STUDY PLAN FOR MEASURING ECONOMIC IMPACTS OF ATP'S DIGITAL VIDEO PROGRAM

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EXECUTIVE SUMMARY

Purpose and context

- This report is part of a series of reports on the economic impacts of the Digital Video Focused Program Area of the Advanced Technology Program (ATP). ATP is a division of the National Institute of Standards and Technology (NIST), US Department of Commerce. This series is under preparation by the Institute for Public Policy and Business Research (IPPBR) at the University of Kansas.

- Two previous reports in this series provided a preliminary analysis of the digital video (DV) market place and its economic impacts.
  - Burress *et al.* (1998) established an approach for mapping complex marketplaces in terms of the general attributes of goods (based partly on Lancaster's (1971) demand model). The approach was then applied to provide a detailed empirical description of existing and potential DV-related markets.
  - Burress *et al.* (1999) extended this approach to provide a map of technologies needed to implement the identified types of DV goods. It also provided 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 proposed 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.)

- Two planned reports in this series will establish empirical baseline data on the economic impacts of the Digital Video Focused Program Area.
  - One report will describe designs for specific protocols for gathering data, and submit test data.
  - One report will describe the baseline data and analyze its significance.

- It is anticipated that follow-on reports 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.

- The current report has three goals:
  - to propose general methodologies for the entire study, including possible follow-ons and *ex post* economic impact analyses
  - to propose specific methodology for gathering the baseline data (but not the detailed protocols)
  - to propose a research plan for gathering and analyzing the baseline data needed for the overall study.

Empirical and analytic framework

General modeling approaches

- An "economic impact" of an ATP intervention refers to the *difference* between what happened in the actual world with the intervention, and what hypothetically would have happened in a "counterfactual" world without any intervention. It follows that any economic impact measurement depends on an (either explicit or implicit) model of the counterfactual world.

- To the extent possible, we will place the analysis within a general equilibrium framework, using a CGE model. This has several advantages:
  - the CGE model helps us construct a very clear and explicit model of the counterfactual world
  - the CGE model helps keep track of the distinct spillover channels, shows how can they be aggregated, and avoids double-counting.
  - the CGE model can account for some Keynesian indirect or "multiplier" effects of innovation.

- At the same time, the detailed data on DV markets and innovations will come from micro-economic sources as described below, and we will take pains to maintain comparability with previous partial equilibrium (single market) approaches.

- Previous reports showed there are an extremely large number of potential DV markets (assuming substantial disaggregation) which change over time. Moreover there are an extremely large number of potential spillover channels for each innovation in each market. Therefore any practical study of economic impacts will have to use some combination of aggregation and sampling over markets, innovations, spillovers, and time.

Spillovers as an organizing device

- "Spillovers" can be loosely defined as the side effects or externalities of an innovation. We will describe the economic impact of an innovation as the sum of all of its (positive and negative) spillovers, plus the direct effect on the innovator's profits (suggested by Jaffe, 1996, 1998). One advantage of this decomposition is that it focuses on very specific and micro-economically-measurable channels of influence.

- There are five general classes of spillovers (Burress *et al.*, 1999): market, knowledge, network, fiscal, and material. In addition, there are a large number of possible overlapping cases.
  - A market spillover refers to a surplus value received by one party in a contractual exchange of knowledge, dollars, and/or material goods or services.
  - A network spillover refers to a surplus value received by an agent as part of a multilateral non-contractual circulation of spillover flows.
  - A knowledge, fiscal, or material spillover refers to a surplus value of knowledge, dollars,

or material effects, respectively, that is received by one agent from another agent when they are not directly engaged in a contractual exchange.

- An implication is that we will have to piece together information from a variety of micro data sources to get at the various spillovers. One disadvantage of such an "adding-up approach" is that there are intractably-many possible spillover channels (Burress *et al.*, 1999). A second disadvantage is that some disaggregated channels are hard measure. We will address these problems using sampling, aggregation, and more aggregated approaches (e.g., the "event study" described below), but inevitably many potential channels of influence will be omitted from the study. We do expect, however, to provide a significantly more comprehensive analysis than previous studies.

Micro-based measurements of particular spillover channels

- We have identified three especially important micro-based methods used in previous empirical research on impacts of technology innovation, generally within a partial equilibrium framework. We will employ variants of each of these methods, extending each into a general equilibrium framework.

- The most influential approach, following Mansfield *et al.* (1977), examines the social value of particular innovations that lead to small-scale changes in supply and demand curves, using interview data.

- Tratjenberg (1990) examines the social value of individual innovations that lead to large changes by estimating a demand function for Lancastrian *characteristics* of goods rather than on discrete *categories* of goods. This has several advantages:
  - it provides a natural framework for aggregating goods
  - it supports estimates of empirical (hedonic) demand functions that can be extrapolated to new goods that may exist in the future

  This approach, like the previous approach, is focused largely on market spillovers.

- Austin (1993, 1994a) used an event study approach to measure the anticipated social value of knowledge spillovers from patent announcements. This approach promises to fill in some of the gaps left by other approaches. However, it uses *ex ante* (anticipated) valuations, which constitute imprecise estimators of *ex post* social values.

Macro-based approaches

- Macroeconomic effects of innovation areas and technologies have been studied using various approaches, including
  - growth accounting (e.g., Sichel's 1997 study of computing)
  - social savings (i.e. comparison of the cost of production with a counterfactual world lacking the innovation; Fogel, 1964)

- These approaches attempt to capture the social value of all types of spillovers comprehensively. However, the cost is a low level of precision and a very high degree of aggregation. We will not use these methods.

Summary of ongoing research activities

- We will identify a sample of up to 11 digital video projects for detailed study, including all DV projects previously funded by ATP and willing to participate. We will identify a control sample of projects in the same firms. Over time, we will add to these samples if additional DV projects are funded.

- We will gather data about sampled projects from several sources:
  - telephone and mail interviews with project personnel.
  - telephone and mail interviews with personnel in affected firms (including competitors, suppliers, customers, and producers of complementary goods)
  - published data and information, such as patent applications and scholarly publications

- We will interview experts on industries and technologies related to the innovations and if feasible conduct a teleconference.

- We will gather data on household consumers and estimate a system of Lancastrian demands for DV-related goods versus other goods.

- We will follow the sampled projects and demands over time. In particular, we will replicate or augment our data gathering at two or three year intervals for a period of approximately ten years.

- We will use this data to estimate input demand functions for goods directly affected by the sampled projects, both before and after any innovations.

- To supplement the interview data, we will perform an event study to estimate the effects of project announcements on capitalized values of publicly-traded firms producing related products and services. These effects are aggregated over all spillover channels.

- We will estimate and calibrate the CGE model proposed in Burress *et al.* (1999).

- Using a combination of interview data and published data, we will build "bridge" models that link the sampled markets into the CGE model.

- We will build several models of "attribution," showing the difference between innovation outcomes with and without ATP intervention, for each year studied, in probabilistic terms.

- Using all of these models we will estimate the state of the economy for each year covered in the study, both with and without ATP intervention. The vector of differences between the two

worlds is an estimate of the economic impact of ATP intervention in the digital video market. This data will be used to estimate the net social value of the ATP intervention.

- We will use a Monte Carlo model to integrate the net social values over the attribution rates (i.e. joint probabilities that ATP caused various years of acceleration of the various innovations.)

Summary of goals for gathering baseline data

- Data should be classified by its permanence *prior to* capture by the researcher (i.e., by IPPBR).
  - "transitory" data is data that resides in the mind of market participants, and degrades rather rapidly over time until it is captured through interviews or surveys.
  - "volatile" data is data that has been captured by a commercial or industrial firm and put into hard copy or electronic form. This data tends to disappear over time as well, because it typically has a high time value, and consequently profit-seeking organizations have no incentive to maintain it in permanent archives.
  - "semi-permanent" data is official governmental data in electronic or print-out form. While government agencies do have an obligation to preserve this data, nevertheless it tends to disappear over time because of the decay or obsolescence of media, or else because it gets misplaced.
  - "permanent" data is data that is catalogued and resides in major libraries in hard copy media such as trade books, scholarly journals, or government publications.

- We will define "baseline data" as that which is:
  - needed for the research plan, and
  - either transitory or volatile.

  The main goal of the next two reports, then, is to capture important data about DV that will disappear if it is not gathered now.

- We will gather some additional non-transitory data to help use analyze the transitory and volatile data.

- Data gathering protocols will be completed and tested by December 31 1999. Data gathering will be complete by May 31, 2000.

- Analysis of preliminary data will be completed by June 30, 2000. The analysis will include a preliminary estimate of economic impacts that have already occurred.

1. INTRODUCTION

1.1. Purpose

This report is one of a series of reports on the economic impacts of the Digital Video Focused Program Area of the Advanced Technology Program (ATP). ATP is a division of the National Institute of Standards and Technology (NIST), US Department of Commerce. The goal of ATP is to "partner... with U.S. businesses of all sizes in high-risk scientific research to develop enabling technologies with strong potential for broad-based economic benefit". Focused Program Competitions are efforts to fund "suites of related projects to achieve pre-identified sets of technological and economic goals developed in concert with industry" (Ruegg, 1998). The Digital Video Focused Program Area is a Focused Program Competition with a projected $120M funding that seeks to support infratechnology related to digital video (or DV).

This series of reports is under preparation by the Institute for Public Policy and Business Research (IPPBR) at the University of Kansas. The current report has three goals:

- to propose general methodologies for the entire study, including possible follow-ons and *ex post* (retrospective) economic impact analyses
- to propose specific methodology for gathering the baseline data needed for the over-all study (but not to propose detailed protocols)
- to propose a research plan for gathering and analyzing the baseline data.

1.2. Context and project overview

Two previous reports in this series provided a preliminary analysis of the digital video (DV) market place and its economic impacts.

- Burress *et al.* (1998) established an approach for mapping complex marketplaces in terms of the general attributes of goods (based partly on Lancaster's (1971) demand model). The approach was then applied to provide a detailed empirical description of existing and potential DV-related markets.
- Burress *et al.* (1999) extended this approach to provide a map of technologies needed to implement the identified types of DV goods. It also provided 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 proposed 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, using moderately to highly aggregated market sectors and time periods.

Two planned reports in this series will establish empirical baseline data on the economic impacts of the Digital Video Focused Program Area.

- One report will describe designs for specific protocols for gathering data, and submit test data.
- One report will describe the baseline data and analyze its significance.

"Baseline data" will be defined as data that is needed for the research plan, and that will tend to disappear if it is not gathered now. A more specific definition is given in Chapter 4.

It is anticipated that follow-on reports will track the Digital Video Focused Program Area over time, and then provide comprehensive *ex post* (i.e., retrospective or summative) measurements of its economic impacts on the US. It has also been proposed to study *ex ant*e (i.e., forecast or formative) estimates of these economic impacts.

1.3. Analytic framework

The counterfactual method

An "economic impact" of an ATP intervention refers to the *difference* between what happened in the actual world with the intervention, and what hypothetically would have happened in a "counterfactual" world without any intervention. It follows that any economic impact measurement depends on an (either explicit or implicit) model of the counterfactual world. Modeling the counterfactual constitutes a major part of any impact study.

Impact dimensions

In principle, the economic impact of an event is measured by a vector that includes many different economic dimensions of that impact. In practice, impact studies focus on a small number of dimensions that are closely related to human welfare - most commonly, changes income, job creation, and/or changes in tax revenues. This study will be directed mainly towards measuring changes in equivalent income (meaning income generalized to take into changes in prices and the types of goods available over time). At the same time, the data we will gather could be used to estimate many other dimensions of impact.

CGE modeling

To the extent possible, we will place the analysis within a general equilibrium framework, using a CGE model. This has several advantages:

- the CGE model helps us construct a very clear and explicit model of the counterfactual world
- the CGE model helps keep track of the distinct spillover channels, and shows how can they be aggregated. In particular, the model provides an accounting framework that helps prevent

"double counting." Double counting emerges as a serious problem in partial equilibrium (single market) approaches whenever an effort is made to account for effects in many different markets, mainly because the approach can't model interaction between markets very well.
- the CGE model can account for some Keynesian indirect or "multiplier" effects of innovation.

At the same time, the detailed data on DV markets and innovations will come from micro-economic sources as described below, and we will take pains to maintain comparability with previous partial equilibrium (single market) approaches.

Impacts decomposed into spillovers

The microeconomic data will be organized and classified using the idea of "spillovers." "Spillovers" can be loosely defined as the side effects or externalities of an innovation. We will describe the economic impact of an innovation as the sum of all of its (positive and negative) spillovers, plus the direct effect on its innovator (suggested by Jaffe, 1996, 1998). One advantage of this decomposition is that it focuses on very specific and micro-economically-measurable channels of influence.

Aggregation and sampling

The two previous reports in this series showed that, assuming substantial disaggregation, there are an extremely large number of potential DV markets which will change significantly over time. Moreover there are an extremely large number of potential spillover channels for each innovation in each market. Therefore this study (and any other DV impact study) will have to use some combination of aggregation and sampling over markets, innovations, spillovers, and time.

1.4. Report roadmap

Chapter 2 reviews and interprets previous literature related to the measurement of technology impacts. However literature reviewed in Burress *et al.* (1998) and Burress *et al.* (1999) is not addressed in detail here. This review focuses mainly on three issues that are especially significant in micro-economic assessment methods :

- measurements of attribution, i.e., the degree of causal connection between a government intervention and any subsequent innovations.
- measurements of profits and spillovers
- methods of aggregation over spillovers, markets, innovations, impact channels, time, and probability.

The chapter also briefly reviews some more macro-economic methods, and summarizes major limitations of existing approaches.

Chapter 3 proposes a program of research for the study of ATP's digital video focus area, in light of

existing literature. We propose particular methods for handling attribution, measurement of spillovers, and aggregation which address the limitations identified in Chapter 2.

Chapter 4 reviews and inventories known data sources that would be helpful in carrying out this program.

Chapter 5 applies this program to propose specific research activities. These activities will occur in two phases:

- initial activities for gathering and analyzing baseline data, and
- repetitive activities for monitoring and analyzing economic impacts over time.

Chapter 6 proposes specific timetables, deadlines and outputs for gathering baseline data.

Chapter 7 summarizes the proposed research program, while highlighting what is new or innovative and suggesting other future research not included in this program.

Appendix 1 specifies a preliminary qualitative model for analyzing the internal consistency of attribution reports provided by recipients of ATP funding.

Appendix 2 provides a selected inventory of relevant public data sources.

Appendix 3 analyzes the completeness of the proposed research program. In particular, it summarizes the data sources and data needs of the project, and then shows that a data source has been planned for each data need.

Appendix 4 lists identified proprietary datasets the include data relevant to digital video markets and technologies.

2. LITERATURE REVIEW

2.1. Introduction

Without a firm theoretical foundation it is impossible to know what quantities must be measured to gauge the economic impact of ATP's Digital Video (DV) focused program. The purpose of this chapter is to lay out the theoretical underpinnings of our proposed measurement plan, and to review the state of the literature relating to measurement issues identified here.[1]

Figure 1: Schematic Model of ATP's Economic Impact

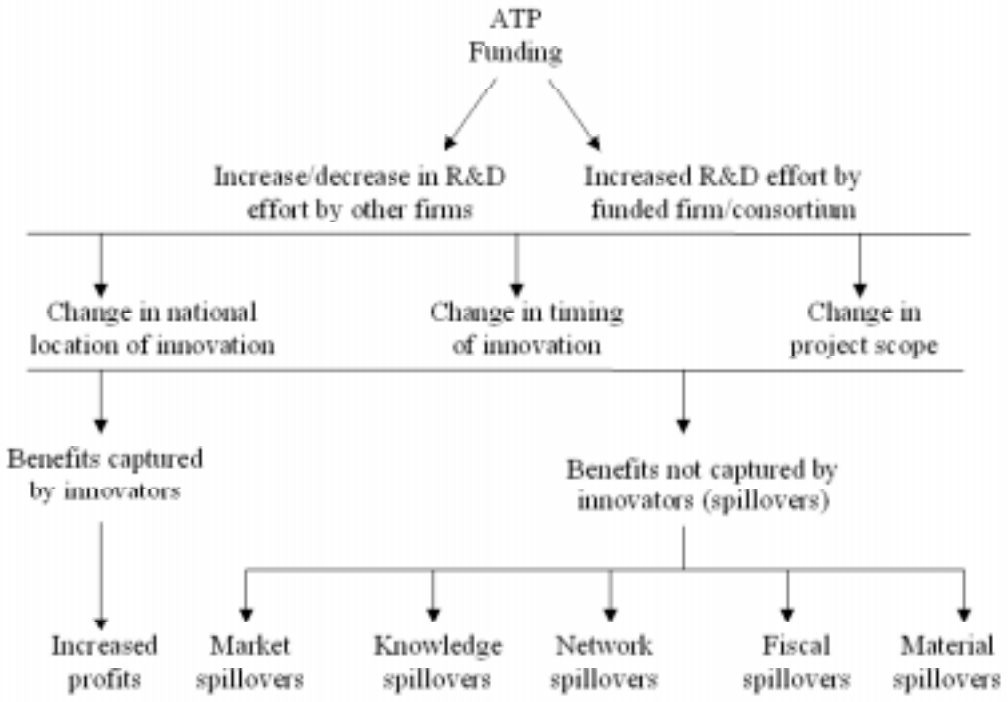

Figure 1 provides a schematic model of the economic impact of ATP support for a single DV research project. As the diagram illustrates, ATP funds influence the economy through their effect on the level and quality of the R&D effort devoted to the project. This impact on R&D effort operates both directly–by making additional resources available–and indirectly through improvements in planning and organization, enhanced access to external funding, and increased collaboration in joint

[1] However, literature reviewed in Burress *et al.* (1998) and Burress *et al.* (1999) will not be discussed in detail here.

ventures.[2]

An increase in effort in turn accelerates the development of a commercially successful technology, which produces economic benefits. These benefits take the form of: (1) private profits accruing to the innovator, and (2) benefits not appropriated by the innovator, which are often referred to as "spillovers." Note that "benefits" is a generic term that includes negative as well as positive economic effects. For example, a new product innovation typically replaces existing products to some extent, leading to reduced profits for existing producers. The reduction in pre-existing profits is a spillover that constitutes a negative benefit.

Jaffe (1996, 1998) distinguishes three types of spillovers of importance for ATP projects–market, knowledge, and network. We have extended his schema to incorporate two additional categories (Burress *et al.*, 1999; Burress, 1999):

- fiscal spillovers are changes in tax revenues and government subsidies as a result of an innovation; and
- material spillovers include positive or negative environmental consequences that an innovation may produce.

One advantage of this decomposition is that it focuses on very specific and micro-economically-measurable channels of influence. An implication is that the researcher must piece together information from a variety of micro data sources to get at the various spillovers.

To measure the impact of ATP funding on profits and spillovers, it is necessary to compare the *actual* state of the world with a *counterfactual* or hypothesized state of the world that would have occurred in the absence of ATP funding. The *difference* in economic benefits between these two situations is what is meant by the economic impact of the ATP intervention. Many of the issues that arise in measuring this economic impact are the result of the need to construct a plausible counterfactual model with which the realized state of the world can be contrasted.

Figure 1 suggests that for each funded project the measurement problem can be subdivided into three distinct questions. The first involves measuring the direct economic effects (positive and negative benefits) of innovations resulting from ATP-funded projects. The second involves determining the contribution of ATP funds to the production of these benefits, which is referred to as the problem of "attribution." The third concerns the appropriate techniques for aggregating multiple spillovers that include both direct and indirect impacts of particular projects in multiple markets, as well as the impacts of multiple innovations resulting from the ensemble of digital video projects funded by ATP.

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[2] The importance of these indirect effects is emphasized by Laidlaw (1997). In interviews with a sample of 28 companies that had received ATP funding, she found 15 firms cited ATP's project planning and management requirements as a key factor in the acceleration of R&D projects. Another 12 cited the "halo" effect of ATP support as beneficial in attracting external funding, and 6 mentioned benefits of increased collaboration as a factor in accelerating their R&D.

We take up each of these questions in turn, beginning with the issue of "attribution," then examining the issues involved in measuring the gains due to each technological innovation, and finally providing a discussion of aggregation.

One disadvantage of such an "adding-up approach" is that there are almost intractably-many possible spillover channels (Burress *et al.*, 1999; Burress, 1999). However, most of the possible channels are expected to have small effects and might reasonably be ignored. A second disadvantage is that some disaggregated channels are hard measure. A more macro-oriented approach could avoid the problem of omitted channels, but that would entail a different problem: data on the effects of ATP are aggregated with many other effects, and may get "lost in the shuffle." This chapter contains a brief discussion of some possible macro-oriented approaches. The chapter concludes with a summing up on the current status of measurement methods.

It should be noted that Figure 1 includes only the effects of ATP activities, which are generally expected to be positive. It does not include the effects of withdrawing taxes from the economy to support ATP; these effects are generally expected to be negative. Since taxation effects have been widely studied and have nothing to do with ATP in particular, we will not discuss them here. However they must be addressed in any full-scale impact study.

2.2. Measuring attribution

Concept and measurement

ATP's goal is to intervene in R&D decisions and activities and cause new innovations and other changes in outcomes. But merely observing an ATP intervention followed by an innovation does not show that causal responsibility for the innovation can be *attributed* to ATP. "Attribution" refers to measurements of ATP's degree of responsibility. Attribution could be modeled as a dummy or switch variable, with a value of 1 if ATP caused a given innovation at a given time and place, zero otherwise. More generally, it would be desirable to model attribution as a continuous percentage between 0% and 100%. This percentage could be interpreted in two somewhat different ways:

- as the share of responsibility for the innovation that is due to ATP; or
- as the probability that the innovation would not have occurred in the absence of ATP.

Measuring attribution is a major problem, not only in the assessment of technology transfer, but more generally in the evaluation of every type of economic development program or micro-economic intervention of government. Four general methods have been identified for studying attribution:

- interviews with experts
- quasi-experimental methods
- econometric studies
- full experimental methods.

Interviews with experts

The most common method of establishing attribution in previous studies has been an appeal to expert opinion. The data are generally based on interviews with key actors involved in the R&D. However these data must be used with some caution. There are at least two important problems:

- ATP-funded firms could have an incentive to exaggerate the benefits of the support they have received; or there may be other kinds of reporting bias.
- Even if ATP funding recipients respond truthfully and accurately, it is important to clearly articulate the counterfactual situation against which actual experience is being compared.

Controlling reporting bias. Averch (1997) is especially critical of on the question of reporting bias in a review of Link's (1996) ATP study:[3]

> [Link] invents ... ad hoc research procedures... Depending on the situation on the ground, [he] carries out surveys of prospective customers, interviews, workshops, etc. He manages to aggregate all of this "soft" data into a bottom line benefit-cost ratio. ...Predicting some final benefit-cost ratio when working to change and improve a project is perilous. ...serious evaluators and benefit-cost analysts create strategic difficulties for high level managers. ...Many [evaluations] rest on self-reporting by project managers or other NIST employees. In the federal R&D world, reporting failures and difficulties is foolish, because this immediately raises questions of competence and budget. Most managers have to report that all is well.

Averch is focusing partly on interview data viewed as especially susceptible to bias because it:

- was reported by ATP employees
- was collected by ATP employees
- consisted in "formative" (*ex ante* or forecast) data about outcomes.

Nevertheless, he and many other economists distrust interview data even when (at best) it is collected by independent contractors on an *ex post* basis from outside R&D firms that had been awarded ATP funding.[4]

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[3] Note that these comments go well beyond the question of attribution, and apply also to measurements of benefits discussed in sections 2.4 and 2.5 below.

[4] Economists have historically distrusted data from surveys and interviews, often with good reason. However, in most cases there really are no alternative data sources. Official statistics, for example, are largely based on surveys and interviews. And even administrative records such as tax returns are based on complex survey forms subject to obvious incentives for mis-reporting. Consequently official statistics have much larger biases than economists probably like to admit. (Morgenstern's seminal 1950, 1963 study of this problem has not been outmoded.) Avoiding bias in data is arguably more a matter of rhetorical persuasiveness than an obtainable, concrete ideal. That is, data are more persuasive to that extent that more careful procedures have been followed

These concerns might be addressed, though never completely assuaged, by use of careful procedures. In particular, using a qualitative analysis it may be possible to test the internal consistency of these reported attribution claims in a new way. As Jaffe (1996, 1998) pointed out, the incentive to invest in R&D should depend in a predictable way on the current and anticipated economic conditions that would affect profits resulting from the intended innovation. Jaffe listed a number of factors that affect this incentive. If ATP causes a change in the decision to invest, then two things must be true:

- absent ATP invention, the balance of factors would have been negative
- given ATP invention, the balance of factors was positive

In other words, ATP's intervention shifted key factors to support the investment. Interviews could elicit the innovators' views on the status of each of the identified factors in two states of the world:

- in the actual world in which ATP intervention and the R&D did take place, and
- in the counterfactual world without ATP intervention, where (in the opinion of the interviewee) R&D either would or would not have taken place

Analysis and modeling could then be used to divide configurations of factors into two types:

- insufficient configurations for R&D investment to occur
- sufficient configurations for R&D investment to occur.

Then ATP intervention is viewed as causing the R&D if it changed the configuration of factors from the first to the second type.

Specifying the counterfactual. ATP's Business Reporting Survey asks firms to compare the actual progress of their R&D project with the progress that they would have made in the absence of ATP support. But this response does not take into account actual or potential R&D projects being carried on by competitors of the ATP funding recipients. When Laidlaw (1997) asked firms why reducing R&D cycle times was important, most responses indicated that the benefits derived from beating competitors to market. Typical of these explanations were statements such as (see Laidlaw 1997, pp. 16-21):

- "Reducing cycle time and being first to market with technological innovations and new products provides one with a competitive advantage."
- "Hitting the market first–with a viable product–gives you a chance to be more competitive and successful. It gives you a leg-up."
- "[my company] faced very strong competition from the Japanese. They have a much shorter cycle time....It is critical that we reduce cycle time if we are to be competitive with them."
- "If you're the first one there with a bug-free technology, you have a chance of establishing market dominance–and can then set the bar for everyone else."

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and better cross checks have been performed in the course of surveys, interviews, and data interpretation.

- "When you're the first to market and one year in advance over your competition, sales volume goes up."
- "Applied research cycle-time reduction is critical for our product class."

In other words, by accelerating their projects ATP funding recipients believed they would be able to move project completion dates ahead of those of key competitors.[5] These responses indicate that most firms believed that there were other competitors who in the absence of ATP support would be capable of beating them to market. To the extent that this is true, the reduction in R&D cycle time reported by ATP funded firms represents an *upper bound* on ATP's impact on the timing of innovation.

Resolution of this problem will require interviews not just with ATP recipients, but with other firms engaged in related areas of research to determine the rate at which their research was progressing, and how the awarding of ATP support may have affected their level of R&D effort.

Quasi-experimental methods

The impact of ATP funding could be measured in a quasi-experimental framework, by comparing funding and effort devoted to projects that are in other respects comparable but did not receive ATP funding. These might be drawn from a pool of other projects being conducted by recipients of ATP funding, or from the populations of firms that applied for but did not receive ATP funding, and firms that did not apply for ATP funding. The greatest difficulty here is in finding truly comparable projects that would allow a measurement of the impact of ATP support -- since projects that were not funded, or projects that were not proposed to ATP may be qualitatively different from those that received funding. We are left with the impression that any quasi-experimental comparison is likely to suffer from an unknown but possibly serious degree of bias.

Econometric studies

Econometric studies could be performed to show relationships between government interventions and economic outcomes, in which statistical control of multiple variables is used in place of matching projects (see e.g., Burress and Oslund, 1998, Chapter 7). The problem of bias would be addressed by using a large sample of projects. Unfortunately, there are no comprehensive lists of R&D *projects* to sample from. There do exist lists of *firms* that conduct R&D, but discovering what projects they may have planned or undertaken would be a formidable task. Consequently, econometric comparisons usually have to done at the firm level. For the larger firms, this implies that effects of any one project are lost in the aggregated data. Also, it is very hard to obtain data on the subset of firms that failed to receive funding and went out of business.

Full experimental methods

[5] The discussion further suggests that the source of competitive advantage derives from the existence of important first mover advantages that allow early innovators to set standards and dominate markets.

Any of the types of data described above would be based on outcomes of the usual operations of ATP—that is, we would be using "natural experiments" rather than true controlled experiments. Measurements of causal relationships based on such data are never entirely conclusive—rather, interpretations must depend upon a preponderance of the evidence. Questions of causation would best be settled by means of controlled experiments -- see Burtless (1995); or see Jaffe (1998), who states:

> ...if we really desire to know how effective [technology] programs are, then the programs need to incorporate elements of experimental design into their ongoing operation, in the same way that the efficacy of drugs is determined by scientifically-designed clinical trials, which we have not done.[6]

Administrative experiments using randomly selected control groups may conflict with the purposes and ideals that we expect agency administrators to uphold, such as fairness and universal service. Also, if good R&D investment opportunities for ATP are scare, administrators may be unwilling to sacrifice any of them for use as controls. To our knowledge, there have been no controlled experiments in technology assessment, or more generally, in the evaluation of economic development efforts. There have however been numerous experiments in other areas of economic and social policy; 143 US experiments completed through 1996 are documented in Greenberg and Shroder (1997). An actual experimental evaluation of technology interventions using randomly selected treatment and control groups would, of course, be of very great interest, not only to specialists in technology interventions, but also to those engaged in economic development in general and in other types of evaluation as well. Controlled experiments would be especially valuable if they could be used to benchmark non-experimental evaluation methods. But until that happens, evaluators will have to be content with non-experimental, or at best quasi-experimental, studies. In any case, experimental methods are outside the scope of this project.

2.3. Applications by type of change attributed to ATP

Three types of changes in innovations

The goal of ATP is to encourage beneficial technology innovations in the US. We will conceptualize ATP as affecting an innovation through three channels. In comparison to a counterfactual world in which there is no ATP, intervention can:

- change the timing of the innovation;

[6] However, not even controlled experiments can provide a panacea. Because of difficulties in ensuring that social experiments are actually conducted in the manner planned, some of the same problems of sample selection bias may occur, and regression models are needed to test for those possibilities (Heckman and Smith, 1995). In the end, interpreting social causation *always* depends on a preponderance of the evidence, rather than on a decisive proof. Experimental data are simply more persuasive than other data.

- change the national location of the innovation; or
- change the particular characteristics of the innovation as it is implemented.

In this framework, a change in the probability of success of an R&D project would *not* be an independent type of influence. *Ex ante* (prospectively), we conceptualize a world in which every technically and commercially viable innovation that reasonably *can* happen, *will* happen at some time in the future, with some probability distribution over time. The *ex ante* effect of an ATP intervention is to change the distribution of probabilities at each future time. In this framework, changes in the probability of success of the innovation collapse into changes in its timing.[7]

Ex post, the situation is somewhat different. After the fact, we will know that the innovation did happen at a definite time in the actual world. However, it is still most natural to model the counterfactual world as a probability distribution over different times at which the innovation might have succeeded in the absence of ATP.

The economic effects produced by ATP funding are the consequence of changes in R&D efforts that result from the effects of the funding on the relative private cost of different research projects in the US. To determine what share of the benefits we should attribute to ATP funding, it is necessary to measure the impact of ATP's funds on the amount, national location, and qualitative success of the R&D effort devoted to the technology in question.

Synergy and momentum

In addition, ATP focus areas may have an additional impact at a higher level of aggregation. If ATP

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[7] This breakout should be contrasted with that given in Martin *et al.* (1999), who focus on an R&D *project*, rather than on an *innovation*. The difference is that, once the times are "ripe" for a particular innovation, multiple projects may ensue until the innovation succeeds. They also focus on *ex ante* (forecast) rather than *ex post* outcomes. Martin *et al.* (pages E-2, 1-4) assume that ATP can affect the technology developed by a project in three ways:

- accelerate the technology's benefits
- increase the likelihood of success
- widen the technology's applications.

Note that we can sensibly ask project personnel to estimate both the acceleration and the improved chances of success of the *project*. They can't as easily estimate these factors for the *innovation*, because that depends on multiple projects that might have happened in the counterfactual world.

In addition, we believe that "widening the technology's applications" should be generalized into "changing the technology's characteristics." For example, as compared with the conventional QWERTY keyboard, the Dvorak keyboard has a potentially improved quality, without having any wider application, and this improved quality is a distinct benefit of the Dvorak technology implementation. Note also that Martin *et al.* omit the question of national location.

We also believe that Martin *et al.*'s subsequent analysis of the likelihood of project success contains a conceptual error which overstates the social value of the project. They implicitly assume that, in the absence of the current project, the innovation would never occur at all. A more persuasive counterfactual is that the innovation would eventually have been introduced by some other firm.

enables an entire group of innovations that work together, then success in one innovation may increase the perceived marginal benefits of success in another. At the same time, skills, techniques, and organizations developed for one innovation may reduce the marginal cost of developing another innovation. Consequently, an entire cluster of innovations might be potentiated collectively. In shorthand language, we could say: "ATP may change the degree of synergy and momentum of R&D for a cluster of innovations."

While it is tempting to treat synergy and momentum as a separate channel of influence, their impacts will be manifested through the three channels enumerated above, and consequently should not be separately enumerated. At the same time, synergy and momentum effects do need to be measured explicitly, because they emerge only at the level of an *ensemble or portfolio* of projects, rather than at the level of an individual project.

We are not aware of any formal efforts to track these kinds of ensemble effects. Data on this type of influence could, however, be gathered from interviews with the ensemble of ATP-funded firms, as well as with other actors.

The timing of an innovation

The most important effect of ATP is likely to be a change in the time at which an innovation is introduced. At one extreme it is possible to imagine that in the absence of ATP funding a particular technology would not have been developed within any finite time horizon.[8] In such a case, all of the resulting benefits accruing to this innovation could be attributed to ATP support. At the other extreme, it is conceivable that ATP funds are simply substituted for funds that would have been spent by the private sector, with no net change in R&D effort. In this instance ATP support would have no impact on the timing of the innovation, and it would not be appropriate to attribute any benefits produced by the innovation to ATP support. More commonly ATP would have an intermediate effect on timing.

Several studies (Laidlaw (1997), Link (1997), Powell (1998) and Silber (1996)) have examined the impact of ATP funding on technological success using data gathered by ATP's Business Reporting System in conjunction with interviews with funding recipients. All of these studies indicate that ATP recipients believe that funding has resulted in an acceleration of their Research and Development activities. Of those who reported that they were ahead in their R&D cycle as a result of ATP funding, 34% said that they would not have conducted the project without ATP support, while another 55% indicated that they were from 1 to 3 years ahead.
Note that these results refer to acceleration of individual projects; they would have to be corrected for a counterfactual in which a different company might have developed the innovation.

The national location of an innovation

[8] We continue to assume all commercially viable innovations will be produced eventually. However, it is still possible that the probability of the innovation occurring is less than one within any finite time horizon.

Measuring effects on national location parallels the problem of measuring ATP's impact on the timing of innovation. To the extent that some of the competitors of ATP funded firms are located overseas, any changes in the timing of innovation may cause the innovation to be made by a U.S., rather than foreign, firm. If there are important first mover advantages then this shift in the location of innovation will also have an impact on the national location of benefits derived from the innovation.

When ATP funding serves simply to accelerate development within the United States, the net benefits of this funding are those associated with the earlier introduction of the technology. When ATP funding allows a United States-based company to move ahead of a foreign-based company, all of the benefits of this shift in national location should be attributed to ATP funding.

The data necessary to address this question are nearly identical to those discussed above. The only additional requirement is to keep track of the national locations of actual and potential competitors.

The displacement of investment

Implicit in any estimation of the acceleration or change in national location of a project is the converse idea of investment displacement. It is conceivable, for example, that ATP funds for a given project are utilized 100% to displace available funds from other sources, with no net change in total funding for the project; in that case ATP funding might have no effect at all on timing or location of the innovation. More generally, displacement is a very complicated problem in which the counterfactual has several dimensions:

- The funded project might or might not have proceeded in the absence of ATP funding.
- Competing projects in the US or elsewhere might or might not have proceeded in the absence of ATP funding.
- ATP funding could lead to reductions in funding for the funded project; or for competing project(s); or for both.
- ATP funding could also leverage additional investment funds (i.e. displacement can be negative). At the other extreme, under certain conditions displacement could conceivably exceed 100% (e.g., 100% displacement for the funded project plus some additional displacement for competing projects.)
- In addition to the displacement of funds for projects related to the given innovation, there could be positive or negative displacement effects for unrelated projects, or for the aggregate of funds available for R&D of all types.

We are not aware of any empirical research that has considered complex alternative counterfactuals for displacement. If interviews are undertaken with ATP funding recipients and their (actual or potential) competitors, some of these dimensions would need to be spelled out clearly and explored. Other dimensions, however, refer to possibilities for which the interviewees may have no special knowledge, and alternative modeling methods would have to be used.

The qualitative characteristics of an innovation

Several previous studies have suggested that ATP funding has encouraged recipients to pursue broader or more ambitious research projects than they would have in the absence of ATP funding. Powell (1999), for example, reports that 80 percent of small firms, and 72 percent of all organizations felt that ATP support had increased the scope of their R&D project. This suggests that the characteristics of innovation as implemented may have been affected by ATP intervention.

As far as we are aware, there have been no formal efforts to measure *changes in values* of an innovation due to effects of government intervention on its characteristics. Data on changes in R&D scope or thrust would necessarily have to come from interviews with ATP funded firms; data on valuation of those changes could come from other sources.

Once again, the counterfactual must be considered with care. If ATP had not intervened and some other project had eventually developed the innovation, then the qualitative innovation could have been similar either to that originally planned for the awarded project, or to that which the awarded project arrived at subsequently to ATP intervention. It is also possible that it would have been dissimilar to both.

If the leading alternative project is in the U.S. and can actually be identified, then interviews with its personnel could cast light on this question. However, such situations are likely to be unusual, given that ATP's goal is to fund projects that would not happen otherwise, or would not happen as quickly, or would not happen in the U.S.

Attribution for knowledge spillovers

Suppose we observe a second-round innovation whose development may have been influenced by an initial ATP-funded innovation. Then we are faced with a kind of "second-order" attribution problem. Using a probability interpretation of attribution and assuming that the probabilities for the two causal links are independent, we would say that

> P(the second innovation was caused by ATP) = P(the second innovation was caused by the initial innovation)*P(the initial innovation was caused by ATP),

where P(.) denotes a probability estimate.

We are not aware of any empirical research on "second order" attribution as such, but the two causal links have been studied separately. Interviews with the second-round innovators could cast light on the second causal link. Bibliometric influence studies (described in Section 2.4 below) are also relevant.

There several possible counterfactuals. The simplest are:

- A delay in the initial innovation might have led to a roughly equal delay in the second innovation.
- In the absence of the initial innovation at the time of the second innovation, the second innovation might have followed a more time-consuming research path.

2.4. Measuring benefits

Concept and measurement

The second element in measuring the economic impacts of ATP funding involves measuring the *size* of the positive and negative benefits resulting from ATP funded innovations. As Figure 1 illustrates, the benefits of ATP funding take a variety of forms. Most recent efforts to measure the economic impacts of technical innovations have built up estimates through measurements of each separate category of benefits. An alternative approach, however, is to use more aggregated or macro-oriented approaches. As we explain in Section 2.6 below, while this latter approach is attractive in some contexts it does not seem well suited to the task at hand. Consequently our focus in this section is on building up suitable measurements for each type of benefit.

Note that there two separate measurement problems, which may require different techniques:

- identifying particular benefits or spillovers
- measuring their value or impact.

Griliches (1992) summarizes the results of many technology spillover studies. A number of general methods have been identified for identifying and measuring particular benefits:

- interviews
- bibliometric studies
- correlations of weighted R&D with economic outcomes
- econometric estimates of the production function
- econometric estimates of the demand function
- event studies of effects of innovations on stock market evaluations
- analogical modeling (i.e. comparisons to otherwise "similar" cases that are easier to measure)

Interviews

Influential studies inspired by Mansfield *et al.* (1977) provide considerable guidance in formulating and implementing measurement plans based on interviews, although it will be necessary to extend and adapt their approaches to make them compatible with the specifics of ATP's DV program.

The problem of interview bias has already been discussed. Note that the *ex post* estimates of outcomes we will need are likely to be less subject to bias than either *ex ante* estimates of outcomes or estimates of causal attribution, because in the former case the firm is likely to have relevant

accounting data.

Bibliometric influence studies

A number of studies have traced relationships either among innovations or between innovations and actors using bibliometric approaches. These relationships are usually interpreted as knowledge spillovers. The bibliometric links may be patent citations, citations in scholarly publications, or the names of authors or firms. Innovations may be classified by industry code (of the patent, of the originating industry, or of the using industry), by geographical location, and/or by cluster of linked researchers. e.g., Jaffe (1986) measured "technological proximity" of firms based on the overlap of classifications of their patents. An especially interesting type of study is the use of patent data to create a "technology flow" matrix showing the fraction of patents originating in one industry that are used by another. (See the 1997 special issue of *Economic Systems Research* on invention input-output analysis.)

A basic problem with bibliometric approaches is that these data by themselves haven't any natural economic metric. The average economic value of a patent or a scholarly publication is generally unknown and differs widely by industry code and by author. Also, different sectors differ widely in propensity to patent (as opposed to using other forms of intellectual property protection) and in propensity to publish. Hence bibliometrics can identity channels of influence but can't as easily yield any direct measures of benefits. (However Griliches' 1990 review argues that patenting rates do contain substantial and reasonably stable scalar information about knowledge production.)

On the other hand, if we assume that the average value of a patent is constant by originating industry and independent of using industry, then the technology flow matrix does yield useable measures of relative closeness which can be analyzed using input-output techniques. (The vice-versa assumption could also be made.) These measures could be used, for example, to pre-identify sectors or firms for inclusion in an event study (see below).

Correlations of weighted R&D with economic outcomes

Terleckyj (1974) found that R&D in industries supplying intermediate industries increases productivity in downstream industries. Scherer (1982, 1984) created a technology-flow matrix for patents, and then showed that R&D weighted by use is better predictor of productivity than R&D weighted by source.

Econometric estimates of the production function

A related approach uses unweighted cumulative R&D investments as an input in a conventional production function. (Contemporaneous R&D is also relevant, because it helps determine the capacity to absorb knowledge spillins.) This approach can measure spillovers within an industry or between industries within a nation, depending on which R&D measure is included in the production function. Many studies of this type have been performed; they are reviewed in Griliches (1994) and Mohnen

(1996).

Econometric estimates of the consumer demand function

Estimation of demand is a staple of econometrics. In a partial equilibrium context, "demand function" often refers to just two parameters -- e.g., the demand at zero price, plus a slope; or the demand at unit price, plus an own-price elasticity. The general equilibrium context is more data intensive -- we need a complete system showing all cross-price elasticities for all goods (at some reasonable level of aggregation).

In impact studies, consumer surplus or welfare changes may result from efficiency improvements leading to a changes in price of the good being demanded. This application is straight-forward.

However, this framework is best suited to the analysis of situations in which innovations are purely cost-reducing. That is, the innovations do not have any impact on the characteristics of the goods or services consumed other than through their impact on price. Trajtenberg (1989), has developed an empirical framework that is well suited to the measurement issues posed in the contrary case, when characteristics of goods change. The approach is based on Lancaster's (1971) idea that differences between products can be described in terms of a small number of attributes (quality dimensions), and that change occurs through improvements in these attributes. Trajtenberg's approach amounts to the estimation of a "hedonic demand function" -- i.e. a demand for characteristics.

Hausman (1997) suggests a different approach to the problem, which treats innovations that alter product characteristics as the introduction of a new good or service. His approach assumes that there is a well defined demand for the newly introduced good or service, but that prior to the innovation its price is sufficiently high that consumers will choose to purchase zero units. The innovation lowers prices, causing an increase in consumer welfare, that can be measured by extrapolating the demand curve back to its intersection with the vertical axis. While this approach is conceptually straightforward, implementation rests on the ability to estimate the parameters of the demand curve over a large range of prices and quantities, which may be difficult to implement in practice (a point that Bresnahan,1997, makes in his comments on this paper; pp. 239-43).

Event studies

For publicly traded firms, an alternative approach is possible through the use of stock market valuations. In particular, the change in stock market valuation associated with announcements related to the innovation–such as patent grants–can be interpreted as a measure of investor expectations about the present value of the future flow of profits that the innovation will generate. Obviously, this calculation must control in some way for other factors–such as general stock market movements–that also influence prices. This approach is akin to the "event study" methodology that has been employed by a number of studies in finance (see, e.g, the survey in Mackinlay 1997). Recently Austin (1993, 1996) has used a version of this analysis to estimate the value of patents in the biotechnology industry. His general methodology can be applied in a relatively straightforward way to other

industries. An extension of this method could perhaps be used to identify separate spillovers for different classes of firms -- e.g., suppliers, demanders, competitors.

Analogical modeling

Mullick *et al.* (1987) suggest forming analogies between counterfactual goods (whose demands cannot be directly measured) and actual, historic goods (whose demand curves are measurable). Note that this method does not stand on its own; e.g., after we form an analogy to a given industry, we still need to estimate demands for that industry using other techniques.

2.5. Applications by type of benefit

Private Profits

Assuming that the innovating firm has some degree of market power, due either to first mover advantages, patents, or other factors it will be able to appropriate some of the benefits of the innovation in the form of increased profits. Mansfield *et al.* (1977) relied on self-reported information from innovating firms to measure the profits that they attributed to the innovation each year. This appears to be the most promising route available.

It should be noted again that the relevant comparison that must be extracted from information provided by the firms refers not simply to the increase in profits following introduction of the innovation, but the difference between *actual* profits, and the profits that would have been earned in *counterfactual* state of the world in which the innovation had not been made, but all other conditions were as they actually are.

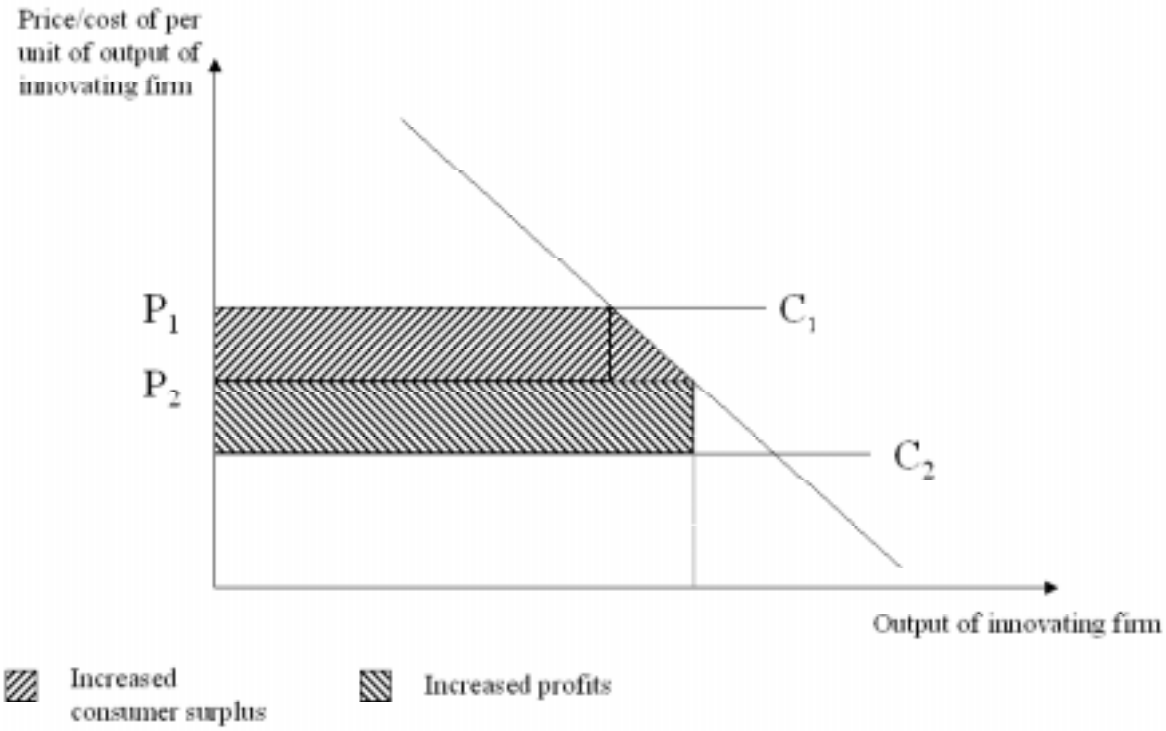
Market Spillovers

Market spillovers consist in increases in consumers surplus that occurs when an innovation lowers the price that consumers pay for a product. On the one hand, consumers who were already buying the product can now purchase the same quantity at lower prices. On the other hand, they and other consumers will be induced to purchase more of the product because its price has declined. The measurement of market spillovers can be illustrated with reference to Figure 2, which closely follows Mansfield *et al.* (1977, p. 232). Here we have assumed that the innovation is a process innovation, that the innovator uses to lower his or her costs of supplying a good or service. The argument for innovations that are sold or licensed to other producers or innovations that are directly used by consumers to lower their cost of carrying out an activity are conceptually quite similar (see Mansfield *et al.* 1977).

As a result of the lower cost of production due to the innovation the innovator's average cost curve shifts down from C1 to C2. Part of this reduction is passed on to consumers as a decrease in price from P1 to P2. The rest is captured as profits by the innovator. The reduction in price from P1 to P2,

causes a movement along the demand curve from Q1 to Q2. The increase in consumer surplus is equal to the shaded area (or (P1-P2)Q1(1+0.5Kn) where K = (P1-P2)/P1, and n is the price elasticity of demand). As is apparent measuring this quantity requires information about the elasticity of product demand along with information on consumption in the absence of the innovation and the size of the innovation's effect on prices. However, Mansfield *et al.* (1977, p. 226) found that K is

Figure 2: Private Benefits and Market Spillovers Resulting From a Cost Reducing Process Innovation



generally quite small, and that their results were not very sensitive to the value used to approximate n. Values of P and Q were obtained mainly through interviews with firms.

Against these positive market spillovers must be offset the lost profits of firms supplying competing products that lose sales as the result of an innovation. Mansfield *et al.* (1977) relied primarily on interviews with the affected firms to calculate the extent of these losses.

This approach assume that the qualities and characteristics of demanded goods remain constant. It seems likely, however, that many of the innovations flowing from ATP's DV program will not fit this pattern. Rather, DV innovations seem likely to give rise to new products or to enhance a variety of different quality dimensions of goods and services. Fortunately, Trajtenberg's (1989) Lancastrian

framework addresses this apparently more complicated situation

Note that significant qualitative and quantitative work has already been done on measuring demands for existing (Owen and Wildman, 1992; Owen, 1999) and future (Klein and Sherman, 1997; Cermak 1996) analog video and DV-related goods. This work can be used to supplement part of the measurement effort, and also will serve as a cross-check.

Knowledge Spillovers

Once an innovation has been introduced it is often possible for other firms to imitate it or use it at a nominal cost. The resulting transfer of knowledge is what is commonly referred to as a knowledge spillover. The increase in profits realized by other firms as a result is properly treated as part of the benefits produced by the innovation. Mansfield *et al.* (1977) relied primarily on interviews with the relevant firms to calculate the magnitude of these benefits.

Another potential approach is to use an event study to capture the potential effects of knowledge spillovers. If an innovation is likely to be readily imitated and this imitation is likely to increase profit opportunities for publicly traded companies, then this should be reflected in the price of the company's stock after knowledge of the innovation becomes public. Austin's (1996) study of the effect of biotechnology patents on stock prices explored the impact of patent grants not only on the firm receiving the patent but on other firms in the same industry. The focus of his investigation was on rivalry effects where more than one firm was doing research on a particular compound, but the methodology he uses could easily be extended to deal with knowledge spillovers.

Network Spillovers

Network spillovers occur because of interactions between different goods and services that cannot be readily internalized by any of the relevant economic agents. An example of a network spillover is the relationship between the development of new methods of capturing digital images and techniques for editing and reformatting them. Advances in one of these products enhances the value of the other to consumers and (other things equal) increases their demand for that product resulting in increased profits, and higher consumer surplus.

Methods of measuring the effects of network spillovers are identical to those discussed above in the context of private profits and market spillovers. The first step is to identify the classes of products which benefit from network spillovers and the producers who are responsible for these products. Once these have been identified the problem is simply one of measuring the increased profits and market spillovers attributable to these spillovers.

As in the case of knowledge spillovers, it may be possible to use event study methodologies to analyze stock data to extract additional information about network spillovers. One approach is to use these data to identify beneficiaries of network spillovers. This can be done by finding companies whose stock prices are positively influenced by announcements related to ATP funded DV

innovations. A second use of this approach is to measure the size of the resulting gains in stock prices, which can be used as a measure of the value of the network spillovers produced by ATP funded research.

Material Spillovers

Some innovations may generate social costs and benefits through their effects on the environment. Mansfield *et al.* (1977) found for example that one product they studied increased ground water pollution. Improvements in communications can have third party effects on quality of life; for example, passing motorists now sometimes report accidents by cell phone. A full accounting of spillovers requires that any such negative or positive impacts be accounted for. A priori, in the case of digital video such effects seem unlikely to be large. Interviews with industry experts is one approach for identifying any effects.

Fiscal Spillovers

Taxes, subsidies, and other government operations can be affected by ATP activities in two general ways:

- firms experience changes in benefits stemming from the sponsored R&D or the resulting innovations; these changes then lead to changes in taxes paid and subsidies or services received.
- changes in budgetary expenditures for ATP entail offsetting changes elsewhere in the federal fiscal balance. This is usually modeled as changes in taxes, but changes in non-tax revenues, federal debt, or expenditures for other programs are also possible.

Firm-level effects: Reports on previous studies have been largely silent about whether benefits are accounted for in a pre- or post-tax way. Presumably, however, increased profits have been measured after taxes. To the extent that federal, state and local governments benefit through increased tax payments, these tax revenue benefits also need to be accounted for. It would appear that this information is best gathered through interviews with the involved firms, where possible. For impacts that are more indirect, fiscal impact models would be needed.

Federal budgetary effects: it is necessary to make essentially untestable assumptions about the counterfactual source of ATP funds. That is, we have to choose at the outset what alternative government policy regime we want to compare the actual policy regime with.[9] Once that is done, there is no real alternative to some form of macro-modeling of the resulting budgetary effects. (At the most primitive, we might assume for example a macro-model in which ATP is funded by marginal tax increases that lead to equal marginal losses in real after-tax household income, with no multiplier effects and no dead-weight losses.)

[9] This statement generalizes a truism in general equilibrium tax incidence analysis which states that "absolute tax incidence" is not a meaningful concept; changes in taxes are necessarily offset by changes elsewhere in the fisc, and both sides of the budget affect the economy.

2.6. Selection and aggregation across impact channels

Concept and measurement

Economic impacts are empirically complicated and highly multi-dimensional. Consequently the results of impact studies are always condensed and abstracted, which is to say they are reported in highly selective and aggregated terms. Two very different aspects of reality are being abstracted: the economic consequences of interest to policy makers, versus the channels of causation that bring them about; i.e., the *what* versus the *why*.

Abstraction over economic consequences. The economic impacts that people care about cross a number of different dimensions. However, there are conventional approaches for abstracting each of these dimensions. Examples of these conventions are:

- welfare criterion: while many studies focus on jobs, tax revenues, or output by industry, economists conventionally prefer to focus on income (often generalized to account for price differences or consumption of non-market goods).
- distributional measure: most technology studies focus on simple aggregate income and ignore inequalities across households.
- efficiency measure: as a measure of income gained per income foregone, technology studies have traditionally focused on the internal rate of return (usually comparing the private rate of return to investors, with the social rate of return to all beneficiaries).[10]
- time: if data are available for multiple years, a discounted present value aggregate is commonly used.

While these conventions can certainly be challenged, modifying them does not seem to pose insurmountable technical challenges (see, e.g., Burress and Oslund, 1994, 1998). The important question, rather, consists mainly in determining which aggregates are of interest to policy-makers.

Abstraction over channels of causation. A much harder question for researchers is handling the complexity of the causal links leading from ATP interventions first to innovations, and then to economic impacts. In particular, researchers adopting a micro-economic approach will need to address problems identified in Burress *et al.* (1998), Burress *et al.* (1999), and Burress (1999):

- multiple innovations: for evaluating a entire program, or even a specific focus area, we need to look at the simultaneous effect of its full ensemble of projects and innovations. Because of

[10] However, it is well known in benefit-cost analysis that a better measure would be either a ratio of present-value benefits to present-value costs, or else a net present value of income (Boadway and Wildasin, 1984, p 192-193). The internal rate of return sometime gives a perverse ranking of outcomes, especially in cases where the sign of the flow of benefits changes over time. Also, it ignores (or is inconsistent with) the value judgements expressed by the social discount rate.

synergy and momentum the impact of the ensemble need not equal the sum of the individual impacts. There may be other kinds of constructive or destructive interference between project outcomes as well. Moreover, a very large number of DV innovations are possible in the future, many of which could potentially be affected by network or knowledge spillovers from a DV innovation under study.

- multiple markets: at a reasonable level of disaggregation, a large number of different markets will potentially be affected by DV innovations.
- multiple spillover types: as noted previously, there are a very large number of potential configurations of spillovers within any given set of innovations and markets.
- multiple contact points with the larger economy: a given innovation has several different kinds of effects on the national economy - not only changes in production and consumption patterns within the economy, but also changes in imports and exports, and gross savings and investment.
- multidimensional probability space: if we model the counterfactual using a probability distribution, and if joint probabilities are assigned to innovations, spillovers, points in time, etc., then we must integrate over the probability space to find expected values or variances for the estimated impacts.

Simply keeping track of all of this complexity while adding up economic effects is a major task. Previous empirical research in technology assessment has provided very little guidance. Our two previous reports provided descriptions of possible DV markets, technologies, and innovations, and also proposed methods for:

- counting spillovers and contact points,
- aggregating over causal channels using a CGE model, and
- integrating over probability space using a Monte Carlo model.

Counting spillovers and contact points

Most studies of spillovers have focused either on market spillovers or on knowledge spillovers. Jaffe (1996) states "I can think of no study that, at the conceptual level, is designed to capture both..." Moreover, very little attention has been paid to network, fiscal, or material spillovers. Clearly we are very far from having a *comprehensive* measure of the spillovers of any particular innovation. Burress *et al*. (1999) and Burress (1999) make an initial step by proposing theoretical and technical definitions of spillovers showing how various spillovers and contact points can be accounted for and aggregated. Those concepts are not reviewed here in full detail, but will be used in our research.

General equilibrium modeling

The value of a spillover has commonly been estimated using a partial equilibrium, consumers surplus approach. Unfortunately, when partial equilibrium techniques are applied to multiple, simultaneous markets, there is an inherent double counting problem, because consumers surplus is a summary measure of change in all other markets. The natural way to avoid double counting in a situation with multiple markets is to use a multi-sectoral general equilibrium model.

Burress *et al*. (1999) shows how one can embed the study of spillovers within a multisectoral Computational General Equilibrium (CGE) model. It conceptualizes each benefit or spillover as affecting either:

- the production or input demand function in a particular sector (i.e. by changing input patterns and output cost structures); or
- the demand or utility function of the household (usually by adding a new good to the demand set.)

The complete set of demands is solved for an equilibrium, subject to resource constraints and market structures (e.g., competitive or monopolistically competitive). The model is solved both with and without the new innovations. The most significant output of the model consists in net changes in household utility, denominated in real present value terms.

Advantages. The CGE approach provides a unified method for managing five problems:

- double counting of impacts when multiple pathways affect the same activity;
- displacement and offsets, e.g., losses experienced by competing forms of entertainment;
- aggregation of impacts from multiple pathways (innovations, spillovers, contact points)
- approximation errors that are inherent in partial equilibrium methods, e.g., from use of consumers and producers surplus; and
- indirect or multiplier effects in the macroeconomy.

One previous study (Consad, 1997, 1998; Robles, 1996) used the REMI model -- a multisectoral CGE model generally used under assumptions of a slack economy -- to estimate total effects of particular ATP projects. The study focused solely on effects of a shift in the domestic share of demand for automobiles (in response to a relative quality improvement), and consequently did not address the first three problems listed above.

Focus on demand functions. The focus on demand functions is merely a way of representing the economy and is *not* a limitation of the CGE approach. In technical terms, the CGE model expresses all possible direct impacts purely as changes in conditional input demand functions in each sector (including household and non-profit sectors). In a partial equilibrium setting, such an approach would be incomplete because it would omit changes in supply functions, and especially changes in productivity. (The accounting framework could be completed, for example, by including producers surplus as well as consumers surplus in the analysis.) In a general-equilibrium setting, that is not the case. That is, under usual assumptions the complete set of demand functions for a given actor *completely describes* the production or consumption behavior of that actor, including any changes in productivity (see, e.g., Chambers 1988, p. 131. This is sometimes referred to as "integrability", meaning that the production function and the cost function can be recovered, or "integrated", from the demand functions.) For example, any increase in productivity is expressed as a reduction in the total value of inputs demanded per unit of output.

Measuring demand functions. Data for measuring changes in input demands of firms can come partly from interviews, and partly from published information sources. Data on changes of input demands for households should come ultimately from surveys of households.

Monte Carlo modeling

We are not aware of any impact study based on a complex probabilistic counterfactual -- i.e., one that presented a non-trivial problem in integrating over probabilities. However, empirical probability models that would be analytically intractable are often solved in other areas of economics as well as many other fields using Monte Carlo methods (see e.g., Cragg, 1987, 1990; Hammersley and Handscomb, 1964). In other words, we calculate "draws" of a pseudo-random vector that approximates the probability distribution of the underlying variables of the model; calculate the model for each draw of the random vector; and average the model outcomes over the draws. Such an approach could handle complex counterfactuals under very general conditions.

2.7. Macro-oriented approaches

Above we have concentrated on bottom-up measurements of specific categories of benefits from technological innovations. There is a distinct strand of literature that approaches the problem from a top-down or macroeconomic perspective.

Social savings

One approach was pioneered by Robert Fogel (1964) in his examination of the *social savings* produced by the railroad in the nineteenth-century United States. In his work, Fogel sought to compare the actual resource expenditure on transportation in the U.S. economy in 1890 to that in a counterfactual world in which there were no railroads. The difference in costs between the actual situation and a hypothetical world in which all goods were obliged to travel by water or wagon was what Fogel termed the social saving attributable to the railroad. Because Fogel's goal was to argue that this saving was relatively small he sought to ensure that his estimates would be an upper bound of the actual savings by assuming that the demand for transportation services was perfectly inelastic with respect to its price. He did, however, also offer his own conjectures about a more plausible level of demand.

Fogel's work has been widely discussed among economic historians. Much of this literature is reviewed in Fogel (1979)), making it unnecessary to address the methodological difficulties inherent in this approach in detail. Among the most nettlesome of these issues, however, is the problem of developing an appropriate measure of the counterfactual cost of replacing railroad transportation services with other modes of transportation. Fogel used actual prevailing water rates, but his critics have correctly pointed out that there is good reason to believe that water rates would have been quite different had canal and river routes not faced competition from the railroad.

From our perspective there are important features of the social saving approach that make it unattractive as a framework for studying the economic impact of ATP's DV focused program.

Large-scale aggregation. Fogel's approach bundled together all of the technological, social, and organizational changes embodied by the railroad as a single, discrete innovation. Because ATP funded projects are only a fraction of all research on digital video technologies, such an approach would make it difficult or impossible to disentangle the contribution of ATP funded projects from those not funded by ATP.

Unfocused counterfactual. Like the more micro-oriented approaches reviewed above, measurements of social saving are only as good as the counterfactual model against which the actual situation is compared. In the context of a bundle of technologies such as the railroad the limited number of possible alternatives makes aggregation an attractive strategy. But for the diverse array of technologies associated with digital video, counterfactual models will need to be constructed at a relatively disaggregated level in any event, so there is likely to be little or no benefit from aggregation. Von Tunzelman's (1978) discussion of the social savings attributable to steam engines makes clear the scope of the difficulties of posing a plausible counterfactual where innovations are incremental and interrelated. In this case, social savings calculations are relatively sensitive to precisely which technologies are assumed to have been developed and which ones are assumed not to have been available.

Growth accounting

Daniel Sichel's (1997) examination of the impact of computers on the U.S. economy offers another, rather different aggregative approach. Sichel modifies the conventional growth accounting framework by separating out the contribution of computer capital to output growth from the contribution of other forms of investment. That is, Sichel (1997, p. 76) specifies that output growth is equal to the sum of:

- neoclassical contribution of growth in computer capital;
- neoclassical contribution of growth in the stock of all other capital;
- neoclassical contribution of labor growth;
- multifactor productivity growth.

In this framework the problem then becomes one of measuring the growth of computer capital, and the marginal productivity of additions to the stock of computer capital. As a first approximation he assumes (as would be true in a competitive market equilibrium) that the rate of return–and hence marginal productivity–of computer capital is identical to that of other conventional forms of capital

To the extent, however, that markets are in disequilibrium or economic actors have failed to accurately predict the course of technological developments the latter assumption may be in error. Sichel recognizes this and argues that an upper bound on the range of this error is provided by the contribution of total factor productivity growth–which is measured as the residual growth not

explained by growth of conventional inputs or computer capital.

Given the much smaller size of digital video technologies within the U.S. economy, this sort of approach seems unlikely to be useful here. It seems unlikely that we could obtain a meaningful measurement of DV's contributions to the economy in this framework, because the residual term would dwarf the normal returns to DV investment. Moreover, as we noted earlier in discussing the social savings approach, Sichel's methodology provides no mechanism to disentangle the contributions due to ATP-funded versus non-ATP-funded research.

2.8. A summing up

We have argued that macro or top-down approaches are not well suited to assessing the impacts of relatively disaggregated areas of technology such as DV. However, the micro or building-up approaches do not lack problems of their own. We have identified a number issues that may be especially problematical, or else have not yet been addressed in the micro-oriented literature:

- Subjectivity of data on attribution. To establish causal links between government intervention and innovations, most studies have relied on interviews that are simply taken at face value.
- Absence of ensemble effects. There have no attempts we are aware of to measure the "synergy" or "momentum" effects of a portfolio of technology interventions.
- Lack of comprehensiveness. Previous studies have focused on particular types of spillovers, rather than trying to examine all major spillovers simultaneously. Some studies have considered first-round displacement of investment (i.e. within the same firm), but not much attention has been paid to more complex types of displacement. Studies have focused on particular contact points with the larger economy (especially changes in domestic demand and investment displacement) but have not considered them simultaneously with aggregate savings or international trade.
- No valuation of changes in technology implementation. We have not seen research that measured economic impact of government intervention that caused qualitative changes in technology.
- Naive aggregation. Most studies have used a partial equilibrium framework, which is ill-suited for adding up impacts across multiple spillovers, markets, and innovations.
- Naive counterfactuals. No studies have developed explicit descriptions of complex counterfactuals that would be needed to handle features such as:
  - uncertainty about the timing of the second-best alternative project
  - degrees of attribution other than 0% or 100%
  - interference between different spillover paths.

The research program proposed in Chapter 3 would attempt to make significant progress on each of these issues. Given a relative scarcity of research dollars, and given differences in the tractability of the various issues, we expect that progress to be uneven. Nevertheless we believe that worthwhile improvements can be made that address each of these issues.

3. PROPOSED METHODS AND MODELS

3.1. Introduction

This chapter explains and justifies the specific methods we propose for measuring the economic impact of ATP's DV focused program. Any specific measurement method reflects a trade-off between the desire for accuracy in the resulting measurements and the cost of producing them. In chapter 2 we articulated the issues involved in measuring the economic impacts of ATP's DV focused program, and reviewed the existing literature relevant to each of these issues. This chapter synthesizes this material and proposes new approaches.

The next section of this chapter discusses our criteria for research design. The following three sections describe the specific methods we propose, taking in turn the three points of view:

- measurement of attribution,
- measurement of spillovers, and
- aggregation of impact channels.

The final section of the chapter discusses methods that have been considered but are *not* being proposed because they are viewed as redundant, impractical, or not cost effective.

In most cases a given research activity has implications for more than one of these points of view, and also requires data from multiple sources. The following chapters will describe the data sources, and itemize and define in more detail the particular research activities -- i.e. types of modeling, data collection and analysis -- that will be necessary to implement these methods.

3.2. Issues in research design

Proposing a comprehensive program to study impacts of DV technology entails a complex problem in research design. Some of the problems are:

- Measuring ATP's effects and the impacts of a major technology will entail error bands that are likely to be both large and unknown. Or making the same point in terms of the rhetoric of evaluation, impact study results face substantial scepticism which must be persuasively overcome.
- Many different measurement methods are possible. There is great variation in the cost of different techniques. Error bands probably tend to decline as cost increases.
- There are a large number of markets and pathways of influence. Each pair of (market, pathway of influence) poses a logically separate research problem. In general, different measurement methods are optimal for different pathways or markets.
- ATP funds for this study are limited in relation to the size of the task. In order to optimize the

research plan, it is necessary to make judgements about the available trade-offs between cost and accuracy of measurement methods.

Thus, we believe the single hardest design problem in this research lies, not in identifying specific research topics and measurement methods, but rather in covering a large number of detailed research topics at a reasonable cost. We plan to concentrate relatively more resources on impact pathways and issues where:

- effects on measured impacts are expected to be large,
- threats to credibility of the results are high,
- existing published data is more limited, and
- effects are more direct and more short-term.

In most respects, the approach we propose could be described as an elaboration of the Mansfield format described in Chapter 2. That is, most of the raw data for measuring attribution, profits, and direct spillovers will be derived from interviews with affected business people and consumers. We will supplement that data with event study data, and we will use more sophisticated analysis includes estimation of a Lancastrian demand function and a CGE model.

3.3. Proposed methods for measuring attribution

To assess the contribution of ATP support to the economic benefits generated by each technology it is necessary to measure the amount by which completion of the project was accelerated as a result of ATP funding, whether its national location was shifted, and any qualitative effects on the technology developed. The actual timing and location of the innovation along with its characteristics are directly observable, so the problem is one of estimating the difference between the *actual* state of the world and a *counterfactual* state in which the project did not receive ATP support.

Overview of attribution measurement

Interview and survey research reviewed in Chapter 2 amply established that recipients of ATP funding generally credit ATP intervention for initiating their R&D project and/or accelerating its technical or commercial success. We propose to rely substantially on similar interview data, using two sources:

- data from ATP's Business Reporting System
- interviews with recipients of ATP funding

Addressing criticisms. However, research of this kind has been criticized on three significant grounds:

- it may be subject to reporting bias -- e.g., funding recipients may report what they think ATP wants to hear
- it is uncontrolled -- i.e. it reports expert opinion rather than statistical analysis implying causation

- it is based on the wrong counterfactual -- i.e. ignores the possibility that some other project might have developed the same innovation.

We believe that these criticisms constitute the most serious threat to the credibility of the impact study. We will address these criticisms using a combination of five approaches. Most of the approaches are new, and as far as we are aware none has previously been applied to measuring attribution for ATP.

- Two of these approaches are directed to the question of reporting bias, and are intended to test or improve the internal consistency of opinions expressed by funding recipients:
  - qualitative modeling of barriers
  - axiomatic modeling of probability distributions in the counterfactual world.
- One approach taps data sources that may be less biased, or at least have different biases:
  - interviews on counterfactual outcomes with other actors in the marketplace.
- One approach addresses the need for statistical analysis and is embedded within a measurement of spillovers:
  - an event study of the effects of DV announcements on market values of DV-related firms.
- One approach looks for quasi-experimental controls:
  - interview workers on non-ATP-funded projects within firms funded by the DV focus area.

<u>Exploring new issues in attribution.</u>

In addition, we will explore three new issues concerning attribution:

- attribution for qualitative changes in characteristics of an innovation will be examined using interview data
- attribution will be modeled using rigorously probabilistic counterfactuals
- "second order" attribution will be modeled by assuming independence between the probability that ATP caused an initial innovation, and the probability that an initial innovation caused a second innovation.

Measuring attribution for the initial R&D project

To measure the acceleration of R&D, any change in its national location, or qualitative differences in resulting innovations we will rely on information provided by recipients of ATP funding through ATP's Business Reporting System, which regularly surveys ATP funding recipients about the progress of their research. We will supplement data from these surveys with information obtained from telephone interviews with ATP funding recipients which will help to clarify issues relating to the impact of ATP funding on time to completion, as well as helping to identify any qualitative impacts on the nature of the technologies developed. In some cases telephone interviews may be supplemented with on-site visits.

Measuring attribution for knowledge spillovers

Knowledge spillovers resulting from ATP-funded research projects will be identified through interviews with ATP funding recipients and through telephone interviews with industry experts. To the extent that ATP funding has altered the timing, location, or qualitative nature of the resulting innovation it will similarly affect the nature of the resulting knowledge spillovers. Telephone interviews with affected firms will be used to assess the extent of these effects.

Modeling attribution as barriers overcome

To evaluate the consistency of attribution reports, we will build a qualitative model of barriers to investment, starting from Jaffe (1996, 1998) and Tassey (1999). Barriers are of two types: spillover and non-spillover. Jaffe groups the factors that affect spillovers by their effect on four major variables that affect the incentive to invest in R&D:

- is the innovation protectable?
- is US licensing likely?
- are positive US spillovers likely for other reasons?
- is commercial success likely?

In addition, Tassey identifies a number of non-spillover factors arising because of risks arising because of adverse macroeconomic conditions, or technological uncertainties.

Appendix 1 sketches a qualitative model based on these ideas. In particular, we classify each of these factors by more detailed major variables. Qualitative data on the presence or intensity for each factor can be gathered in the course of interviews with researchers. If ATP intervention shifted the decision to invest in R&D, then the interviews should show that the intervention was perceived to have shifted the balance of factors affecting one or more major variables.

Measuring and modeling the counterfactual world

We need two very important kinds of information about the counterfactual world:

- what is the probability distribution of times at which various events would have been likely to occur, in the absence of ATP intervention? The key events include:
  - initiation of an R&D project for the innovation
  - technical success for the innovation
  - commercial success for the innovation
  - commercial replacement of the innovation with a subsequent innovation
- what is the probability distribution of economic outcomes that would have been likely to occur, in the absence of ATP intervention? The key outcomes for a given firm include:
  - profits
  - sales

- wages and payroll.

In addition, it is desirable to obtain information on other characteristics of the counterfactual:

- possible differences in qualitative characteristics of the innovation as implemented
- possible differences in national location
- possible differences in synergy or momentum across innovations.

In each case, we are faced with a problem of eliciting hypothetical distributional information from interviewees. As noted previously, this kind of information is vector rather than scalar in nature, and is gathered using common language rather than precise functional forms. Consequently it is hard to impose internal consistency on interpretations of the interview data. We will develop extensions of the model used in Burress and Oslund (1994; documented in Burress, 1992) so as to set up interview questions in terms that lead to axiomatic consistency.

Measuring qualitative changes in the innovation

Qualitative changes in the innovation either improve its performance or broaden the scope of applications for which it is relevant. These effects will in turn be manifested in increased economic benefits–greater market spillovers, more extensive knowledge or network spillovers–which will be captured in the measurements described below. Information about the nature of qualitative changes obtained through interviews with ATP-funded firms will provide the basis for assessing the extent to which these types of economic benefits should be attributed to ATP funding.

3.4. Proposed methods for measuring profits and spillovers

Overview of benefit measurement

We will sample all ATP-funded DV projects for which project personnel are willing to cooperate. If possible, we will form an additional sample of non-funded projects taking place simultaneously in funded firms.

We will gather data about sampled projects as well as related innovations from several sources:

- telephone and mail interviews with project personnel
- telephone and mail interviews with industry experts and personnel in affected firms (including competitors, suppliers, customers, and producers of complementary goods)
- published data and information, such as patent applications and scholarly publications
- if feasible, teleconference with industry experts
- event study
- consumer focus groups
- survey of consumers

Measurement of private profits

To measure the increase in private profits that each innovation produces it is necessary to compare actual profits with *counterfactual* profits in the absence of the innovation. That is, it is not appropriate to use historical profit levels. Rather profits in the counterfactual case must be estimated on the assumption that ATP did not fund the specific R&D project, but all other relevant conditions were identical to their actual state.

The gain in profits for innovating firms must, however, be reduced by the amount of lost profits of other competing firms (a market spillover). We propose to use two approaches to measure the impact of each innovation on profits.

Interviews. The first approach relies on interviews with the recipients of ATP funding. Each firm will be asked to estimate the increment to its profits that has resulted from the innovation. Firms will also be asked to identify major competitors, and we will conduct interviews with these firms to assess the impact on their profits attributable to each innovation

Event study. The second approach, which we will use for publicly traded companies, relies on financial markets to provide an independent assessment of the value of an innovation. In this approach we will examine the change in the value of stock associated with announcements related to the development of the technology. After controlling for other factors like general movements in equity prices in the period in question, and any other events affecting the company, the change in stock market equity should provide an unbiased estimate of the net present value of future earnings flows that are likely to be generated by the innovation.

Measurement of Market Spillovers of Individual Projects

The measurement of market spillovers requires estimating the increase in consumer surplus that results from a drop in prices or improvement in quality of products that either directly or indirectly embody each of the innovations funded by ATP. As discussed in Chapter 2, the approach to measuring these benefits will depend on the nature of the benefits that each innovation produces.

In the first case, where innovations are strictly cost reducing, the problem can be reduced, in effect, to one of measuring the difference in area under the consumer demand curve for the product in question under the actual state of the world and under a counterfactual case in which the innovation did not exist. Measurement of this quantity requires information about the difference in prices and quantities between the actual and counterfactual cases as well as an estimate of the price elasticity of demand for the product.

In the second case, where innovations take the form of improvement in one or more dimensions of product quality along with changes in product prices, as is likely to be the case for many DV related technologies, it is necessary to adopt a somewhat more complicated approach. As Trajtenberg (1987)

has shown, however, it is straightforward to reconstruct gains in consumer surplus in this context within a discrete choice random utility framework.

Data for innovations that conform to the first case can be obtained from interviews with the recipients of ATP funds and–where innovations are embodied in producer goods used by other firms to produce consumer products–their customers.

Application of the discrete choice approach developed by Trajtenberg will require information from suppliers to characterize the range of available products in terms of their performance along relevant quality dimensions and prices, as well as survey data from consumers about which specific goods and/or services they have purchased.

Measurement of Network and Knowledge Spillovers

As the discussion of these topics in Chapter 2 made clear, the literature on the measurement of network and knowledge spillovers is thin and incomplete. We propose to use several distinct approaches to identify the scope and magnitude of theses spillovers.

Interviews with primary researchers. First, following Mansfield, et al (1977) we will use telephone interviews with ATP recipients to identify imitators benefitting from knowledge spillovers, as well as the producers of complementary products who may have benefitted from network spillovers. These firms will then be interviewed to obtain their estimates of the resulting profits.

Event study. Second, we will conduct an event study using stock market data to assess the size and scope of knowledge and network spillovers associated with DV innovations. We will begin by identifying a class of DV related technology announcements, and then explore their impact on other publicly traded firms. On this basis we can identify three classes of firms–those whose value is unrelated to DV technology developments, those who are beneficiaries of DV technology developments, and those who are negatively affected by DV technology developments. We will then use the changes in stock values of the firms in the latter two groups relative to those of the firm making the DV innovation to construct a measure of the ratio of spillover benefits–the increase in value of firms other than the one making the DV announcement – to private benefits–i.e., those captured by the innovating firm. We can then apply this ratio to inflate the measures of private profits for each innovation to account for network and knowledge spillovers.

Interviews and possible teleconference of experts. Information gathered through a structured dialogue with and between industry experts provides another method of identifying network and knowledge spillovers resulting from ATP funded research projects. Industry experts will be provided with information about ATP funded projects and asked to identify actual and potential influences of this research on other areas of economic activity.

Measurement of material spillovers

Environmental issues related to DV technologies are likely to be a relatively small component of economic impacts and we do not propose to conduct a systematic examination of them. We will rely primarily on interviews with ATP funding recipients to identify any potential effects, and will base estimates of the resulting material spillovers on these interviews possibly supplemented by additional information obtained through interviews with environmental scientists.

Measurement of fiscal spillovers

Information on the direct fiscal spillovers generated by each innovation will be obtained as part of the interviews with ATP funding recipients along with any follow-up interviews with their customers. Indirect fiscal spillovers will be calculated using the CGE model described below.

Valuation of qualitative changes in the innovation

Assuming we can identify any differences between an innovation as implemented, and its characteristics in a counterfactual world without ATP intervention, then we still need to place dollar values on those differences. Most likely, any such differences will have to do with quality of the innovation for intermediate use as an input to production, rather than for final use by consumers. We will explore two approaches:

Expert opinion: industry experts may be able to cast light on any changes in costs of production resulting from the difference.

Analogical modeling: we may be able to identify actual examples of qualitative improvements in technology that appear similar in nature and utility to the improvement in the innovation under study.

However, even ignoring the uncertain nature of the assumed counterfactual, estimates from these sources might be valid only to within an order of magnitude.

3.5. Proposed methods for aggregation

Overview of aggregation

The problem of aggregation is to add up the effects of different innovations and different spillovers over various time periods and markets, attempting to capture as many different channels of influence as possible, accounting for interference and multiplier effects while avoiding double counting, at the same time (ideally) taking into account the probabilistic nature of the counterfactual world.

As shown in Chapter 2, previous micro-based studies of technology impacts have generally focused on a single innovation, a small number of spillover channels, and a deterministic attribution model

under partial equilibrium assumptions. When effects across multiple markets were aggregated, rules of thumb and informal analysis was used to avoid double counting, and interference and multiplier effects were generally ignored.

We will adopt two approaches:

Partial equilibrium: a traditional consumers and producers surplus approach, using relatively naive rules of thumb for aggregating over substantial numbers of markets, spillovers, and innovations.

General equilibrium: a new "meso-economic" approach that uses a CGE model to aggregate over markets, spillovers, and innovations. In addition we will use a Monte Carlo model to aggregate over states of the counterfactual world.

Our main focus is on the second approach.

Sampling spillovers and affected industries

Because the number of affected industries appears to be large, we do not propose to study every spillover to every industry in detail. Instead, we will select a sample of spillovers and affected firms for more detailed study, and use qualitative and quantitative stratification to extrapolate effects from firms studied in detail to other firms and industries.

Sampling spillovers. We will form a list of all spillovers identified or predicted by interviewees either for individual innovations or for the ensemble of DV innovation affected by ATP funding. We will categorize each spillover on the list as "large" or "small" based on judgements of interviewees. ("Large" is defined rather arbitrarily as having a potential present value of $10 million.) We will study all "large spillovers" and up to 2 "small" spillovers for each sampled pair of (innovation, affected firm).

Sampling firms. For each innovation we will form a list of all firms identified as being affected by a spillover. If possible, we will find estimates of output by each firm of goods affected by the innovation. During Task 5 we will sample approximately 10 affected firms, with an approximately equal number of firms for each innovation under study. (In some cases multiple innovations will affect the same firm.) To the extent that affected firms can be categorized into unique product sectors, we will select firms associated with a wide variety of products. During subsequent Tasks we will revisit some firms studied previously, but also add new firms to the sample. If output estimates are available, we will select a given firm with probability proportional to its output. Otherwise, we will use a straight probability sample. If a firm refuses to participate in the study, we will draw a replacement sample.

Projecting to the population of firms. We will assume that firms not sampled are similar to firms that were sampled for the same innovation and affected product (assuming constant returns to scale). To estimate sampling variation, we will use the bootstrap method.

Special data requirements of the CGE approach

While much of the required spillover data is the same for the two approaches, the CGE approach has more extensive data requirements. In particular, it is necessary to estimate complete input demand functions rather than simple partial equilibrium demand curves. The questions used in surveys and interviews will be constructed accordingly.

We will use this data to estimate input demand functions for goods directly affected by the sampled projects, both with and without any innovations.

Aggregation over spillovers, sectors, and time

Using a combination of interview data and published data, we will build models of the actual and counterfactual worlds. The counterfactual world contains two parts:

- "bridge" models that link the sampled markets into sectors of the CGE model.
- attribution models, as described in Section 3.3.

We will estimate and calibrate the CGE model proposed in Burress *et al.* (1999). We will solve the model for the actual and counterfactual worlds.

Using all of these models we will estimate the state of the economy for each year covered in the study, both with and without ATP intervention. The vector of differences between the two worlds is an estimate of the economic impact of ATP intervention in the digital video market. This data will be used to estimate the net social value of the ATP intervention in present value terms, given a particular counterfactual world.

Aggregation over probability states of the world

Monte Carlo modeling: In most general terms, any counterfactual world can be described by a probability distribution. For example, in the absence of ATP intervention, there may be separate probabilities that:

- a given innovation "i" would have occurred in year "t" and nation "n"
- a given innovation "i" would have had quality characteristics "q"
- assuming it was influenced by "i" in the actual world, in the absence of "i" in the counterfactual world a given innovation "j" would have occurred in the year "t" and nation "n"

(for each i, j, t, q, and n), and so on. Modeling such a probability space is a reasonably straight-forward task. Parametrizing the space is less straight-forward but feasible (using for example

sophisticated interview data). A general algorithm for integrating over this space is:[11]

Solve (and benchmark) the CGE model corresponding to the actual world.
Repeat:
  select a random counterfactual (e.g., use pseudo-random numbers to select years for each innovation under the given probability distribution)
  solve the CGE model for that counterfactual world
  calculate each impact variable (e.g., income impact) as a difference between its actual and counterfactual value
Until: we have a "large enough" sample of impacts.
Calculate the mean and variance of the sample.

For example, a sample of 100 impacts would require solving the CGE model 101 times. A major benefit of the Monte Carlo approach is that an uncertainty measure (the variance of the sample) is as easily calculated as the impact estimate (the mean of the sample).

3.6. Summary and status of models

Table 3.1 lists the major models that will be used in the project, and provides a citation to the available sketch, summary, or specification that is most complete at this time.

[11] This algorithm is known to be inefficient when the impact variable has a dispersed or skewed distribution. This can be handled by stratifying the probability space, as in Halton and Zeidman (1969).

Table 3.1
Status of Models

Brief Description of Model	Citation	Contents of citation
Econometric models		
Consumer demand model	Section 3.4	summary description
Event study model	Appendix 2	preliminary specification
Bibliometric influence model of relationships of DV firms	Section 3.4	summary description
Data models		
Qualitative model for the R&D decision and attribution	Appendix 1	preliminary specification
Axiomatic model of interview information on probability distributions	Burress (1992)	theoretical specification
Data model for CGE parameters	Unpublished work by Burress and Oslund, referenced in Burress and Oslund (1997)	spreadsheet implementation
Accounting system for spillovers and impact pathways	Burress *et al.* (1999), Chapters 3 and 4	theoretical specification
Computational models		
Actual and counterfactual worlds at the micro level (for each year under study)	Section 3.5	summary description
CGE model	Burress *et al.* (1999), Chapter 2 and Appendix 1	theoretical specification
Monte Carlo aggregation model	Section 3.5	sketch

3.7. Methods not used

In this section we list some selected additional methods we believe to have significant merit, but which for various reasons we are not proposing.

Other approaches to attribution

- true experimental methods.
- constructing a comparison group of projects not funded or affected by ATP
- constructing a comparison group of projects that applied for ATP funding but were rejected.

True experimental methods are outside the scope of the contract. A control group of projects not touched by ATP would be helpful if a reasonably large sample size could be obtained, but the cost would be high and samples would be less comparable than the proposed use of control projects within ATP-funded firms. Since data on applicants are confidential, collecting a control group of rejected applicants assumes they could be identified from independent sources and would be willing to participate.

Other approaches to measuring spillovers

- perform full impact study for selected R&D projects that are spinoffs or were influenced by knowledge spillovers from the projects funded by ATP.
- surveys of a sample of all DV-using businesses, especially on knowledge and network spillovers

broadbased sampling for knowledge and network spillovers is premature until ATP-funded innovations are commercialized. The same goes for studies of R&D projects affected by spillovers. We may reconsider these methods during a subsequent Task.

Other approaches to aggregation

- Macroeconomic approaches

Macro-based studies have generally assumed that the aggregate of all effects is implicit in the macroeconomic data, and the problem is to infer the share of income, output or productivity that is caused by an aggregated technology (consisting of many interrelated innovations). The inference is generally based on upper bound arguments rather than a detailed tracking of causality. In this case, the upper bound would include too much non-ATP funded DV to be meaningful. There may be some merit in performing a lower bound study which assumes that R&D and commercialization investments receive average market returns, but that will not be feasible until after commercialization takes place.

4. DATA REVIEW

4.1. Introduction

Chapters 2 and 3 discussed in a general sense the types of data needed for an impact analysis. This chapter discusses data needs more specifically, and provides an overview of the specific data that satisfy those needs.

Data collection will be guided by answers to six key questions:

- What data are necessary to support the economic impact models? In some cases, sub-models (bridge models in the language of Chapter 3) can transform available data into the data items required by the main impact models. So we really need to ask what is necessary to support the impact models either directly or indirectly.
- What types of data are or might be available?
- How do we find data relevant to digital video?
- Is it possible to generate the model results from pre-existing data, or is it necessary to generate original data?
- How volatile are the data that support the models? Do the data need to be collected immediately, or will it be possible to go back and collect historical data at some later time?
- Once it has been decided to capture a data item, how can it be archived so that it is easily available for the impact analysis?

We discuss each of these issues in turn.

4.2. What types of data are necessary?

As discussed in Chapter 3, the modeling impact of ATP funding requires modeling of attribution, measurement of benefits to consumers and other end-users of DV products, and aggregation of results into a consistent framework. Attribution requires us to be able to say what share of a development is due to ATP intervention. Measurement of benefits requires us to estimate demand curves for digital video products; which at a minimum requires price and quantity information. Aggregation requires us to estimate parameters of a model of an economic system in which digital video forms a sector or sectors.

Appendix 3 summarizes the detailed data items needed to accomplish these tasks.

4.3. Data originality: primary, secondary, and tertiary

Data sources can be placed in three distinct categories according to their originality: primary, secondary, and tertiary. We will use somewhat specialized meanings for these term in this report.

Primary data

These are data items that we collect ourselves through interview and survey methods. Primary data will be designed to exactly fulfill particular needs of various models. Protocols for the collection of primary data will be developed and tested in Task 4 of this project. Primary data are expensive and time-consuming to collect; therefore, we will rely on primary data only when pre-existing data fail to meet the needs of the models.

Secondary data

These are data that come from three main published data sources:

- government agencies
- industry and trade groups
- private consulting firms.

Sometimes the ultimate origin of the data is administrative records, sometimes it is surveys and other reports required by government agencies, and sometimes it voluntary surveys of firms and consumers.

Tertiary data

These are data that result from parameter estimates from someone else's model. In a limited sense, almost all secondary data are the result of models. Usually the models are statistical: data are aggregated, missing data are "filled," inconsistent data are cleaned, etc. Tertiary data undergo much more drastic transformations from their original sources. Tertiary economic data most commonly take the form of regression coefficients in models of economic behavior. For this study, the most important tertiary data will estimates of demand elasticities for US sectors.

4.4. Published versus original data

Published data from a variety of sources will be essential in all of the models. For example, secondary data will be used to help estimate prices and quantities of digital video goods, to calibrate the general equilibrium model, and to look at relationships of innovating firms to other related firms (in the event study). Furthermore, secondary data may be used to put wide limits on the size of a market (for example, movies made with digital video animation technology will not exceed the size of the movie industry as a whole).

But however useful secondary data are, none of the models (with the exceptions for the event study and the bibliometric study) can be estimated using published data alone. There are several reasons:

- Published data, especially data from the federal government, are generally aggregated by industry or commodity. Examples are data from the economic censuses and import-export data. But

digital video is not a commodity-it is a set of technologies that cut across many products and industries.

- Even non-aggregated "micro" data are generally organized by firm, not by research project.
- Limited data (generally from industry groups and consulting firms) on HDTV and selected other digital video goods are available; these data are generally in the form of price and aggregate quantity time series. However the data are usually not sufficient to calculate a "demand function" for a digital video good because other key variables on which the projections may be based (income, availability of programming) are not included in the data provided. Also, household-level data would be preferred for estimating household demands functions.
- The underlying survey data on which many industry-consulting group projections are made are generally not made available.
- Lists of firms that are affected by particular technologies are not published by any agency or trade group.
- Even the event study approach, the approach most reliant on published data, relies in some of its versions on a predefined list of firms judged likely to be affected.

4.5. Locating relevant published data sources

We have conducted an extensive search for secondary data relevant to digital video. The search has centered on two types of sources: government agencies and proprietary sources (consulting firms and industry groups).

The search for government agency sources was fairly straightforward. We compiled a list of the general types of data we desired, and checked the "usual suspects" to find out if and in how much detail data were available. Key data from government sources that we will for the study include:

- *1992 Benchmark I-O Table Six-Digit Transactions.*(U.S. Bureau of Economic Analysis (BEA)) (Provides benchmark coefficients for the CGE model. We will use more recent data if they become available).
- *Shipments of Manufacturing Industries.* (U.S. Bureau of Economic Analysis) (Allows updates of transaction flows in the CGE model for sectors other than DV).
- *Gross Domestic Product by Industry.* (U.S. Bureau of Economic Analysis) (Allows updates of transaction flows in the CGE model for sectors other than DV).
- *Foreign Trade Statistics.* (U.S. Bureau of the Census, http://www.census.gov/foreign-trade/www) (Allows division of demand between foreign and domestic).
- *U.S. Patent and Trademark Office Web Patent Database.* (U.S. Patent and Trademark Office, http://www.uspto.gov/web/menu/seach.html) (Drives event-study model. Also may be used for a bibliometric "sphere of influence" study at a future date).
- *1997 Economic Census.* (U.S. Bureau of the Census, http://www.census.gov/epcd/www/econ97.html). (The new *1997 Economic Census* will have information on output, labor, and investment by NAICS code. Can be used for reasonable up-to-date information on the broader industries of which DV is a subset).

The search for data from private sources involved Internet key-word queries and scans of various trade publications. An extensive listing of sources is presented in Appendix 5. Three sources, all from the Consumer Electronics Manufacturing Association, stand out as offering promising data on price and sales trends. Furthermore, the publications are available at a reasonable cost.

- *Historical Time Series for 50 Electronic Products*;
- *US Electronics Sales and Forecasts;*
- *The Electronic Market Book.*

Additionally, we plan to use newspaper and wire-service material available from LEXIS-NEXIS® for up-to-date news on DV firms.

4.6. Data Volatility

To perform a one-time baseline estimate of an economic impact, all data would have to be collected as soon as possible. But for an on-going analysis of impacts, the timeliness of collection of some data items is much more critical than that of others. The issue is that of data volatility. It will be difficult if not impossible to reconstruct historical data for some data items, whereas other items (typically gathered by government agencies) become more accurate over time due to data revisions.

Data volatility can be assessed along a sliding scale. We will define four categories of data in order of permanency: transitory, volatile, semi-permanent, permanent.

Transitory data

Some data must be collected as close to the event that they measure as possible because they reside mainly in human memory. Recollections of events fade or become distorted over time and the identity of people who have knowledge of events becomes hard to trace. One example of a transitory data set is our proposed consumer surveys: it is unlikely that a person can tell you in 2001 what she felt about the characteristics of HDTV in 1999. Another example is the set of interviews with key personnel working on ATP-funded projects: even if the key personnel could be identified in a later year, it is unlikely that they could recall exactly who all their competitors and collaborators were, and even more unlikely that they could recall how much of a project's success was due to ATP. Chapter 5 suggests intervals for updating some of the transitory data that support the models of approximately 2 to 3 years.

Volatile data

Some data could in principal be reconstructed at a later date, but in practice are best collected as close to the events as possible. The best examples of volatile data are data found in the "informal" literature produced by industry groups and consulting firms, and circulated over the Internet and

through privately-published documents. Most volatile data never make it into the permanent collections at research libraries. To maintain data sets to use for impact analysis, volatile data should probably be updated annually–especially data items that prove especially useful in the baseline study.

Semi-permanent data

Some data possibly could be reconstructed at a later date, but the costs of reconstruction will increase with time, and eventually might be very high. The best examples are data series published by government agencies other than the most frequently-used series. Data that are easy to access today (say because they are on the Internet) may become difficult to find in the future. Formats of the data might become outdated (for example, computer tape formats).To maintain data sets for use in an impact analysis, key semi-permanent data items should probably be captured at least biannually. In general, most data that exist in an electronic format but not in print should be viewed as having semi-permanency (at most), because at this time there are no electronic formats that are not subject to obsolescence.

Permanent data

Data can be viewed as permanent if they are both

- almost certainly able to be reconstructed at a later date, and
- likely to entail little if any cost from waiting to collect the data.

These data will ordinarily be in print-form government publications, or in publications in well-known journals. Permanent data only need to be updated when a new impact analysis is about to take place.

In order for electronic format data to be included in the "permanent" category, there must be an ongoing commitment on the part of the government agency to create and distribute a historical series in an easy-to-use format. Examples are the Gross Domestic Product series maintained by the Bureau of Economic Analysis, and the data set of patents maintained by the U.S. Patent and Trademark Office.

Table 4-1 provides examples of various data types. Additional data examples (arranged by the models that they support) are found in Appendix 5.

Table 4.1
Data Characteristics

Data Origi-nality / Data Volatility	Primary	Secondary	Tertiary
Transitory	interviews, surveys of households, surveys of businesses, focus group results		
Volatile	event study materials (announcements in trade journals, etc.)	data from consultants and industry organizations (e.g., CEMA annual data books).	unpublished conference and workshop papers
Semi-permanent		data on ATP funded projects (ATP Business Reporting System); input-output coefficients; details of consumer price index.	University working paper series
Permanent		federal patent data; federal import and export data; various BEA series; economic census data.	books, periodicals and occasional papers subscribed by major research libraries

4.6. Data Archival

Exact procedures for data archival will be worked out along with other protocols in Task 4. This section lays out some general principles for archival.

- A database should list all of the other files in the archive. Ideally, the database would contain searchable information about the files that would facilitate the location of data items.
- All files should specify a source and date.
- All computer source code that transforms raw data into "inputs" for a model should be included in the archive.
- Source code for models (such as the baseline impact analysis or the event study) should be included in the archive so that results can be updated over time.
- Flow charts illustrating the inter-connections of files should be included in the archive.
- Where possible, all data used by any model should be included in the archive. Exceptions might be the stock market files that will be used in the event study (the data set might be very large). In exceptional cases, pointers to the source (including date and version) should be included in the archive.
- The archive should be redundant to help guard against physical damage or deterioration.

- Provision must be made to roll over or refresh the archive from time. For example, data formats may start to become obsolescent; in that case, data must be translated into new formats before it is too late. If source codes are needed for future computations (as opposed to mere documentation), they may need to translated into modern language dialects.

4.7. Summary

In summary,

- Specific data needs must be clarified for each of the models identified in Chapter 3;
- Pre-existing data that meet these needs must be identified;
- New data must be generated in cases where the data needs cannot be met from pre-existing sources;
- Data items that are transitory or volatile should be captured during the time period that they are available;
- Data items that are semi-permanent still need to be captured a regular intervals;
- Data must be captured and archived systematically, along with related models.

We note again that Appendix 3 summarizes data sources proposed for each data item needed in our research methodology. Appendix 4 provides an inventory of DV-related data from proprietary sources, most of which are cited on the Internet.

5. PROPOSED ACTIVITIES

5.1. Introduction

Proposed measurement methods and data sources were discussed in general terms in Chapters 3 and 4. This chapter specifies the particular research activities that are entailed. Activities are specified here in general terms, but not to the point of detailed protocols – those will be developed in Task 4. Each activity is classified by type, based on its role in the flow of research:

- collection of primary data
- collation of secondary data
- collation of tertiary data
- model specification that affects data gathering and analysis
- model specification that affects estimation and analysis only
- model construction and estimation
- analysis of results.

The proposed activities will extend over a decade. In particular, we propose sequential, phased activities:

- gathering baseline data (Tasks 4 and 5, under contract)
- replicating or augmenting our data gathering at approximately two or three year intervals for a period of approximately ten years. However, different activities may be on different replication cycles, and the replication periods may be revisited at various times during the project.
- preliminary and updated model estimation and data analyses.

The next section summarizes all of the proposed activities and their timing or phase. The following seven sections describe the individual activities in more detail. The final two sections summarizes which activities occur during which phase.

5.2. Summary of proposed activities

Activities listed below are organized by type. Activities are followed by a code indicating when they were or will be conducted. Some activities also have a data ID indicating which sample they are associated with. An explanation of the codes and IDs follows the list of activities.

The proposed activities

<u>Collection of primary data</u>
- Identify the sample of DV projects (T4) ATPDV
- Telephone interviews for sampled projects (TR) ATPDV

- Identify a sample of other affected firms (competitors, customers, and other firms identified as being directly affected by innovations of sampled projects) (TR) AFF
- Telephone interviews and mail questionnaires with other affected firms (TR) AFF
- Focus groups or demos with consumers (TR) FCS
- Surveys of households (TR) HSE
- Telephone interviews or teleconference with DV experts (TR) EXP

Collation of secondary data
- Identify relevant markets and technologies for spillovers (T1, T2)
- Identify and classify relevant publicly-traded firms (TR) PTF
- Collection of stock market data on DV events (TR) TRK
- Collection of newspaper event data on DV events (TR) TRK
- Collection of newspaper/Internet background data (other than event study) (TR) ATPDV, AFF
- Collection of patent data on DV events (TF) TRK
- Collection of output and intersectoral flows for major US domestic and trade sectors (TF)
- Collection of output and intersectoral flows for disaggregated sectors producing DV goods (TF)

Collation of tertiary data
- Collection of demand elasticities and cross elasticities for US sectors (TF)
- Collection of demand function estimates for video and entertainment goods (TF)

Model specification (that affects data gathering and analysis)
- Accounting system for spillovers and impact pathways (T2)
- CGE model (T2)
- Qualitative model for the R&D decision and attribution (described in Appendix 1) (T3) ATPDV, C-ATP, AFF
- Axiomatic model of interview information on probability distributions (T4) ATPDV, C-ATP, AFF
- Consumer demand model (T4) HSE
- Bibliometric influence model of relationships of DV firms (TR) TRK

Model specification (that affects estimation and analysis only)
- Data model for CGE parameters (unpublished work by Burress and Oslund, referenced in Burress and Oslund, 1997) (T3)
- TRK: Event study model (T3)
- Monte Carlo aggregation model (TF)

Model construction and estimation
- DV-related demand functions (TR) HSE
- Bibliometric model of relationships of DV firms (TR) TRK
- Event study model (TR) TRK
- Actual and counterfactual worlds at the micro level (for each year under study) (TR)
- CGE model (TF)

- Monte Carlo aggregation model (TF)

Analysis of results
- Preliminary partial equilibrium impact estimate (TR)
- Preliminary general equilibrium impact assessment (TR)
- Preliminary policy analysis-related research (TR)
- Updated partial equilibrium impact estimate (TF)
- Updated general equilibrium impact assessment (TF)
- Updated policy analysis-related research (TF)

Timing of activities

The activities listed above are classed by timing or sequence using the following codes:

- (T1) indicates that the activity was substantially accomplished, as reported in Burress *et al.* (1998).
- (T2) indicates that the activity was substantially accomplished, as reported in Burress *et al.* (1999).
- (T3) indicates that the activity is substantially accomplished in the present report or in documents cited therein.
- (T4) indicates that the activity will be substantially accomplished during Task 4.
- (T5) indicates that the activity will be substantially accomplished during Task 5.
- (TR) indicates that the activity is recurring. The first iteration will be substantially accomplished during Task 5.
- (TF) indicates that the activity is not needed until an overall impact assessment is being made for ATP's DV focus area. However, we expect to make a preliminary assessment during Task 5.

Activities marked (T1), (T2), or (T3) have already been substantially accomplished. The remaining activities are described in the next seven sections.

Summary of samples, and sample IDs

Table 5.1 summarizes the structure of several major samples that will be created in this research. Each sample listed in the table is given an ID which is used as a cross-reference in the above list and in the discussion that follows.

Table 5.1
Structure of baseline samples and subsamples

Sample ID	Description of sample; Data instrument	Type of entity	Approximate baseline sample size	Included sub-samples
ATPDV	Cooperating DV projects (ATP funding recipients) - telephone and mail surveys [a]	project	up to 11	-
ATP+	All ATP DV funding recipients [b] - ATP and published sources	firm	11+	ATPDV, C-ATP
C-ATP	Control group: another project in the same firm as ATP project (if available) - telephone and mail surveys	project	significantly less than 11	-
EXP	Industry and technology experts - phone and mail surveys and possible teleconference	person	10	-
TRK	Publicly traded firms tracked over time [c] - published sources	firm	100	ATP+, AFF, PTF
AFF	Firms affected by spillovers from ATP - phone and mail surveys	firm	20	-
PTF	Additional publicly-traded firms - published sources only	firm	70	-
HSE	US household consumer demand - phone survey	household	500	-
FCS+	Focus groups	person	2x10	-

Source: IPPBR. Note that samples may be augmented and new samples may be defined in Tasks subsequent to Task 5.
a. ATPDV may be supplemented in subsequent Tasks with a sample of outside innovations that were influenced by knowledge spillovers from ATP-funded projects.
b. ATP+ includes *firms* corresponding to *projects* in ATPDV and C-ATP. (A single ATP DV project may be a consortium with more than 1 firm.)
c. TRK consists of PTF plus the *publicly traded subset* of firms in AFF or ATP+.

Sub-activities of data gathering

Note that each data gathering activity has up to four sub-activities:

- developing protocols
- testing protocols

- data collection
- data archiving.

Except as noted below, developing protocols and testing will be performed during Task 4; in some cases (such as literature searching) formal protocols and tests are judged to be unnecessary. Collection and archiving will be performed in Task 5 and repeated in subsequent Tasks.

5.3. Activities for collecting primary data

Identify the sample of DV projects (ATPDV)

All recipients of ATP funding are required to cooperate in evaluation studies as a condition of funding. Nevertheless, the degree of cooperation actually offered by project personnel could vary anywhere from the barest minimum to a full and most enthusiastic maximum. Mansfield (1996) states: "Based on a sample of 16 ATP award recipients, it appears that most of them would be willing to cooperate by providing descriptive material, analytic assistance, and data."

In subsequent Tasks, we may propose on-site interviews, which would require a more intensive involvement. Some award recipients may be willing to cooperate with telephone interviews but not with on-site interviews.

During task 4, we will briefly interview personnel form all DV Focus Area recipients that were awarded by the time of the 1998 competition (11 projects); of these, we will sample all those that are judged reasonably willing to cooperate with telephone interviews. If additional DV awards are made in the future, they will be included or not included in the sample under the same criterion.

In subsequent Tasks, we will endeavor to identify and sample additional outside projects that were influenced by knowledge spillovers from ATP-funded projects. The impacts of these projects will be followed over time using the same techniques applied to the ATP-funded projects. Note that this is most direct possible way of measuring the value of knowledge spillovers that lead to new innovations. However, it is not practical to begin this effort during Task 5 because:

- a very limited number of outside projects are likely to have been affected by knowledge spillovers at this early stage, and
- the delays in identifying these projects and obtaining their cooperation would place the effort outside the time frame planned for Task 5.

Telephone interviews with funding recipients (ATPDV)

Much of the information needed to solve problems of attribution, calculate private profits and market spillovers must be obtained primarily through interviews with recipients of ATP funding. These firms will also provide important information about the identity of other companies to interview. Follow-up

data from these firms can be gathered by email and other data collection instruments.

During Task 5 we will conduct intensive telephone interviews with all sampled award recipients. However, these interviews will vary in intensity, depending on the stage of development of the project. We expect that approximately 7 projects will be given full interviews, and 6 projects more abbreviated interviews. During subsequent Tasks we may propose additional on-site interviews with sampled projects.

The specific topics to be covered in on-site and telephone interviews include:

- The impact of ATP funding on intensity of R&D activity, the timing of project completion and its likely impacts on the national location of the resulting innovations (which is needed to measure "attribution effects"), and qualitative changes in the nature of innovations due to ATP funding;
- R&D expenditures on each funded project; both ATP and total;
- Impact of each innovation on firm profits as compared to a *counterfactual* situation in which ATP funding was not available;
- Volume of sales and prices of products incorporating innovations resulting from ATP funded projects -- both the actual figures, and figures for a *counterfactual* case in absence of ATP funded innovations (to be used for market spillover calculations);
- Changes in product characteristics and pricing resulting from ATP funded research (needed to calculate market spillovers where innovation results in improvements in price-performance trade-offs);
- The identities of all significant competitors, imitators, customers, suppliers, and producers of complementary goods (needed to trace knowledge and network spillovers, and to identify users of intermediate goods who can provide data needed to measure market spillovers);
- Any environmental impacts associated with each innovation (material spillovers);
- Any impacts on tax payments associated with each innovation (fiscal spillovers).

Telephone interviews and teleconference with DV experts (EXP)

We will consult with DV experts not attached to the sampled projects, but knowledgeable about the subject matter of each sampled project. During Task 4 we will identify relevant experts. During Task 5 we will interview approximately 10 experts by telephone on questions which include:

- what firms and products are potentially or actually affected by the funded innovation
- what data is available on prices, sales and market shares for affected products
- what network and knowledge spillovers are occurring from the sampled projects
- subjective estimates of values of spillovers by types of identified spillover

To motivate participation, we will provide experts with a report summarizing what other experts had to say. We will also explore the feasibility of their attending a teleconference to discuss the results.

Identifying other affected firms (AFF; TRK)

We will identify competitors, customers, suppliers, and other firms believed to directly affected (or potentially affected) by innovations of sampled projects (AFF). These firms will be identified through the interviews with ATP recipients, through Internet search (using our previous work on DV markets and products as a guide), and through interviews with DV experts. We will select a sample of these firms for direct interviews. The interview sample will be stratified informally so as to oversample firms anticipated to be knowledgeable about spillovers that have especially high values.

We expect to sample approximately 10 affected firms for interviews during Task 5. Most of these firms will be re-interviewed at approximately 3 year intervals during subsequent phases of the research, and additional firms will be added to the sample at that time.

During Task 5, we will also select approximately 100 firms for tracking though published media over time (TRK), including

- all ATP- DV funding recipients (ATP+)
- the (approximately) 10 affected firms that were interviewed (AFF)
- approximately 80 additional firms that use or produce DV (PTF).

This sample may be augmented in subsequent Tasks.

Telephone interviews and mail questionnaires with other affected firms (AFF)

Additional information related to the impact of each innovation on private profits, market spillovers, knowledge spillovers and network spillovers will be obtained through telephone interviews and mail questionnaires with the sample of affected firms. The key information to be obtained through these interviews includes:

- The impact of DV innovations used by these firms on prices and quantities of goods and services produced using these innovations;
- A description of DV related goods and services produced along with relevant quality dimensions and prices;
- The impact of DV innovations on profits of the affected firms;
- The nature and value of any network or knowledge spillovers resulting from ATP-funded DV innovations;
- Any impacts of ATP's DV focused program awards on R&D activities of these non-ATP funded firms (to be used to assess the positive and/or negative spillover effects on R&D momentum due to ATP's DV focused program).

We will also ask about fiscal and material spillovers.

Focus groups and demos with consumers (FCS)

We will conduct focus groups with samples of consumers. The purpose of the focus group is not to obtain a representative sample of opinion, but rather:

- to uncover consumer attitudes and issues that had not been anticipated by researchers
- to uncover changes in attitudes when consumers are exposed either to conversation or to actual demonstrations of consumer products or services.

The main goal of the focus groups will be to uncover unanticipated consumer attitudes or desires with respect to possible DV products and services.

A secondary goal has to do with attitude change. We expect to arrange actual demonstrations of wide-screen HDTV (high definition television), but HDTV will be merely one topic rather than the primary subject of discussion. The immediate purpose is see whether the demonstration leads to changes in attitudes about HDTV for those not previously exposed to HDTV. Note that this is basically a test of the validity of *ex ante* attitudes, hence is of limited significance in the proposed *ex post* study tracking DV products over time. In particular, our *ex post* surveys will eventually uncover any changes in expressed consumer attitudes that happen over time due to demonstration effects. We believe however that having rough knowledge in advance on the importance of demonstration effects will help us refine our surveys.

Kansas City is often used as a representative medium-sized city for consumer product tests and is convenient to IPPBR. We will conduct two focus groups in Kansas City during Task 5. Depending on their perceived usefulness, we may conduct additional focus groups at other locations during subsequent phases of the study.

Surveys of households (HSE)

We will gather data on household consumers that can be used to estimate a system of Lancastrian or hedonic demands for DV-related goods versus other goods. (In other words, the demands are for characteristics rather than for specific products.) A randomly selected sample of approximately 1000 households will be surveyed by phone to determine purchasing patterns of DV-related goods and services. This survey will be modified as needed and replicated over time. Information to be obtained from this survey includes:

- Share of expenditures on DV related goods and services
- Share of expenditures on entertainment in general
- Purchases of specific DV related goods and services, specific models purchased, prices of models purchased
- Demographic and economic characteristics necessary to model demand and utility
- Contingent evaluation of hypothetical future DV goods, according to their characteristics.

Details of the survey will depend on the Lancastrian DV consumption model developed during Task 4. The baseline survey will be conducted during Task 5. Resurveys will be conducted at approximately 3 year intervals. We will also attempt to track a subsample of households over time so as to create a small panel data set.

5.4. Activities for collecting secondary data

Identify and classify relevant publicly-traded firms (TRK)

Several of our proposed measurements rest on event studies that examine changes in stock price data for DV-related firms in response to DV-related public announcements. It is necessary to identify specific firms that will be tracked over time, and also to classify those firms in relationship to any given innovation. Note that a particular firm might fall into more than one class, or to fall into different classes depending on the particular innovation. The classes may include:

- an innovating firm
- firms expected to compete with the innovator
- firms expected to supply the innovator
- firms expected to utilize the innovation

The firms will not be selected by innovation, however; rather we will select firms that are active in DV, and then examine all DV innovations for those firms. (A firms classification depends on the particular innovation.) Initially, selection and classification will be based on the "designation" method -- i.e., based on informed judgements of researchers and experts. In particular, we will include all firms identified as "affected firms" (see section 5.3 above). However, if the event study procedure proves promising, then in subsequent Tasks a sharper selection and classification scheme might be based on bibliometric model described below. We anticipate that the initial sample of publicly traded firms will include approximately 200 firms.

Note that we are especially interested in public data on firms in the smaller samples described above:

- the sample of ATP-funded projects
- the sample of interviewed affected firms
- the sample of affected firms being tracked.

We will gather a more extensive data set for these firms.

Collection of stock market data on DV events (TRK)

Stock market prices of the selected firms will be captured on a high frequency basis, probably daily. These data will mainly be used in the event study, and are available from several competing data sources.

Collection of newspaper event data on DV events (TRK)

We also need to identify a chronology of events associated with DV innovations. The chronology will include all public announcements related to ATP funded DV research, as well as a broader class of all DV-related announcements made by all selected firms.

During Task 5 we will construct this data by searching Lexis/Nexis and other more specialized financial news databases for DV-related terms. In the course of that search we will construct a lexicon of DV-related terms. In subsequent phases of the project, if the event data prove useful we expect to employ that lexicon to accomplish a more systematic search using the computerized Kansas Event Data System (KEDS, 1999).

Collection of newspaper/Internet background data (other than event study; ATP+; AFF)

For smaller samples of firms (recipients of ATP funding and affected firms), we will need to track some non-DV-related events as well. We will use the same techniques that we use for tracking DV events. In addition, we will also perform Internet searches.

Collection of patent data on DV events (TRK; ATP+; AFF)

We will collect data on DV patents by selected firms. During Task 5 we will construct an initial data set. This dataset will be augmented during subsequent Tasks as additional patents and firms are added to the sample.

Collection of output and intersectoral flows for major US domestic and trade sectors

Where possible the CGE model will use data from the 500+ sector Benchmark US Input-output Tables. Those tables are issued at intervals of 5 to 15 years. In intermediate years we will estimate updates by pro-rating on the 80+ sector annual Input-Output Tables. Because of substantial lags in publishing the tables, half or more of the years used in any CGE impact analysis will be based on forecasts of flows constructed partly from the most recent Input-output Tables and partly from US GNP accounts. We will also collect annual data showing the extent to which each industrial sector is operating at capacity.

During Task 5 we will aggregate these data for a CGE model with a limited number of sectors. In subsequent Tasks we plan to disaggregate the CGE model as far as the data allow. (The model as proposed in Burress *et al.*, 1999 can be solved efficiently even with a large number of sectors. However, if in the future the CGE model is respecified to include more features, it is possible that computational constraints could place limits on disaggregation.)

Collection of output and intersectoral flows for disaggregated sectors producing DV goods

We will collect data on DV sectors (which will need to be more disaggregated than in the 500+ sector

US input-output model) from various sources, including industry and trade publications. These data will be used in Task 5 and subsequent Tasks to help construct the counterfactual world.

5.5. Activities for collecting tertiary data

Collection of demand elasticities and cross elasticities for US sectors

We have already collected many studies on demand elasticities, and have a set of estimates (though of widely varying quality) for every major sector. Reviews of demand elasticities are also published occasionally by other CGE researchers. We will update our collection continuously using standard literature searching techniques. In Task 5, we will summarize the elasticities for use in the CGE model.

Collection of demand function estimates for video and entertainment goods

We will continue to survey the scholarly and trade literature for studies of consumer demands that are related to entertainment and to DV. During Task 5 we will reconcile the findings from our demand model with other findings in the literature.

5.6 Activities for model specification (affecting data gathering and analysis)

Revise qualitative model for the R&D decision and attribution (ATPDV, C-ATP, AFF)

During Task 4 we will revise the model sketched in Section 3.4 and Appendix 1. This model will help us systematize interview questions on causal effects from ATP intervention on the project under study.

Axiomatic model of interview information on probability distributions (ATPDV, C-ATP, AFF)

During Task 4, we will develop a model for imposing axiomatic consistency on probability distributions, as sketched in Section 3.4. In particular, we will revise a model used by Burress and Oslund (1994) and apply it to the current situation.

Consumer DV demand model (HSE)

During Task 4 we will develop a formal specification of the Lancastrian demand model sketched in Section 3.4. We anticipate that the demand for a recreation/entertainment aggregate will depend on its aggregate price and quality (and on the price of leisure time and other parameters). The aggregate price and quality will depend in turn on the prices and qualities of component goods, some of which can be affected by DV innovations.

Bibliometric influence model of relationships of DV firms

If results of the event study approach proves to be promising, then in subsequent Tasks we will develop a formal specification for the bibliometric model sketched in Section 3.4. This model will show relationships of knowledge flows and knowledge uses between DV and other sectors. It can be used to form a sharper specification of the event study. Since it depends on published data that is not volatile, this model does not require any "baseline data."

5.7. Activities for model specification (not affecting data gathering and analysis)

Monte Carlo aggregation model

During Task 5 we will fully specify the Monte Carlo model for integrating over counterfactual probabilities, as sketched in Section 3.5. In particular, we will design a simple representation for a probabilistic outcome space.

5.8. Model construction and estimation

DV-related demand functions (HSE)

During Task 5 we will estimate an initial consumer demand model based on the survey of households. In subsequent Tasks, this model will be revised and re-estimated at the time of each resurvey of households.

Event study model (TRK)

During Task 5 we will implement a preliminary version of an event study model. This model is experimental; if the results seem useful, it will be replicated with added data in subsequent Tasks. Note that the preliminary model will not contain much information on ATP-funded projects, but if successful will reveal general patterns in DV spillovers. Subsequent versions of the event study would hopefully contain specific ATP-related data, as it becomes available over time.

Bibliometric model of relationships of DV firms (TRK)

During subsequent Tasks we may implement a bibliometric model, provided that initial results of the event study model (which will be based on a judgement-based assignment of firms to roles) suggest that the bibliometric model is needed.

Actual and counterfactual worlds at the micro level (at annual intervals)

For the partial equilibrium analysis, we will model the effects of all measured impact pathways on attribution and producers and consumers surplus in all affected markets. For the general equilibrium

analysis, we will model the effects of all measured impact pathways on all demand functions. These models include attribution models (which estimate the probability distributions of counterfactual outcomes) and bridge models (which apply interview data and other sources to estimates effects on complete demand systems).

Effects will be modeled for each year being studied. During Task 5, data will be available for years 1996-1999, but the data are expected to be incomplete. Additional study years will be added during subsequent Tasks, and also more complete information will become available about earlier years.

CGE model

During Task 4 we will implement a highly aggregated version of the CGE model described in Burress *et al.* (1999). Implementation of a fully disaggregated model is not needed at this time, and will be deferred until data are available on market impacts of fully commercialized ATP-funded innovations, subsequently to Task 5.

Monte Carlo aggregation model

During Task 5 we will implement a highly aggregated version of the Monte Carlo model described in Section 3.5. Implementation of the fully disaggregated model will be deferred until data are available on market impacts of fully commercialized ATP-funded innovations, probably subsequently to Task 5.

5.9. Analysis of results

Preliminary partial equilibrium impact estimate

During Task 5 we will estimate the total impact of all *ex post* effects of the ATP DV focus area that have been captured, using traditional partial equilibrium methods. Note that the effects are expected to be limited, in that commercialization has not occurred for any of the funded projects.

Preliminary general equilibrium impact assessment

During Task 5 we will estimate the same impacts using an initial version of the CGE model as an aggregator. Note that we do not expect any strong discrepancies between the two approaches, except that the CGE will add some multiplier effects to the direct effects. (We will be able to distinguish the multiplier effects from the direct effects within the CGE model.) The discrepancies are expected to become more noticeable in subsequent Tasks, when commercialization and knowledge spillovers will become more pronounced, and when the CGE model will be more disaggregated.

Preliminary policy analysis

In the Task 5 report we will discuss the policy implications of our findings. We anticipate that the policy implications of the *ex post* portion of the baseline data on ATP-funded projects will be limited, because most of the intended spillovers from the DV focus area have not yet had a chance to materialize. However, extrapolating from the results of interviews with DV experts performed in Burress *et al.* (1999), we do expect to identify a substantial number of anticipated spillover channels for these projects. Descriptions and diagrams of these channels may help policy makers understand why the underlying rationale for this and other focus areas does make coherent sense. We are also hopeful that the preliminary event study will help demonstrate spillovers of (non ATP-funded) DV R&D in a persuasive manner.

Updated partial equilibrium impact estimate

During subsequent Tasks we will estimate the total impact of all *ex post* effects of the ATP DV focus area that have been captured at the time of the analysis, using traditional partial equilibrium methods.

Updated general equilibrium impact assessment

During subsequent Tasks we will estimate the same impacts using a fully disaggregated version of the CGE model as an aggregator. We expect to find increasing discrepancies between the two approaches as the size and variety of realized spillovers increases over time. We also expect that we can use the CGE model to improve the partial equilibrium methodology: the CGE model will clarify questions of accounting for spillovers in multiple markets without double counting, and help clarify the extent of positive or negative interference between spillovers.

Updated policy analysis-related research

In subsequent reports we will discuss the policy implications of our findings. *Inter alia*, we anticipate that we will discuss:

- the gap between social and private returns to projects in the DV focus area
- the extent to which we attribute the existence of that gap to ATP intervention
- the extent to which we have been able to document "momentum" or "synergy" effects, implying that a focused area program has benefits above and beyond an aggregate of unrelated projects.

5.10. Summary of proposal on gathering baseline data

During Task 4 we will:

- Revise analytic models:
  Qualitative model for the R&D decision and attribution (described in Appendix 1)

Axiomatic model of interview information on probability distributions
Data model for CGE parameters
Event study model

- Develop analytic model:
  Consumer demand model
- Develop and test protocols for all major data gathering activities:
  Telephone interviews for sampled projects
  Telephone interviews and mail questionnaires with other affected firms
  Focus groups or demos with consumers
  Surveys of households
  Telephone interviews or teleconference with DV experts
- Develop protocols for archiving data and programs
- Identify a sample of up to 11 digital video projects for detailed study in Task 5, consisting in all DV projects previously funded by ATP and willing to participate.
- Perform 2 focus groups/demos
- Perform telephone interview for 1 funded project
- Perform telephone interview with 1 expert
- Draw a test sample of household surveys
- Form a "pro-forma," partial equilibrium impact estimate for 1 R&D project
- Write a report that summarizes instruments and test data
- Make a presentation at ATP on our findings.

During Task 5 we will:

- Perform telephone interviews for approximately 10 funded projects
- Interview approximately 20 affected firms and experts
- Survey approximately 500 consumers
- Estimate a Lancastrian DV consumption function
- Develop and test all major analytic models - CGE, Monte Carlo, counterfactual
- Estimate partial equilibrium economic impacts of R&D activities accomplished so far
- Estimate CGE economic impacts of R&D activities accomplished so far
- Perform an initial event study and estimate ratios of earlier DV spillovers to profits
- Archive all data and models
- Propose general revisions to the research plan based on experience gained.
- Analyze the policy implications
- Write a report that summarizes our findings and the implications
- Make a presentation at ATP on our findings.
- Make a proposal for a "Task 6" follow-on
- Submit 1 or more articles on the results to referred journals.

Some important limitations of the baseline impact analysis should be emphasized.

- Since no innovations have been commercialized as yet, the realized economic impacts will mainly

consist in Keynesian effects from R&D expenditure plus R&D displacement.

- In particular, while many potential spillovers will be identified, few or none (other than displacement effects on R&D) will be measurable in an *ex post* sense.
- At this stage of the research, the estimated household DV demand model will be substantially based on hypothetical (i.e. contingent evaluation) data (together with some actual behavioral data).
- The CGE model will be left fairly aggregated at this stage. Since complex spillovers have not been realized yet, an aggregated model is sufficient for estimating economic impacts.
- The event study probably cannot be run using ATP-funded innovations because the sample of events is too small. Instead it will be based on generic DV innovations.

5.11. Summary of proposal on ongoing data gathering

Major additional activities proposed for one-time completion

- Program the fully disaggregated CGE model
- Program the fully disaggregated Monte Carlo model
- Make major revisions of research plans as needed in light of Task 5 experience

Major activities proposed for repetitive cycling

- Update protocols as needed
- Gather data about sampled projects from several sources:
  - telephone, mail, and possible on-site interviews with project personnel
  - telephone and mail interviews with industry experts and personnel in affected firms (including competitors, suppliers, customers, and producers of complementary goods)
  - published data and information, such as newspaper article, patent applications and citations, and scholarly publications
- Gather data on household consumers and estimate a revised system of Lancastrian demands for DV-related goods versus other goods.
- Estimate input demand functions for goods directly affected by the sampled projects, both with and without any innovations.
- Perform event studies to estimate the effects of project announcements on capitalized values of publicly-traded firms producing related products and services.
- Update the CGE model for prior years, based on newly released data; and extend the CGE model to new years
- Update and extend "bridge" models that link the sampled markets and create annual models of the counterfactual worlds
- Revise and update models of "attribution," showing a probability distribution of differences between project-level and innovation-level outcomes with and without ATP intervention.
- Using all models and data, estimate the state of the economy for each prior year covered in the study, both with and without ATP intervention. The vector of differences between the two

worlds is an estimate of the economic impact of ATP intervention in the digital video market. This data will be used to estimate the net social value of the ATP intervention.

- Archive all data and models
- Analyze policy implications and write reports.
- Make presentations and submit articles to refereed journals.

6. RESEARCH PLANS

6.1. Purpose

This chapter lists the proposed deliverables and gives the timing of check points for Tasks 4 and 5.

6.2. Assumptions

The plans given below are based on the following assumptions:

- Tentative authorization to proceed on Task 4 received by IPPBR from ATP by November 15, 1999
- Final authorization to proceed on Task 4 received by IPPBR from ATP by November 30, 1999
- Tentative authorization to proceed on Task 5 received by IPPBR from ATP by
- Final authorization to proceed on Task 5 received by IPPBR from ATP by February 28, 2000
- IPPBR will rely on ATP for help with:
  - Providing ATP data collected from its DV funding recipients
  - Encouraging funding recipients to participate in the study.

6.3. Task 4 deliverables

IPPBR will deliver a report which will include:

- New or revised model specifications:
  - Event study model
  - Consumer demand model
  - Qualitative model for the R&D decision and attribution
  - Axiomatic model of interview information on probability distributions
- Final instruments, protocols, and summary of test data for:
  - Identifying the sample of DV projects (ATPDV)
  - Telephone interviews for sampled projects (ATPDV)
  - Identifying a sample of other affected firms (competitors, customers, and other firms identified as being directly affected by innovations of sampled projects) (AFF)
  - Telephone interviews and mail questionnaires with other affected firms (AFF)
  - Focus groups or demos with consumers (FCS)
  - Surveys of households (HSE)
  - Telephone interviews with DV experts (EXP)
  - Identify and classify relevant publicly-traded firms (PTF)
- Revised identification of data sources and data searching plans for:
  - Collection of stock market data on DV events TRK
  - Collection of newspaper event data on DV events (TRK)

- Collection of newspaper/Internet background data (other than event study) (ATPDV, AFF)
- Collection of patent data on DV events (TRK)
- Collection of output and intersectoral flows for major US domestic and trade sectors
- Collection of output and intersectoral flows for disaggregated sectors producing DV goods

- Final data and results for
  - Identifying the sample of DV projects (ATPDV)
  - Focus groups or demos with consumers (FCS)
- Revised plans for data analysis for Task 5
- Personnel and staffing plan for Task 5; and
- Operating schedule for Task 5

At the option of ATP, IPPBR will also deliver computer-readable copies of all data sets, models, and computer programs developed for this Task.

IPPBR will make a presentation at ATP describing the results of this Task.

6.4. Task 4 timeline

Task	Deliverable	Date
1	First draft report to ATP	January 31, 2000
2	ATP gives feedback on draft report	February 14, 2000
3	Second draft report and presentation at ATP	February 28, 2000
4	ATP gives final authorization to proceed on Task 5	March 13, 2000
5.	Final written report	March 127, 2000

6.5. Task 5 deliverables

IPPBR will deliver a report which will include:

- New or revised model specifications:
  - Event study model
- Summaries of raw data for:
  - Telephone interviews for sampled projects (ATPDV)
  - Identifying a sample of other affected firms (competitors, customers, and other firms identified as being directly affected by innovations of sampled projects) (AFF)
  - Telephone interviews and mail questionnaires with other affected firms (AFF)
  - Surveys of households (HSE)
  - Telephone interviews with DV experts (EXP)
  - Identify and classify relevant publicly-traded firms (PTF)
- Summary of estimated models:
  - Consumer demand model

  - Actual and counterfactual worlds at the micro level
  - CGE model
  - Monte Carlo aggregation model
- Preliminary impact estimates:
  - Partial equilibrium
  - General equilibrium
- Explanations of data analysis approach;
- Results of data analysis;
- Summary of Empirical findings;
- Revised plans for data analysis for subsequent Tasks;
- Policy analysis and recommendations; and
- Proposal for a “Task 6" follow-on.

IPPBR will submit 1 or more articles on the results to referred journals.

At the option of ATP, IPPBR will also deliver computer-readable copies of all data sets, models, and computer programs developed for this Task.

IPPBR will make a presentation at ATP describing the results of this Task.

6.6. Task 5 timeline

Task	Deliverable	Date
1	First draft report to ATP (baseline data)	May 14, 2000
2	ATP gives feedback on draft report	May 29, 2000
3	Second draft report and presentation at ATP	June 12, 2000
4	ATP gives feedback on draft report	June 26, 2000
5	Final written report	July 15, 2000
6	submission to referred journal	July 31, 2000

7. CONCLUSION

7.1. Project Summary

This report sets out a plan to collect benchmark data and to conduct a preliminary evaluation of the costs and benefits of ATP's digital video program to date. The study outlined here (Tasks 4 and 5) will develop new methods and will build upon existing methods to accomplish these goals. The study addresses three main issues:

- to what extent can various digital video developments be attributed to ATP?
- how can spillovers be measured?
- how can benefits and costs be measured and aggregated?

We review the various approaches that we will take to try to answer these questions.

7.2. Methods

Methods to assess attribution

Our information on attribution will come primarily from interview information. We will try to get at attribution from multiple directions rather than simply asking grant recipients the degree to which the grant facilitated their work. Our approaches will include:

- attribution tested using qualitative modeling of barriers;
- possible use of internal unfunded projects as control groups;
- evaluation of changes in characteristics of an innovation that are caused by government intervention;
- interviews on attribution with other market actors (other than the ATP firms).

Methods to measure spillovers

Previous phases of this project have resulted in a formal approach to classifying spillovers. Results from the previous work include:

- classification of spillovers and other barriers to R&D based on interview with industry experts (Burress *et al.*, 1999);
- systematic taxonomy of impact channels and spillover types using spillover diagrams (Burress *et al.*, 1999).

The new work will build upon these ideas, but will be more quantitative in nature. Methods to be applied in the new work include:

- systematic interviews with ATP firms and with related competitors and suppliers;
- spillovers (and attribution) measured using an event study of the effects of innovation announcements on market values of innovating and related firms;
- measurement of all major classes of spillovers in a single study; and
- interviews using axiomatic modeling of the counterfactual world.

Methods to measure and aggregate net benefits

Benefits will be assessed in both a partial and a general equilibrium framework. Methods will include:

- consumer demand for new products estimated using the systematic taxonomy of markets, innovations and technologies in a Lancastrian space of attributes of goods (Burress *et al.*, 1998; Burress *et al.*, 1999).
- consumer surplus measured using such demand estimates;
- use of CGE model to aggregate over channels; and
- use of Monte Carlo simulation to integrate over probabilistic counterfactuals.

7.2. Possible future work

Possible future work includes:

- systematic survey of related firms to detect spillovers from, and measure demands for, an innovation;
- further microeconomic studies of momentum and synergy;
- improved technology forecasting methods;
- macro approach: estimate total effects of DV, then allocate to ATP.

APPENDIX 1: QUALITATIVE MODELING OF ATTRIBUTION FOR R&D AND COMMERCIALIZATION

Introduction

The decision to invest in R&D directed toward a particular innovation is determined by conditions affecting that innovation and its commercialization, as they are known or anticipated by investors. The actual success of the R&D and commercialization efforts depends on the same conditions, but rather as they are realized. These conditions could be viewed in a negative sense, as the collection of all barriers to R&D and commercialization. The role of ATP, then, is to help overcome these barriers.

When a positive investment decision occurs, causality can be attributed to ATP intervention if and only if that intervention led to a decisive change in the investor's perception of the barriers. This appendix models ATP qualitative effects on these barriers case by case, and then models the aggregate effect of ATP on the investment decision.

Following a positive decision to invest, causality for acceleration and/or success of the R&D or commercialization could be modeled in a similar fashion. The last two sections of this appendix sketch some additional issues that would be involved, and also discuss displacement and other aspects of attribution.

The primary point of this model is to guide the collection of interview data from project personnel related to the question of attribution. A secondary purpose is to provide ways to test the internal consistency of the interview data. The key interview questions will ask how ATP intervention affected the perceptions of the investors about each barrier at the time the investment decision was made. Note that questions on the initial investment decision should be put to investors at the earliest practical date, so as to reduce any memory loss and ex post bias occurring with the passage of time. On the other hand, questions on ATP impacts on success of the project would ideally be repeated at different points in time during the project.

The investment decision

In order to classify barriers to investment, we need a simplified model of investment. We will assume that investment in the project occurs if and only if:

$$(1) \qquad e^{-\rho(T1 - T0)}PS(1-R) > K(1 + \kappa),$$

where all terms in the equation represent information or beliefs held by the investor at time T_0.
T_0 is the time at which the R&D decision is made, assumed exogenous.
ρ is the private discount rate, assumed exogenous.
T_1 is the expected time at which commercial sales will begin.

P is the anticipated probability that commercial sales will be undertaken during this project.

S is the social value of the innovation at time T_1 (ignoring sunk costs), conditional on commercial sales beginning.[12] Note that the social value has a discontinuous distribution; it is 0 with probability 1-P, S with probability P.

R is the spillover coefficient - i.e. the share of social value absorbed by spillovers. Hence S(1-R) is the private return (= present value of profits as of time T_1), as anticipated at time T_0.

K is the expected present value of all needed investments.

κ is a capital cost factor which includes: risk premium, any effects of ATP subsidies, any effects of capital sources (e.g., bonds or any equity shared with third parties), and other opportunity costs of capital. If adequate capital is simply not available, we model κ as $+\infty$.

We will classify barriers into categories or channels defined by the elements of this model, and model them in turn.

Social value of the innovation (after commercialization; S)

Given that the innovation has been commercialized, there is only one significant channel through which ATP can affect social utility: by influencing the scope or qualitative nature of the innovation as implemented.

Interview questions can directly address ATP's impact on the planned scope or implementation of the innovation, and on social impact of the project as anticipated by investors. It does not seem useful to try to trace this channel back to any underlying factors.

The spillover ratio (R)

Given that the innovation has been commercialized, the value or profit to investors equals social utility less spillovers. Consequently, Jaffe (1996; 1998) argued that the spillover ratio is the most important determinant of the investment decision.[13] Jaffe proposed four classes of conditions surrounding an innovation that can affect spillovers:

- (-) is the innovation protectable?
- (+) is US licensing likely?
- (+) are positive US spillovers likely for other reasons (a residual class)?

[12] The social discount rate used in evaluating S could differ from the private discount rate used in evaluating profits without affecting this attribution model. The difference between discount rates does constitute another source of spillovers. However, since both discount rates are exogenous to this model, this source of spillovers cannot be affected by ATP.

[13] Note however this claim is not necessarily consistent with equation (1).

- (+) is the likelihood of commercial success high?

(The signs indicate the direction of effect on the anticipated value of spillover ratio.)

We propose to classify these factors using a more detailed scheme. In particular, Table A1.1 cross-classifies Jaffe's four major classes with the possible loci at which a given factor takes effect:

- project or firm-specific
- industry-specific (either world-wide or domestic)
- nation-specific
- innovation or good-specific

The locus of a factor is important because ATP has more potential influence on factors with a locus near the top of this list than those near the bottom. That is, an ATP intervention can affect the project or the firm, and to a lesser extent can affect an entire industry, but cannot have much noticeable affect on the US as a whole; while the general nature of the innovation itself is viewed in our model as exogenous. (We have already discussed ATP's possible effect on the innovation as implemented.)

Each of 16 cells that result contains some number of individual factors. Most of these factors were suggested by Jaffe and are discussed therein; a few were added by us. These factors can reasonably be aggregated within cells because they have similar roles in affecting spillovers. Interview questions can then focus on a block of related questions, cell by cell. If interview time is scarce, it should focus differentially on factors nearer the top of the table, which are more susceptible to influence from ATP.

Table A1.1
Factors affecting domestic spillovers of innovation (S)

locus	**factor class** (sign indicates direction of effect on spillovers)			
	(-) protectable	**(+) US licensing likely**	**(+) positive US spillovers likely**	**(+) commercial success likely**
project or firm-specific	high market power possess co-specialized assets	low US market share lack of co-specialized assets	lack of downstream expertise firm discount rate exceeds social rate	high market share possess co-specialized assets short product cycle
industry-specific (either world-wide or domestic)	need for regulatory approvals need for reputation non-competitive slow technical change	small producers	competitive slow technical change cross-industry (outsider) small producers	non-competitive slow technical change cross-industry (outsider) small producers protectable
innovation or good-specific	possible patent, trade secret, or copyright process, not product long lead time & learning curves	multi-use technology -- key component pathbreaking technology	limited negative impact on competitors multi-use technology -- proof of concept; key component pathbreaking technology technostructure (R&D) network standard poss. learning by failing long-lasting benefits complex goods	protectable radical innovation
nation-specific	US leadership	foreign leadership; US presence	international com-petitiveness	US leadership

co-specialized assets: marketing, production, regulatory, application skills, reputation, market share, finance capital

Sources: Jaffe (1996); IPPBR

Table A1.2 Non-spillover barriers to innovation			
locus	**barriers**		
	finance capital failures (κ)	**entrepreneurialism failures (K, T_0, P)**	**technical or commercial failures (see also Table 1 column 5) (K, T_0, P)**
project or firm-specific	small size lack of experience lacking economies of scope and scale ownership of competing technologies	lack of dynamism bureaucracy	lack of technical skills lack of business skills
industry-specific (either world-wide or domestic)	incumbent monopoly lack of R&D capability lack of potential partners	incumbent oligopoly	lack of infratechnology lack of R&D capability lack of potential partners
innovation or good-specific	high technical risk high market risk		radical innovations high technical risk
nation-specific	low aggregate investment low aggregate venture capital other adverse macro-economic conditions inadequate basic research	low aggregate entrepreneurialism low incentives	net governmental burden of taxes inadequate basic research
Sources: Tassey (1999), IPPBR			

Other barriers (T_1, P, K, κ)

Tassey (1999) discussed barriers to R&D other than spillovers. In our model, those barriers could operate through any of four channels: T_1, P, K, and/or κ. In Table A1.2 we classify non-spillover barriers suggested by Tassey in a similar manner to Table A1.1. (We have added a few barriers of our own.) Tassey's barriers included factors that cause:

- financial market failures
- failures of entrepreneurialism
- technical failures
- commercial failures.

For each type of failure, we have indicated which channels are implicated.

Aggregating attribution for the investment decision

A preliminary qualitative model of attribution for the R&D investment decision can now be stated as follows.

We assume that R&D occurs if and only if all the following six conditions are "approximately" met:

- the innovation is protectable
- commercial success is likely
- other factors encouraging spillovers are limited
  e.g., if US licensing likely, then other factors causing positive US spillovers are not present.
- finance capital is available
- entrepreneurial capital is available
- other barriers to technical or commercial success are absent.

A condition is "approximately" met if either

- all barriers in that column are absent, or
- the barriers present are plausibly judged by interviewees to be surmountable.

Plausibility will be modeled based on the number and types of barriers in a column.

ATP "caused" an R&D effort if and only if

- all six conditions are approximately met, and
- interviewees plausibly perceive that ATP intervention changed at least one condition from not being met to being met.

Plausibility will be modeled based on congruence between locus and the factors alleged to be affected by ATP. For example, ATP can plausibly affect firm-specific factors but not innovation or goods-specific factors.

(For simplicity, this model ignores effects of ATP on scope of the innovation and social utility)

Summary of data requirements

Interview questions should ask both about high level factors and about underlying factors. For each factor, we need to ask about its status both with and without ATP intervention. A number of factors are viewed as not important to this model, and can be downplayed in the interviews (unless needed for purposes other than assessing attribution). The following questions represent the desired information, not the actual wording of interview questions.

High level factors

- Is the innovation protectable?
- Is commercial success likely?
- Will other companies profit significantly from this innovation?
- Is finance capital available?
- Is entrepreneurial capital available?
- Are there other barriers to technical or commercial success?

Important underlying factors

- What is the nature of the firm and its niche?
  - market power
  - US, world market share
  - size of firm
  - nature of its co-specialized assets
  - length of product cycle
  - cross-industry innovation (outsider)?
  - amount of experience
  - economies of scope and scale
  - ownership of competing technologies
  - degree of dynamism
  - degree of bureaucratization
  - level of technical skills
  - level of business skills
- What is the nature of the industry and market?
  - level of downstream expertise
  - need for regulatory approvals
  - need for reputation
  - degree of competition
  - speed of technical change
  - size of producers (market concentration)
  - rate of technical change
  - incumbent monopoly or oligopoly
  - level of R&D capability
  - availability of potential partners
  - level of infratechnology

Less important underlying factors

- Has the scope of the project changed?
- What is the nature of the innovation or good?
  - possible patent, trade secret, or copyright

process or product
length of lead time & learning curves
possibility of learning by failing
degree of negative impact on competitors
time span of benefits
degree of technical risk
degree of market risk
multi-use technology -- key component; proof of concept?
pathbreaking technology?
technostructure (R&D)?
network standard?
complex goods?
radical innovation?

- What is the nature of existing US and international industries or markets?
  US or foreign leadership; US presence?
  international competitiveness
  amount of US aggregate investment
  aggregate US venture capital
  existence of adverse macro-economic conditions
  sufficiency of US basic research
  sufficiency of US aggregate entrepreneurialism
  level of US incentives
  net US burden of taxes

Modeling attribution for project success

Assume for simplicity there are no marginal costs associated with closing down a project. We will define "commercial success" as a situation in which marginal revenues exceed marginal costs of the project and this state of affairs is expected to continue for the near term. After the project has been initiated and up until commercial success has been realized, the project can fail or be closed down because of all the same barriers that were modeled above.

One way to model this possibility is to assume that a new decision to continue or close the project is made at each successive point in time. This decision is made using the criterion (1), just as in the initial decision. However the values of all variables in equation (1) change over time. Thus, the initial decision to proceed leads to a reduction in the perceived capital hurdle κ, for example because internal bureaucratic procedures and political commitments within the firm are now biased toward continuing the project. Also future investment cost K will tend to decline over time as the R&D and commercialization activities near completion; however it could also rise if new information were uncovered about the difficulty of the task.

As an interviewing strategy, one could conceivably ask a sequence of questions at each point in time

about the effects of ATP's past intervention on the firms' current expectations. Practically, however, it seems better to ask ex post questions about ATP's impact on the realizations of the various factors and barriers.

Once commercial success has occurred or the project has been closed down, presumably no new information will be generated that is relevant to attribution. ATP's share of causality for project outcomes will simply continue to be whatever it was at that point in time.

Attribution for other aspects of ATP's impact

Several issues are not addressed in this model and could not be addressed by simple extensions of it. Instead they depend on largely different issues. Examples include:

- displacement of R&D investment, both within the firm and across firms
- the difference between changes in timing of this project, versus changes in timing of the innovation.
- "second-order" spillovers, for example when knowledge spillovers lead to additional innovations.

APPENDIX 2: EVENT STUDY MODEL

This appendix describes a preliminary model for studying the impact of DV-related public announcements on stock prices. The purpose is to gain information on the effect of spillovers on profits of other firms. In particular, we would like to estimate parameters of the form:

(1) $R_i = E(\Delta P_i / \Delta P_0)$, where

R_i is a ratio which can be used to predict spillover profits from direct profits of an innovation
E is an expectation operator
ΔP_0 is the change in present value of profits for an innovating firm in response to an announcement related to the status of its innovation.
ΔP_i is the change in aggregate profits of the ith class of firms in response to an announcement related to the status of its innovation.
"i" runs over classes of firms.

Note that R_i is an *ex ante* estimate. However, if markets are fully rational, then R_i is an approximately unbiased estimator of the corresponding *ex post* ratio as well.

APPENDIX 3:
CROSS CHECK OF DATA NEEDS VERSUS DATA SOURCES

Table A3.1
Sources and uses of data

Data used for...	Kind of Data	Sample of ATP firms: Interviews and mail surveys	Other affected firms: Interviews and mail surveys	Expert Inter-views	House-hold Surveys and focus groups	ATP data-base	Public data	News-paper articles (search)	Propri--etary data	Econ-omics Liter-ature
Mansfield-type partial equilibrium study of project impacts	R&D Expenditures on: a) funded project, b) all projects, c) uncommercialized projects	X	X			X				
	ID of sample projects (directly or indirectly influenced by ATP or control)	X	?	X		X	X			
	Change in quantity Sold	X	X				?		?	
	Change in price per unit	X	X				?		?	
	Additional or lost profits due to innovation	X	X							
	ID of imitators	X	?	X						
	ID of competitors	X	?	X						
	Change in profits of imitators	X	X						?	
	Change in profits of competitors	X	X							
	Elasticity of Demand for DV products - by sector		X	?	X				?	X
ATP attribution for ATP projects and investment	Impact of ATP Funding on Expenditures (for project; for innovation; for all R&D)	X		X		?				
	Impact of ATP Funding on timing of innovation	X		X		?				
	Impact of ATP funding on national location of innovation	X		X						

Data used for...	Kind of Data	Sample of ATP firms: Interviews and mail surveys	Other affected firms: Interviews and mail surveys	Expert Inter-views	House-hold Surveys and focus groups	ATP data-base	Public data	News-paper articles (search)	Propri--etary data	Econ-omics Liter-ature
	ATP cost to taxpayers					X				
Impacts on Consumers	Exhaustive list of specific DV products and relevant characteristics	X		?			X		X	
	Exhaustive list of product prices	X					X		X	
	Household adoption decisions				X					
	Business adoption decisions									
	Household characteristics				X					
	Business characteristics									
Event Study of Market, Knowledge Spillovers	ID Patents and links	X		X			X	X		
	dates of patents						X			
	ID, links, dates of other "events"	X		X			X	X		
	stock prices						X	X		
CGE Modeling	sector quantities						X			
(Sectors other than DV)	sector input elasticities									X
	sector input quantities						X			
	sector imports						X			
	sector exports						X			
	export price elasticities									X
	R&D matrix						X			
	investment matrix						X			
DV Sector (in addition to the data needs of the Mansfield-type study	output quantities for DV users		?						X	X

Data used for...	Kind of Data	Sample of ATP firms: Interviews and mail surveys	Other affected firms: Interviews and mail surveys	Expert Inter-views	House-hold Surveys and focus groups	ATP data-base	Public data	News-paper articles (search)	Propri--etary data	Econ-omics Liter-ature
	demand elasti-cities for other goods by DV users								?	X
	demand elasti-cities for other goods by DV suppliers	X	?							X

Legend:
X indicates an expected data source
? indicates a possible data source

APPENDIX 4: DATA FROM PROPRIETARY SOURCES

The table below describes known data sources, most of which were located from an Internet search. Most of the data sources are proprietary, and costs range from very moderate to very expensive. A few of the listed data sources are micro-data from large surveys conducted by the federal government.

Table A4.1
Identified published information sources

Type of Information	Source of Information
name of specific data source	**Electronic Industry data: Historical data**
private or public?	private
name of agency, firm, etc	CEMA (consumer electronics manufacturing association)
website of agency	http://www.ebrain.org
address of source	CEMA Market Intelligence Center, 2500 Wilson Blvd., Arlington, VA 22201
phone number of source	(703) 907-7763
contact person and phone if different from above	Angela Titone
location of pointer to source	http://ebrain.org/pubs_main.html
location of source itself	Historical time series data for 50 electronic product can be ordered from CEMA. The period of time for each product are different.
general description of the source	Historical time series data include U.S. factory summary(factory sales, new orders, inventory, unfiled orders, production), employment summary, producer price indices. Factory summary data are monthly from 1982 to present, producer price indices are monthly from the year available to present. Household penetration rate is presented for some products. Average U.S. spending per household on consumer electronics and factory sales of home theater product in dollars can be purchased at additional costs. .
cost of the source	Historical time series prices for 50 products are available at $395 or $25 per each product or 3 tables for $60. Average U.S. spending per household on consumer electronics, factory sales of home theater products in dollars are available at $ 40 for each. Annual subscription to The Electronic Trends are $155 for non-members.
specific price variables included in source	50 electronic products includes camcorders(1985-98), DVD players(1997-98), Direct-to-home and direct broadcast satellite systems(1986-98), Home theater-in-a Box(1996-1998), Set-Top Internet Access Devices(1997-98), TV, Color(1954-98), TV, color with stereo(1984-98), TV, LCD color(1985-98), TV/PC combination(1997-98), TV, Projection(1984-98), TV/VCR combination(1997-98), PC monitors(1993-98), Digital cameras(1996-98), PCs(1982-98), Video games, electronic games(1990-98), home security systems(1987-98)
specific quantity variables included in source	The same products above + PC Peripherals(1994-98) and PC software(1990-98).
other quantitative information included in source	Factory sales in dollars, household penetration for selected products.

Type of Information	Source of Information
is this based on original survey data?	yes.
if yes, is raw survey data available?	yes. The price is described above.
if yes, fill out another record for the raw data	
name of specific data source	**U.S. Consumer Electronics Sales & Forecasts**
private or public?	private
name of agency, firm, etc	Ebrain Market Research (CEMA consumer research center)
website of agency	http://ebrain.org
address of source	2500 Wilson Blvd., Arlington, VA 22201
phone number of source	(703) 907-7500
contact person and phone if different from above	Mike Mccomack, (703) 907-7764
location of pointer to source	http://ebrain.org/pubs/consensus/consensus_about.html
location of source itself	The report can be ordered from Ebrain.
general description of the source	The latest unit and dollar sales data of 125 consumer electronic products, including digital TV, PC's and auto sound equipment. The projected grand total sales are from 1994 to 2002. Total industry forecasts by product are from 1994-1999. It has been published two times a year since 1994. Updated annually. 1998 US consumer electronics sales and Forecasts report is available now.
cost of the source	$95
specific price variables included in source	prices for color TV, Projection TV, TV/VCR combination, LLCD color TV, DVD players, TV/PC combinations, Set-Top Internet Access Devices, Camcorders, digital camera, Video camera software, Videocassette players, Video game hardware and software.
specific quantity variables included in source	unit sales and dollar sales for 125 consumer electronics products including digital TV, PC's.
other quantitative information included in source	For 1998 projected unit and dollar sales and forecasts through 2002. Household penetration .
is this based on original survey data?	Yes. Based on confidential sales data from various CE manufacturers, the CEMA market activity reports, staff estimates.
if yes, is raw survey data available?	No.
if yes, fill out another record for the raw data	
name of specific data source	**The electronic market book**
private or public?	private
name of agency, firm, etc	Ebrain(CEMA consumer research center)
website of agency	http://ebrain.org
address of source	2500 Wilson Blvd., Arlington, VA 22201
phone number of source	(703) 907-7756
contact person and phone if different from above	Mike Mccomack, (703) 907-7764
location of pointer to source	http://www.ebrain.org/pubs/about_databook.html
location of source itself	The CD-rom can be ordered from CEMA.
general description of the source	the industry's statistical yearbook supplying data, market indicators, overviews, emerging trends, growing markets, and international opportunities. Electronic coverage of consumer, telecom. Defense, components, computers& peripherals, industrial & electromedical equipment. The topics covered are pre and post demonstration reactions, sound, data streaming.

Type of Information	Source of Information
cost of the source	$150 for non-members
specific price variables included in source	provides some historical data.
specific quantity variables included in source	
other quantitative information included in source	
is this based on original survey data?	
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	**Digital TV Research**
private or public?	private
name of agency, firm, etc	Ebrain(CEMA consumer research center)
website of agency	http://ebrain.org
address of source	2500 Wilson Blvd., Arlington, VA 22201
phone number of source	(703) 907-7756
contact person and phone if different from above	Mike Mccomack, (703) 907-7764
location of pointer to source	http://www.ebrain.org/crs/about_cdrom.html
location of source	The CD-rom can be ordered from CEMA.
	Market research CD- rom with video and sound files from seven consumer focus groups. Seven focus groups, each consisting of 10 randomly selected adults, were conducted during January 1999 at the International CES in Las Vegas. Content included live over-the-air high definition broadcasts, movie footage, and data streaming/multicasting. The topics covered pre and post demonstration reactions, sound, questions for retailers, programming, price, and cable/antenna issues. The research shows consumers' awareness and interest trends based on 2,000 U.S. adults' survey..
cost of the source	$395
specific price variables included in source	No
specific quantity variables included in source	Unknown
other quantitative information included in source	Unknown
is this based on original survey data?	yes
if yes, is raw survey data available?	yes
if yes, fill out another record for the raw data	Purchasing the CD-rom give the survey raw data for free.
name of specific data source	**Video Equipment Issues**
private or public?	private
name of agency, firm, etc	Ebrain(CEMA consumer research center)
website of agency	http://ebrain.org
address of source	2500 Wilson Blvd., Arlington, VA 22201
phone number of source	(703) 907-7756
contact person and phone if different from above	the CEMA Market Research Department, (703) 907-7764
location of pointer to source	
location of source itself	The book can be ordered from CEMA
general description of the source	The survey with a random sample of 1000 U.S. households. Covers digital TV, HDTV, Camcorder, TV/VCR combination, DBS. The survey covers preference in TV size, the level of agreement with video products' role as a top source of entertainment, expectation of next TV bought being a digital TV,

Type of Information	Source of Information
	familiarity with digital TV, HDTV, frequency camcorder is used, etc..
	.
cost of the source	$495
specific price variables included in source	No
specific quantity variables included in source	
other quantitative information included in source	number of color TVs owned, number of TV screens that are 25 inches or larger, expectation of how long TV would last if bought today, number of VCRs owned, number of movies or videos rented in the past 30days, number of camcorders owned, number of prerecorded movies or videos owned
is this based on original survey data?	yes
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	**A Consumer Perspective on the Transition to Digital TV**
private or public?	private
name of agency, firm, etc	Ebrain(CEMA consumer research center)
website of agency	http://ebrain.org
address of source	2500 Wilson Blvd., Arlington, VA 22201
phone number of source	(703) 907-7756
contact person and phone if different from above	the CEMA Market Research Department, (703) 907-7764
location of pointer to source	http://www.cemacity.org/mall/startdtv.htm
location of source itself	CEMA
general description of the source	Survey of 1,000 U.S. households. Provides perspective on digital TV: familiarity with HDTV, DTV, purchase intent of digital TV, expectations for the households next TV purchase to be a digital TV , etc.
cost of the source	$495
specific price variables included in source	No
specific quantity variables included in source	
other quantitative information included in source	the number of VCRs per household, screen size of largest TV, the number of current TV viewing hours per week, the number of pre-recorded movies/videos owned, the number of movies/videos rented in a month, the number of hours spent using household computer per week.
is this based on original survey data?	yes.
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	**Leisure time allocation**
private or public?	private
name of agency, firm, etc	Ebrain (CEMA consumer research center)
website of agency	http://ebrain.org
address of source	2500 Wilson Blvd., Arlington, VA 22201
phone number of source	(703) 907-7756
contact person and phone if different from above	the CEMA Market Research Department, (703) 907-7764
location of pointer to source	
location of source itself	Ebrain(CEMA consumer research center)
general description of the source	The survey consisted of seven questions: (1) How familiar are you with the terms WebTV, DTV, MP3; (2) How much time do

Type of Information	Source of Information
	you spend watching TV; (3) how much do you spend watching movies at home on a DVD or VCR; (4) How much do you spend listening to music; (5) How much time do you spend browsing the Internet or using email; (6) How many hours per week do you spend working or playing video games on a home computer; and (7) How much time per week do you spend playing video games with a game system at home.
cost of the source	$50
specific price variables included in source	
specific quantity variables included in source	
other quantitative information included in source	
is this based on original survey data?	yes.
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	Consumer expenditure survey
private or public?	public
name of agency, firm, etc	The U.S. Department of Labor, Bureau of Labor Statistics
website of agency	http://stats.bls.gov
address of source	2 Massachusetts Ave. N.E., Washington, DC 20212-0001
phone number of source	(202) 606-6900
contact person and phone if different from above	the Division of Consumer Expenditure Surveys, Office of Prices and Living Conditions
location of pointer to source	http://stats.bls.gov/news.release
location of source itself	Average annual expenditures (1984-1997) are available on the Internet. Or, the diary and interview microdata CD-ROM can be ordered from the Division of Consumer Expenditure Surveys, Office of Prices and Living Conditions. The CD-rom data contain either separate or various combinations of Interview survey data, Diary survey data, EXPN files, and tabulated data, and is organized by the section of the interview questionnaire in which they are collected.
general description of the source	Consumer Expenditure Survey data include the expenditures classified by income quintile, income class, size of consumer unit, number of earners, type of consumer unit, age of the reference person, region of residence, housing tenure, type of area, race, occupation, and education.
cost of the source	$145
specific price variables included in source	No
specific quantity variables included in source	consumer expenditures to each item.
other quantitative information included in source	
is this based on original survey data?	yes
if yes, is raw survey data available?	The CD-rom seems to contain raw survey data.
if yes, fill out another record for the raw data	
name of specific data source	**Digital Television: Market demand study**
private or public?	private
name of agency, firm, etc	Access Media International
website of agency	
address of source	546 Fifth Avenue, 22nd Floor, New York, NY 10036
phone number of source	(212)944-5100

Type of Information	Source of Information
contact person and phone if different from above	Publications resource group, tel. (413) 664-6185
location of pointer to source	http://www.prgguide.com/reports/telecom/r149-00 w149-007w.html
location of source itself	The report can be ordered from the Publications Resource Group
general description of the source	Telephone survey of 10,008 US households- US consumers awareness of DTV; opinions regarding DTV picture/sound; and attitudes toward DTV content and interactivity; consumers' willingness to pay for DTV set; interest in DTV's communications capabilities; preferences regarding various genres of interactive content; and current/projected usage of PCs(and related IT products), TVS and the Internet.
cost of the source	$2,500
specific price variables included in source	no
specific quantity variables included in source	
other quantitative information included in source	maximum anticipated expenditures on next TV purchased, PC ownership, average viewership among head-of-household by income category.
is this based on original survey data?	yes.
if yes, is raw survey data available?	unknown.
if yes, fill out another record for the raw data	
name of specific data source	**New Technology Product Trends in the K-12 Market: Lap Tops, Hand-Held PCs, DVD, Web TV, Digital Cameras, Scanners, etc.(1999)**
private or public?	private
name of agency, firm, etc	Education Market Research
website of agency	
address of source	
phone number of source	
contact person and phone if different from above	Publications Research Group, (413) 664-6185
location of pointer to source	http:// www.prgguide.com/reports/computer/r185-008w.html
location of source itself	The book can be ordered from Publication Resource Group.
general description of the source	This is a survey result on the adoption of new technology products in the K-12 market. The survey was conducted to 600 computer/technology coordinators in elementary, middle junior high, and senior high schools. The new technology products include Web TV systems, digital cameras/VCRs, DVD drives/players/ Laptop computers.
cost of the source	$395
specific price variables included in source	No
specific quantity variables included in source	
other quantitative information included in source	
is this based on original survey data?	
if yes, is raw survey data available?	Yes
if yes, fill out another record for the raw data	
name of specific data source	**DVD interest and Awareness**
private or public?	private

Type of Information	Source of Information
name of agency, firm, etc	Ebrain
website of agency	http://ebrain.org
address of source	2500 Wilson Blvd., Arlington, VA 22201
phone number of source	(703) 907-7756
contact person and phone if different from above	the CEMA Market Research Department, (703) 907-7764
location of pointer to source	
location of source itself	Ebrain
general description of the source	A survey about consumers' familiarity with DVD and their interests according to gender, age, income, education, ethnicity, region.
cost of the source	
specific price variables included in source	No
specific quantity variables included in source	
other quantitative information included in source	The likelihood to buy a DVD player in next 12 months.
is this based on original survey data?	Yes.
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	**Digital camera and awareness**
private or public?	private
name of agency, firm, etc	Ebrain
website of agency	http://ebrain.org
address of source	2500 Wilson Blvd., Arlington, VA 22201
phone number of source	(703) 907-7756
contact person and phone if different from above	the CEMA Market Research Department, (703) 907-7764
location of pointer to source	
location of source itself	Ebrain
general description of the source	A survey about consumers' familiarity with digital camera and their interests according to gender, age, income, education, ethnicity, region.
cost of the source	
specific price variables included in source	No
specific quantity variables included in source	
other quantitative information included in source	Length of ownership of camera used most often, likelihood of buying a digital camera in next 12 months, likelihood of buying a digital camera at a price of $500, length of time spent on home computer.
is this based on original survey data?	Yes
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	**Study of Communications Technology in Higher Education**
private or public?	private
name of agency, firm, etc	SRI consulting
website of agency	http://www.sriconsulting.com
address of source	

Type of Information	Source of Information
phone number of source	(650)859-2400
contact person and phone if different from above	Susan H. Russell, srussell@sric.sri.com
location of pointer to source	http://www.sriconsulting.com/ipas/srp/ctvC.html
location of source itself	SRI consulting
general description of the source	This report is a survey report to assess how widely and what ways institutional technologies are being used in higher education. The survey covers institutional uses of computers by faculty and students; classroom applications of audio, video, and multimedia applications distance education technologies and computer-based technologies in school libraries. SRI surveyed up to six institutional representatives at each of 1000 U.S. colleges and universities, 2,000 faculty members, and 1,000 students.
cost of the source	
specific price variables included in source	No
specific quantity variables included in source	
other quantitative information included in source	
is this based on original survey data?	Yes
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	**Entertainment and Leisure Market Research Handbook**
private or public?	Private
name of agency, firm, etc	Richard K Miller & Associates, Inc.
website of agency	
address of source	
phone number of source	
contact person and phone if different from above	Publications Research Group, (413) 664-6185
location of pointer to source	http:// www.prgguide.com/reports/computer/r185-008w.html
location of source itself	The book can be ordered from Publication Resource Group.
general description of the source	The report provides a market assessment, forecast, demographics related to general trends in entertainment activities, discussion of the expected future impact of emerging technologies, identification of key players in each sector of the entertainment industry. It identifies and ranks the top 20 firms in the entertainment business based on revenues. A few of the topics of discussion include: the future of television; cable vs. satellite technology; trends in leisure time and activities; evolution of theme parks; impact of the Internet; future of filmed entertainment; and the impact of virtual reality.
cost of the source	275 (The book might be available from interlibrary loan. Interlibrary loan has been requested).
specific price variables included in source	unknown
specific quantity variables included in source	
other quantitative information included in source	
is this based on original survey data?	unknown
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	**Technology Buying Trends in the School Market:1998-99**

Type of Information	Source of Information
	School Year Sales of Software, CD-Rom, Video, and Hardware (1999)
private or public?	private
name of agency, firm, etc	Education Market Research
website of agency	
address of source	
phone number of source	
contact person and phone if different from above	Publications Research Group, (413) 664-6185
location of pointer to source	http://www.prgguide.com/reports/business/r185-003w.html
location of source itself	The book can be ordered from Publications Resource Group.
general description of the source	The report studied trends in the current school market and demand for new technology products by establishing a "technology buying index" and by tracking the actual sales performance of technology products in the k-12 school market. Product category included software, videodisc, computer hardware.
cost of the source	$495
specific price variables included in source	unknown
specific quantity variables included in source	actual sales of software, CD-rom, Videocassette, Videodisc, and computer hardware
other quantitative information included in source	
is this based on original survey data?	yes.
if yes, is raw survey data available?	unknown.
if yes, fill out another record for the raw data	
name of specific data source	**Interactive Services: Video-On-Demand/videodialtone, On-Line & Internet Services** (1996)
private or public?	private
name of agency, firm, etc	Dittberner Associates
website of agency	http://www.dittberner.com/
address of source	
phone number of source	
contact person and phone if different from above	Publications Research Group, (413) 664-6185
location of pointer to source	http://www.prgguide.com/reports/internet/r70-02w.html
location of source itself	The book can be ordered from Publication Resource Group.
general description of the source	The study includes price forecasts for video, audio and data compression. It also provides a cost comparison of competing interactive video network technology solutions for typical service areas.
cost of the source	$3,995
specific price variables included in source	
specific quantity variables included in source	
other quantitative information included in source	
is this based on original survey data?	unknown
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	

Type of Information	Source of Information
name of specific data source	**Interactive Home Entertainment: 1995 Tracking Survey of the US Market(1995)**
private or public?	private
name of agency, firm, etc	Telecommunications Research, Inc.
website of agency	
address of source	
phone number of source	
contact person and phone if different from above	
location of pointer to source	
location of source itself	
general description of the source	This report describes findings from the survey and provides projections of the subscriber revenue growth that can be expected for each of the four types of interactive entertainment services: Movies-on-Demand; Rebroadcast TV; Cable Video Games; and Interactive TV. The report describes detailed survey findings of the consumer profiles and preferences of likely subscribers to each of the four types of interactive entertainment.
cost of the source	$1,645
specific price variables included in source	
specific quantity variables included in source	
other quantitative information included in source	
is this based on original survey data?	yes.
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	**Top 20 favorite American Free and Leisure-time Activities, 1996**
private or public?	private
name of agency, firm, etc	Leisure Trends Group, Boulder, Co
website of agency	http://www.bcbr.com/mar99/leisure2.htm
address of source	3180 Sterling Circle, Suite 201, Boulder, CO 80301-2338
phone number of source	303) 440-4950
contact person and phone if different from above	Jerry W. Lewis (jwlewis@bcbr.com), editor of The Boulder Country Business Report
location of pointer to source	
location of source itself	
general description of the source	
cost of the source	
specific price variables included in source	no
specific quantity variables included in source	
other quantitative information included in source	
is this based on original survey data?	yes
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	**LEXIS-NEXIS®** Business News Section
private or public?	private
name of agency, firm, etc	
website of agency	http://www.lexis-nexis.com
address of source	

Type of Information	Source of Information
phone number of source	
contact person and phone if different from above	
location of pointer to source	
location of source itself	
general description of the source	Business News Section of Academic Universe has wire service and other business and financial news in a searchable database.
cost of the source	
specific price variables included in source	n/a
specific quantity variables included in source	n/a
other quantitative information included in source	n/a
is this based on original survey data?	n/a
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	
name of specific data source	**Dun & Bradstreet Business Sales Leads**
private or public?	private
name of agency, firm, etc	Dun & Bradstreet
website of agency	http://www.dbleads.com/
address of source	Business Marketing Solutions, Dun & Bradstreet, Three Sylvan Way, Parsippany, NY 07054
phone number of source	1-800-624-5669
contact person and phone if different from above	
location of pointer to source	
location of source itself	example at http://www.dbleads.com/edmiplus.htm.
general description of the source	name, address, total sales volume, SIC code, CEO, number of employees, main products sold but not the number sold, 3-year trend in total sales.
cost of the source	$621
specific price variables included in source	no
specific quantity variables included in source	no
other quantitative information included in source	total sales
is this based on original survey data?	no
if yes, is raw survey data available?	
if yes, fill out another record for the raw data	

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Austin, David H. 1993. “An Event-Study Approach to Measuring Innovative Output: The Case of Biotechnology” *American Economic Review* 83(2), May, pages 253-58

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