, 52, 59, 62, 64, 65, 68-72, 76, 77, 79, 80, 83-86, 90, 91, 93, 99, 103, 104, 106, 107, 110-114, 118, 122-126, 133, 178
Sony . . . 72, 107
sound . . . 15, 77
space . . . 68, 146, 147
speakers . . . 83
special effects . . . 65, 90-92, 94
speed . . . 53, 54, 60, 61, 70, 78, 83, 85, 86, 98
spillovers . . . iii, 1-6, 48-51, 56, 58-62, 71, 78, 79, 86, 93, 99, 106, 112, 118, 124, 128-135, 144, 163, 164, 170, 174, 175, 179
sports . . . 23, 90
standardization . . . 77, 78, 106
standards . . . i, ii, 1, 11, 12, 41, 45, 46, 50, 57, 65, 71, 76, 78, 79, 86, 93, 97-99, 104, 106, 112, 118, 122-125, 134, 167, 169, 172, 176, 178, 179
storage . . . 53, 54, 58-60, 62, 64, 65, 77, 78, 93, 98, 113, 122, 174
storage capacity . . . 93
streaming . . . 69, 70, 85, 90-92, 97
streams . . . 53, 55, 58-61, 64, 65, 83, 90, 91, 103, 104, 110-113
Stuart, Alan . . . 169, 179
studios . . . 64, 65, 77, 81, 84, 88, 103
super high definition TV . . . 77
surveillance . . . 92
surveys . . . ii, iii, 2-4, 7-19, 23, 25, 26, 30-32, 37-41, 44, 47, 56, 173, 174, 179, 180
synchronization . . . 52, 53
tape . . . 70
telecommunications . . . 53, 123, 125
teleconferencing . . . 55

telephone 4, 7, 8, 38, 54, 56, 67, 68, 76, 83, 90, 96, 103, 110, 116, 122, 124, 173, 178
telephone survey 7, 173
television 12, 14, 15, 24, 52, 54, 55, 62, 83, 84, 90-92, 103-105, 110-112, 116, 132
terminal 52, 54
test data 1
theaters 18, 66, 77-79, 82
tiny 166
trademark 3, 49, 55, 180
training 60, 65, 84, 90, 91, 95
transitory data 2, 3, 61
transmission 53, 58, 59, 64-66, 72, 97, 103, 116
transmitter 4, 65, 69, 116, 117, 119, 121, 131-133, 135, 137, 138, 162, 168
transport 152, 158, 160, 172
transportation 33, 145, 152, 153, 158-161, 167
TV 12-19, 21, 23, 24, 26, 29, 32, 34, 36-39, 45, 63, 65, 66, 69, 70, 76, 97, 108, 111, 115, 121, 139, 144, 147, 151, 176
types 1, 2, 5, 6, 13, 15, 25, 32, 39, 43, 44, 60, 83, 97, 101, 106, 107, 114, 162, 163, 170, 175
U.S. Bureau of Economic Analysis 146, 180
U.S. Bureau of Labor Statistics 10, 11, 180
U.S. Bureau of the Census 9-11, 151, 179, 180
U.S. Patent and Trademark Office 49, 55, 180
University of Kansas . . . . i, ii, 1, 7, 67, 178
upstream 71, 78, 85, 92, 98, 105, 112, 118, 124
VCR 12, 13, 15, 20, 26, 29, 32, 33, 35, 84
vehicles 54
video mail 69, 74
video on demand (VOD) 18, 21, 24, 26, 28
video systems 59, 62, 63, 65, 67, 68, 72, 122, 134, 135
videoconferencing 63, 83
videotape 83
Wagner, Samuel 179
Warner, Jerold B. 51, 178
watermarking 60, 66, 77, 78
weather 90, 111
web 64, 180
website 69
windows 48, 50, 51, 64, 68, 71, 134
wireless 54, 55, 61, 64, 68, 69
wires 54