

# Micro and Macro Data Integration: The Case of Capital

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## **Abstract**

Micro/Macro data integration should be an objective of economics measurement as it is clearly advantageous to have internally consistent measurement at all levels of aggregation (firm, industry and aggregate). In spite of the apparently compelling arguments, there are few measures of business activity that achieve anything close to micro/macro internal data consistency. The measures of business activity that are arguably the worst on this dimension are capital stocks and flows. In this paper, we document, quantify and analyze the widely different approaches to the measurement of capital from the aggregate (top down) and micro (bottom up) perspectives. We find that recent developments in the data collection permit improved integration of the top down and bottom up approaches. We develop a prototype hybrid method that exploits these data to improve micro/macro data internal consistency in a manner that could potentially lead to substantially improved measures of capital stocks and flows at the industry level. We also explore the properties of the micro distribution of investment. In spite of substantial data and associated measurement limitations, we show that the micro distributions of investment exhibit properties that are of interest to both micro and macro analysts of investment behavior. These findings help highlight some of the potential benefits of micro/macro data integration.

## **I. Introduction**

An ideal but surprisingly difficult goal for the measurement of key economic variables quantifying the activities of businesses is to have the measurement of microeconomic and macroeconomic data be internally consistent. That is, ideally a given measure should be collected at the micro level (i.e., the firm or even better the establishment level) from representative surveys and that macro aggregates of the measure should reflect appropriately weighted aggregation (e.g., sums or means) of the underlying micro data. Surprisingly, this ideal is achieved for very few key economic variables – the measures that come closest to this ideal are measures of employment and payroll. Measures of outputs and inputs are typically far from this ideal (even for nominal measures). In this paper, we focus on the measurement of capital stocks and flows, which are arguably the measures that are the furthest from this ideal. Specifically, we compare and contrast the measurement methodology for investment and capital at the aggregate and at the micro (firm and establishment) level. In so doing, we quantify the extent of the micro/macro measurement inconsistencies and the associated limitations of both measurement and interpretation of capital dynamics at the micro and macro levels.

A key theme of this paper is that the micro/macro inconsistency for capital measurement stems from dramatically different approaches to capital measurement at the micro and the macro levels. In the U.S., aggregate capital measurement is based upon a top down, supply side approach. Production data for the capital goods producing industries, along with export and import data by product (asset) class yield measures of the domestic supply of each type of capital good. Measures of capital purchases/usage by government and consumers are then deducted from domestic supply to obtain gross investment total by asset class. Gross investment totals are constructed using a commodity flow methodology that allocates the commodity totals among private and government consumption and fixed business investment. To construct a measure of the capital stock for each asset class, perpetual inventory methods are used that require the historical gross investment series by asset class as well as depreciation rates and investment price deflators by asset class.

Measuring economic depreciation and investment price deflators are difficult issues in their own right, but much of our focus is on other dimensions of capital measurement. Our analysis of aggregate capital measurement focuses on two closely related issues: (i) how the

gross investment totals by asset class are allocated to industries and (ii) how the gross investment measures by asset and industry classes from the top down approach differ from the gross investment measures by asset and industry classes that can be constructed from a bottom up approach. That is, there are data on capital expenditures in business surveys that can be aggregated to industry/asset totals as well.

Currently, the top down approach for generating industry aggregates is based on the construction of capital flow tables that permit the allocation of the top down asset totals to industries. The periodic capital flow tables (produced by the Bureau of Economic Analysis) are developed every five years as part of the input-output tables for the U.S. Historically there has been limited data available to generate such capital flows tables and the BEA has, in lieu of direct information, used indirect methods and very strong assumptions to generate the capital flows tables. The limited information problem has been improved lately with the development of the Annual Capital Expenditures Survey (ACES) and the BEA has begun to incorporate the information from these data in their capital flows tables. However, the most recent capital flow table released (the 1997 capital flow table has just been released in 2003) only uses ACES data to help construct the structures portion of the capital flows table and still uses indirect methods to construct the equipment portion of the capital flows table. At least part of the reason for this is that, as will become clear, it is difficult to reconcile the industry/asset statistics that are generated from the top down and the bottom up approaches.

Another closely related focus of this paper is the nature and difficulties of measuring capital at the micro level. Increasingly, analysts interested in even macro issues seek to use firm-level data to understand the dynamics of key variables like productivity, job growth and investment. Thus, getting capital measurement right at the micro level needs to be viewed as a critical part of the data infrastructure used to measure capital in the U.S. In this paper, we review the sources of firm-level data on capital and discuss the measurement methods that are available.

Even if the data are not fully reconcilable at the micro and macro levels, it is in principle desirable to have the measurement methodology consistent. However, data limitations render this impossible. The aggregate approach is to use perpetual inventory methods by asset (or industry-asset class). At the micro level, a number of limitations make this difficult. First, even though there has been progress via the development of ACES, detailed asset information is available at the firm level only periodically (currently every five years). Rather, the key annual

business-level surveys (ACES and the Annual Survey of Manufactures, ASM) collect annual data on capital expenditures on broad asset classes: equipment and structures. Second, business-level surveys have enormous sample rotation especially for smaller businesses and (as we will highlight below) under-represent young businesses. These limitations make using perpetual inventory methods difficult at the broad asset class level and impossible at the level of detailed asset classes. Instead, analysts use a modified perpetual inventory approach to the extent possible by initializing the capital stock based upon book value data when available and then using perpetual inventory methods for businesses that have sequential years of data. We examine the properties of the micro data in light of these limitations.

Beyond the perspective that the inconsistencies between micro and macro capital measurement is the result of and induces numerous measurement problems, another key theme of this paper is that the internal inconsistency makes it very difficult to investigate the nature and sources of the variation in key economic variables. That is, given the internal inconsistency it is not easy to drill down from the published aggregates to the micro data to investigate the factors (measurement or economic) generating the observed aggregate fluctuations.

For measurement reasons alone, it would be useful to be able drill down from the aggregates to the micro level. However, recent theory and empirical evidence from the micro behavior of businesses make clear that such micro/macro data integration may be essential for understanding the economic factors driving aggregate fluctuations. For example, recent evidence has emphasized that to understand macro aggregates it is important to measure and understand the contribution of the dynamics of the entry and exit of businesses (and in a related fashion the dynamics of young and small businesses). The basic reason is that U.S. economy (like most advanced market economies) is constantly restructuring and this restructuring is associated with a large and continuing change in the composition of businesses. Entering businesses are quite different on a number of dimensions than the businesses that are exiting. Likewise young and small businesses are quite different than large and mature businesses.

All of this restructuring is quite important for measuring and understanding economic change and, unfortunately, the economic aggregates published by the statistical agencies both neglect some important aspects of the contribution of this restructuring and typically do not generally permit quantifying the contribution of this restructuring. Part of the problem stems from the natural focus on large and mature businesses in the collection and processing of data by

the statistical agencies. While large and mature businesses account for a very large share of the *level* of economic activity, the dynamics of entry and exit and the associated dynamics of young and small businesses account for a disproportionate share of the *change* in activity. This perspective suggests that measuring and understanding aggregate changes requires a measurement approach that permits the decomposition of the contribution of different types of businesses (and not simply just along industry boundaries but by entry and exit, young and mature, large and small). However, such decompositions require micro/macro consistency – that is, in the current context, to decompose the contribution of entering and exiting businesses to capital investment we would need to be able to quantify the capital investment of continuing, entering and exiting businesses in an internally consistent manner. However, since the capital investment data are not internally consistent at the micro and macro levels, this approach is generally not possible.<sup>1</sup>

The paper proceeds as follows. Section II provides a more detailed overview of capital measurement from the top down (macro) and bottom up (micro) approaches. The source data and measurement methods are discussed for both the micro and the macro approaches. Section III presents an analysis of some of the limitations of the top down approach. The focus here is on the measurement of capital at the industry level and an analysis of the relationship between industry level data from the top down and bottom up approach. Analysis of the discrepancies at the industry level makes sense because the top down and bottom up approach both can yield industry-level measures. Moreover, accurate industry level measurement is obviously critical for understanding the dynamics of the U.S. economy (e.g., the adoption of advanced technologies like computers has been far from uniform across industries and thus understanding the impact of changing technology depends critically on high quality industry measures). Section IV presents an analysis of the micro data with a focus on both the measurement limitations as well as the key properties of the distribution of capital and investment at the micro level. Alternative

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<sup>1</sup> A related argument is that recent evidence suggests that micro investment is a highly nonlinear function of fundamentals. Prima facie evidence for the latter is that investment at the micro level is highly skewed to the right, has a mass around zero and a fat right tail. It is unlikely that the distribution of shocks impacting businesses has this same shape (indeed measures of the distribution of shocks at the micro level suggest that the distribution is approximately normal). The nonlinear nature of micro investment behavior implies that the response of aggregate investment dynamics to aggregate shocks will be complex and depend upon the cross sectional distribution of the circumstances faced across firms (see, e.g., Caballero, Engel and Haltiwanger (1995)). Viewed from this perspective, micro/macro consistency is fundamentally important for understanding the aggregate response of the economy to aggregate shocks.

measurement methods and alternative data sources for micro measurement are presented and discussed. The last section provides concluding remarks.

## II. An Overview of the Measurement of Capital in the U.S.

### A. Aggregate Capital Stocks and Flows: A Top-Down Approach

The supply side, top down approach towards capital measurement draws upon production data from the capital goods producing industries, data on capital exports and imports, and personal consumption and government use of capital goods. The primary source for the production data is the Annual Survey of Manufactures (ASM), which collects data on a nationally representative sample of establishments. The ASM collects information on the total value of shipments and inventories in nominal terms and establishments are classified at the detailed industry (SIC and now NAICS) level. The Census Bureau also collects data on U.S. exports and imports via the U.S. Merchandise Trade Statistics, which uses a variety of sources (e.g., U.S. Customs, Shipper's Export Declarations, etc.) to collect data on a detailed transaction basis of the products shipped and the countries of origin and destination. For capital goods industries, combining the shipments, exports and imports data yields a nominal domestic use total by product (asset) class. Private and government consumption are subtracted from these commodity totals to obtain nominal use by the business sector.

Price deflators for these products are derived from the producer price index. Real gross investment by asset type is measured as nominal investment divided by the appropriate price deflator. The capital stock for asset type  $a$  is measured using a perpetual inventory specification given by:

$$K_{at} = \sum_{j=0}^J \theta_{ajt} I_{at-j} \quad (1)$$

where  $\theta_{ajt}$  is the efficiency of asset  $a$  at time  $t$  of vintage  $j$ ,  $J$  is the upper bound of the service life of asset  $a$ , and  $I_{at-j}$  is the real gross investment of vintage  $j$ . The efficiency schedules are based upon the service life distribution of the assets but also differ depending upon whether the measure of the capital is to measure wealth or productive use. To measure wealth, the efficiency schedule needs to reflect both physical depreciation and obsolescence while to measure the

productive capital stock only the service life and physical depreciation during the active service life should be reflected in the efficiency schedule.

While the measurement of capital stocks and flows is already difficult enough, in large part because price deflators for capital goods and efficiency schedules are inherently difficult to measure, our focus (for the most part) is on the limitations associated with measuring capital stocks and flows at the industry level.<sup>2</sup> To compute industry-by-asset gross investment totals, BEA constructs a capital flows table (CFT). The CFT provides shares of each asset type for each industry.

Historically, there has been limited data available to produce the CFT and in lieu of direct measurement, BEA has used alternative indirect source data and strong assumptions. In particular, the historical capital flows tables prior to 1997 are based upon information from the occupational distribution of employment (largely drawn from the Decennial Census data) and strong assumptions about the relationship between the occupational and asset distributions (essentially fixed coefficient technology assumptions). Starting with the 1997 CFT (just recently released in late 2003), BEA has begun to incorporate industry-by-asset information from a direct survey of asset use by businesses (ACES). However, for the 1997 CFT (which will be the source of the industry capital data for the last five years and the succeeding five years) the BEA only uses the structures detail data from the ACES for the CFT. For the 1997 CFT equipment industry-by-asset shares, the standard method of using the occupational distribution of employment is used.

BEA combines the CFT and the gross investment totals by asset to generate annual gross investment by industry and asset class. To provide more discipline on this allocation, BEA uses industry expenditure control totals at a broad asset class (i.e., equipment or structures) from other sources (e.g., ASM and ACES) to produce its final statistics for its measures of the capital stock and expenditures by industry and asset classes reported in the Fixed Reproducible Tangible

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<sup>2</sup> There is a very large literature on the measurement of depreciation and obsolescence. It is obviously of fundamental importance and also inherently difficult to measure depreciation and obsolescence. For the most part, this is not our focus given our focus on micro/macro inconsistencies. However, one area of overlap is the role of entry and exit of businesses and the measurement of depreciation. Depreciation and obsolescence schedules are based upon service life distributions of assets. The latter reflect the physical service life of an asset and to some extent the schedules reflect obsolescence via estimates from the secondary markets for capital (see, e.g., Hulten and Wykoff (1981). However, when businesses exit, the extent of irreversibility is unclear and the nature of secondary markets for businesses that are liquidated is in a related fashion unclear. In our view, this is a neglected area of the measurement of depreciation and obsolescence and our findings in Section IV below suggest this could be important.

Wealth (FRTW).<sup>3</sup>

To produce capital stocks, BEA uses the perpetual inventory approach using the industry/asset gross investment totals and the price deflators and efficiency schedules as described above. Since the FRTW is intended to reflect wealth and ownership of wealth, the efficiency schedules used reflect this conceptual objective and also adjustments are made (more on this in Section III below) for leasing vs. ownership of capital. In contrast, the Bureau of Labor Statistics (BLS) and the Federal Reserve Board (FRB) produce capital stocks by industry and asset class to measure the productive capital stock (for analysis of productivity) based upon a use basis. As such, BLS and FRB use a different efficiency schedule and make different adjustments for leasing.

The obvious micro/macro inconsistency in this top down approach is that, for the most part, the CFT does not reflect actual data on the expenditures on assets by industries. Thus, by construction, there is a potential inconsistency between the business level survey data on capital expenditures and the top down based measures. In Section III below, we analyze the nature and extent of the discrepancies between the top down and bottom up approach.

## **B. Business-level measurement of capital: A Bottom-Up Approach**

The U.S. Census Bureau conducts a number of surveys that provide data that can be used for capital measurement at the microeconomic level. The nature of these surveys has changed substantially over the last two decades so it is useful to review the changes in the survey instruments.

The manufacturing sector has historically had the best measurement of capital at the business level. The ASM through 1987 collected data on book value at the beginning and end of year, new expenditures, used expenditures and retirements (including sales) separately for equipment and structures. Since 1987, the book value questions have been only asked in the ASM in economic census years and since 1997 the book value questions only ask about the total capital and don't break out equipment and structures. Moreover, the retirement and sales

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<sup>3</sup> The use of such control totals is complicated by the fact that the expenditure totals at even a broad asset level summed across all industries do not match up that well with the gross investment totals at a broad asset level from the top down approach. As will become clear in section 3, this is one of several sources of difficulties in reconciling the top down and bottom up approach.

questions have been dropped from the ASM.<sup>4</sup> The ASM is an establishment-based survey so measures of capital can be constructed at the establishment-level and then through information in the Census Business Register can be aggregated to the firm-level if desired.

For the non-manufacturing sectors, data on book values and expenditures has historically been very sparse. In economic census years, a sample of non-manufacturing businesses had been asked in the Asset and Expenditure Survey (AES) questions about the book value of capital (total) and total capital expenditures. The AES is at the same level of aggregation as the economic censuses which for non-manufacturing sectors implies some of the data are at the establishment-level, some at a taxpayer id level (i.e., EIN) and some at the firm-level.

Since 1993, the Census Bureau has been collecting capital stock and expenditures data on an economy-wide basis using ACES as the survey instrument.<sup>5</sup> The ACES is a firm-level survey although firms are asked to break out at least some of their responses on an industry basis (e.g., on a 2 or 3 digit SIC basis). ACES collects data annually on capital expenditures (new, used and retirements/sales) by broad asset class (i.e., equipment and structures) and periodically (1998 and 2003) by detailed asset class. The ACES also collects annual information about the book value of capital (total).

One obvious use of these surveys is to generate expenditure totals (either by broad asset category or detailed asset classes) at the industry level. The expenditure totals by industry and broad asset category are used as control totals in the top down approach discussed in Section II.A above. Moreover, the industry-level data have been used in their own right to construct capital stocks by detailed industry for the manufacturing sector. For example, the NBER/CES/FRB productivity database at the 4-digit SIC level for the U.S. manufacturing sector for the 1958-98 period relies on these data.

These business-level data have also been used extensively by the research community to study investment dynamics at the micro level (the ASM data have been used much more extensively than ACES to date). Several measurement challenges immediately arise in the use of these data for this purpose. First, the historical availability of the micro data as well as the sample rotation of the surveys makes literally applying the perpetual inventory measurement

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<sup>4</sup> The deterioration of the ASM in terms of capital measurement is unfortunate as the expenditures and retirements/sales data have been used at the micro level successfully to analyze the capital adjustment processes across businesses (see, e.g., Caballero, Engel and Haltiwanger (1995) and Cooper and Haltiwanger (2003)). The type of analysis in these studies is no longer feasible.

<sup>5</sup> A pilot version of ACES was in the field prior to 1993.

specification in (1) impossible.

Consider the ASM for which the data are available for a much longer of time than for ACES. There are a large number of manufacturing establishments in the ASM that are left-censored. The ASM data at the Center for Economic Studies (CES) are available from 1972 to the present. For businesses that existed in 1972, the data are left-censored. In addition, the ASM sample rotation is every five years with only large establishments sampled with certainty. As such, data for small establishments are typically left-censored in the first year of a 5-year ASM panel. To overcome these limitations, researchers have typically applied the following variant of the perpetual inventory measurement methodology:

$$K_{et} = (1 - \delta_{it})K_{et-1} + I_{et} \quad (2)$$

where  $K_{et}$  is the capital stock for a broad asset type for establishment  $e$  at time  $t$ ,  $I_{et}$  is real gross expenditures (ideally new plus used less retirements/sales but often just new plus used given lack of retirement/sales data), and  $\delta_{it}$  is the depreciation rate.<sup>6</sup> The latter is indexed by  $i$  and  $t$  to denote that plant-level depreciation schedules are not available so the typical practice is to use the depreciation rate schedule for industry  $i$  at time  $t$ . The depreciation rate at the industry level varies over time as the asset mix of an industry changes over time.

Several measurement difficulties are immediately apparent in implementing (2). Left-censoring implies that the capital stock needs to be initialized in the initial year of observation. The standard practice is to use the book value to initialize the capital stock. Since book values don't reflect price and efficiency factors, typically there is a crude adjustment to this initial capital stock. The statistical agencies (e.g., BLS and BEA) produce capital stocks on an historical cost (book value) and real basis (the real capital stock is measured using the methods described above) at an industry-level. The typical micro researcher uses this information to make the following adjustment of the initial capital stock:

$$K_{e0} = BV_{e0} / (BV_{i0} / K_{i0}) \quad (3)$$

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<sup>6</sup> The depreciation rates and the efficiency schedules are obviously closely related. A standard method for generating industry depreciation rates is to use equation (2) along with the real measures of capital and investment at the industry level to back out the implied rate of depreciation at time  $t$  in industry  $i$ . Note, further, that Caballero, Engel and Haltiwanger (1995) and Cooper and Haltiwanger (2003) use the retirement/sales data in their measures of gross capital expenditures. Use of the latter permits these studies to study the propensity for negative gross investment which is indeed observed in the data. However, these studies find that the distribution of gross investment rates is highly skewed to the right with relatively little negative gross investment suggesting the presence of substantial irreversibilities.

where  $BV_{e0}$  is the book value for the establishment in the initial year 0,  $BV_{i0}$  is the book value at the industry level (from BEA or BLS) for the industry  $i$  that establishment  $e$  is located in for year 0, and  $K_{i0}$  is the real capital stock at the industry level (from BEA or BLS) for year 0. This adjustment of the book value corrects for price and efficiency differences in the asset mix at the industry level but obviously establishments generates mismeasurement for plants within the same industry with different vintages and asset mixes.

In addition to the problem of initializing the capital stock, investment price deflators are typically not available at the establishment-level either. Instead, researchers use the industry-level investment price deflator so that asset mix differences across establishments in the same industry also are a source of measurement error.

While implementation of this methodology for ASM establishments already raises various measurement issues, the problems are even more severe in attempting to measure real capital stock and flows at the firm-level with ACES.<sup>7</sup> For one, given that ACES only started in 1993, the left-censoring problem is large for even the businesses that are regularly sampled in ACES for currently available data. For another, the sample rotation in ACES is annual so that for small businesses the adjusted book value (as in (3)) is the only measure of the capital stock available. In addition, ACES is a firm-level survey and only asks firms to break out data at a 2- to 3-digit level. As will become clear below, there are questions about the data quality of the industry-level data in ACES as firms apparently truncate the set of industries for which they should be reporting capital expenditures. Finally, and this is another theme we return to in Section IV, ACES adds new businesses with a considerable lag. The paucity of data on new businesses raises a variety of questions. New businesses are arguably quite different in the rate and mix of investment across asset classes.

This brief overview makes transparent that the micro and macro capital stock measures are not internally consistent. Even for nominal capital expenditures the micro and the macro data are not internally consistent much less the real capital expenditures and real capital stocks. In

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<sup>7</sup> Another data source for firm-level capital stocks that has been widely used in the literature is the COMPUSTAT data. The methods for measuring capital stocks and flows from COMPUSTAT are typically very similar to the methods described in this section (with similar limitations). In section 4 (in future drafts) we plan on comparing and contrasting the ACES data with COMPUSTAT data as a further check on the quality of the ACES data. We do not focus on the COMPUSTAT data in this paper since it reflects only publicly traded companies so that the sample selection makes micro/macro comparisons not very informative.

what follows, we quantify and explore the nature of the micro and macro approaches on a variety of dimensions.

### **III. Top-Down vs. Bottom-Up: The Industry Allocation of Asset-Specific Investment**

One of the primary objectives of this paper is to quantify the extent to which the top-down and bottom-up approaches to capital measurement differ. In this section, we focus on how the two approaches yield different allocations of asset-specific investment across industries. The primary set of data on investment flows by asset and industry is the Capital Flows Table, constructed at five-year intervals by the BEA. We describe the methodology for constructing the CFT as “top-down” since the BEA first obtains economy-wide investment totals at the detailed asset level and industry investment totals at the broad asset level (equipment or structures), and then allocates detailed asset-level investment to using industries based not on micro expenditures data, but based rather on occupational employment data. As it is derived from the CFT, the BEA’s annual investment by asset-type and by industry data, the FRTW can also be characterized as top-down. An alternative, bottom-up approach would be to aggregate up to the industry-level from micro-level data on expenditures by detailed asset type. Until recently, this could not be done as such micro data did not exist. However, detailed asset-type investment data was collected in the 1998 ACES, allowing us to create a bottom-up investment-by-type-and-by-industry matrix.

Section III.B below describes a number of exercises we performed to quantify the differences and similarities between the BEA’s top-down investment allocations and the bottom-up allocations we obtained from the 1998 ACES. The ACES itself is discussed in more detail in Section III.C, including some of its important limitations as well as potential remedies. First, though, we provide some necessary background regarding the construction of the two BEA investment matrices and their conceptual differences.

#### **A. Background**

##### *Conceptual Differences*

There are two substantial conceptual differences between the CFT and the FRTW. First, the CFT is on a use basis, whereas the FRTW is on an ownership basis. The distinction

primarily has to do with how the two data sets treat operating leases. The CFT allocates leased capital to the lessee (user) industry while the FRTW allocates it to the lessor (owner) industry. The choice of treatment has an enormous impact on the distribution of certain types of capital goods such as autos, trucks, and aircraft.

The second conceptual difference is that the CFT measures only flows of *new* capital, whereas the FRTW seeks to track flows of used capital as well. For instance, for autos, the CFT provides estimates of each industry's use of autos produced in the current year. Purchases or leases of used autos would not be counted. In contrast, the FRTW attempts to first obtain each industry's expenditures on new and used autos and then net out the industries' sales of used autos to consumers or other industries (though, in practice, they can only net out sales to consumers since there is no data on inter-industry transfers).

### *Construction of the Capital Flows Table*

The methodology used by BEA to construct the CFTs in general, and the 1997 CFT in particular, is fully documented in Meade, Rzeznik, and Robinson-Smith (2003). Here we provide a brief synopsis. First, BEA obtains asset-type (row) control totals (i.e., economy-wide investment by asset-type), which are taken straight from the data on private fixed investment by asset type in the BEA's benchmark IO tables.<sup>8</sup> These totals are also published in the private fixed investment tables of the National Income and Product Accounts (NIPAs). For structures, data on private (nonresidential) fixed investment by type of structure comes from the Census Bureau's "Value of Construction Put in Place," which is based on a survey of builders of construction projects. For equipment, private fixed investment by asset in the IO tables is obtained from source data on domestic supply (shipments minus net exports), from which measures of private and government consumption are then subtracted.<sup>9</sup> Thus, we refer to the CFT's approach to obtaining asset-type control totals as the "supply-side" approach.

Second, BEA obtains industry (column) control totals from aggregated firm- or establishment-level data on capital expenditures (over all asset types). The primary sources of these data are the Economic Census (EC) and the ACES (after 1992) or the Plant and Equipment

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<sup>8</sup> For more information on the BEA's supply-side approach to obtaining asset investment totals, see Lawson, et al. (2002).

<sup>9</sup> For certain asset types, special adjustments are made to private fixed investment numbers. For example, for autos, a portion of consumers' purchases of autos are added to the business fixed investment total according to Census data on the average fraction of mileage consumers use their autos for business purposes.

(P&E) survey (before 1992). Note, however, that the ACES source data referred to here are that on total investment (available every year since 1992), not the data on investment by asset-type (available only in certain years). The industry control totals, as derived from the source data, are adjusted for some industries so that expenditures on operating leases are allocated to the lessee (using) industry rather than the lessor (owner) industry.

Third, the asset-type control totals are allocated to using industries via two methods: “direct” and “distributive.” With direct allocation, capital goods thought to be used by a small set of industries are directly allocated (in total) to those industries in proportion to their output. For example, *mining and oil field equipment* is distributed to the following industries: oil and natural gas extraction, coal mining, metal ores mining, nonmetallic mineral mining and quarrying, support activities for mining, and natural gas distribution. For capital goods thought to be used by multiple industries, their investment totals are *distributed* to using industries based on BLS data on occupational employment by industry. As Meade, *et al.* (2003) describe it, “[c]ertain occupations or sets of occupations are assumed to be good indicators of which industries use a specific type of capital good; for example, machine tools are allocated to industries by the employment of machine tool operators.” In the 1997 CFT, 85% of total new equipment investment was allocated to industries using this latter method. For the recently released 1997 CFT, investment for a subset of structures types (constituting 37% of total structures investment) was allocated using the published data on investment by industry and by asset type from the 1998 ACES. Prior to the 1997 CFT, these structures types were allocated to industries using the occupational employment data.

#### *Construction of the Fixed Reproducible Tangible Wealth investment matrix*

Now, consider the BEA’s methodology for constructing the annual FRTW investment matrices.<sup>10</sup> First, as with the CFT, they obtain “supply-side” asset-type control totals from the private fixed investment tables of the National Income and Product Accounts (NIPAs). In contrast to the CFT, for some asset types, this total is then adjusted for net transfers of used capital into the business sector (from consumers, government, or foreign countries), which are estimated using various sources of data. In the case of autos, for example, sales of used autos to

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<sup>10</sup> For a full description of the FRTW methodology, see *Fixed Reproducible Tangible Wealth in the United States, 1925-1994* (Washington, DC: U.S. Government Printing Office, August 1999).

consumers by businesses (e.g., rental car companies) are estimated using auto registration data and subtracted from total business fixed investment in autos.

Second, BEA obtains industry control totals from aggregated firm- or establishment-level survey data on capital expenditures. Starting with 1993 (the first year of the ACES), the survey data primarily consist of the ASM for manufacturing industries and the ACES (and sometimes the P&E survey as well) for non-manufacturing industries. For years before 1993, the BEA primarily uses the Economic Census for years in which it's available, and primarily uses the ASM and P&E survey for other years. Notice that for Economic Census years, the FRTW and CFT use essentially the same source data for industry control totals. However, a major difference in the CFT's and FRTW's industry control totals comes from the fact that the FRTW adjusts industry totals for transfers of used assets. For example, an industry's exports of used assets are subtracted from the industry's capital expenditures to arrive at the industry's investment total.

Third, asset-type investment totals are allocated to purchasing industries. The *initial* allocation is based on the adjacent CFT(s), which, as described above, are based on BLS occupational employment data. Since the FRTW is on an ownership-basis while the CFT is on a use-basis, this initial allocation is adjusted to an ownership-basis "using data from unpublished I-O studies, industry trade associations, and secondary sources" (BEA 1999). For years in between two CFTs, they interpolate the capital flows distribution. For years after the most recent CFT (1992, at time of this writing), they extrapolate.<sup>11</sup>

#### *Uses of the BEA's investment matrices*

The importance of the BEA's data on investment distributions by industry and by capital type is far greater than generally recognized. These distributions are frequently used in academic studies relating to the economic effects of industry IT usage (see, e.g., Autor, et al. (2003), Wolff (2002), Stiroh (2003), Wilson (2003)). In fact, some studies even use these data to analyze the relationship between occupational mix and capital mix, which, given that the distributions are based on occupational mix in the first place, is rather disconcerting. These distributions are also used by other governmental and non-governmental data programs. For instance, these

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<sup>11</sup> For the FRTW data currently available, the most recent CFT used was the 1992 CFT. The next release of the FRTW will make use of the 1997 CFT; that release is expected in late 2004 or early 2005.

distributions provide the weights used (e.g., by the Federal Reserve Board, the BLS, and Jorgenson *et al.*) to generate aggregate investment deflators from asset-specific price indices. These aggregate deflators, in turn, are used throughout empirical macroeconomics. Likewise, the distributions are also used by the BLS and others to generate measures of aggregate capital services by industry. The BLS uses these measures in their estimates of Multi-Factor Productivity (MFP). Lastly, the BEA's investment distribution data are used by businesses, academia, and government to do forecasting, marketing studies, and impact analysis.<sup>12</sup>

## B. Comparing the Top-Down and Bottom-Up Investment Matrices

Given the important and wide-ranging uses of the investment distribution data, evaluating their accuracy is crucial. Until recently however, such an evaluation was difficult (if not impossible) as there was no alternative data to compare to, at least for the United States. That changed with the 1998 Annual Capital Expenditures Survey, which collected firm-level (“bottom-up”) data on investment by detailed industry and asset type. These data can be aggregated up and used to assess the accuracy of the BEA’s investment matrices, built using their “top-down” methodology. In this section, we embark on such an assessment.

First, though, we must decide which BEA investment matrix to compare to the 1998 ACES-derived investment matrix. Since the ACES data are conceptually most comparable to the FRTW, given that both are ownership-based and they pertain to the same year, this seems a natural place to start.

In order to assess the similarity of the ACES and FRTW investment matrices, we look at three statistical measures of similarity: correlation, distance, and cosine. We report only the correlation statistics here; the distance and cosine measures yielded virtually identical results (available from authors upon request).

The two investment matrices can be compared along either the industry dimension or the asset-type dimension. That is, let  $V_{ij}$  denote investment by industry  $i$  in asset type  $j$ . Let  $v_{ij}$  denote an industry’s investment share:

$$v_{ij}^{Source} = \frac{V_{ij}}{\sum_i V_{ij}}; \text{ where } Source = FRTW \text{ or } ACES. \quad (4)$$

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<sup>12</sup> See Meade, *et al.* (2003) for a more thorough description of the uses of the CFT.

One can compute a correlation (or other similarity index) for each industry between the vectors  $\{v_{ij}^{FRTW}\}_j$  and  $\{v_{ij}^{ACES}\}_j$ . Alternatively, one can define an asset type's investment share as

$$s_{ij}^{Source} = \frac{V_{ij}}{\sum_j V_{ij}}, \quad (5)$$

and one can compute a correlation for each asset type between the vectors  $\{s_{ij}^{FRTW}\}_i$  and  $\{s_{ij}^{ACES}\}_i$ .

The mean and median (over industries) of the within-industry, cross-type correlations between the FRTW and the ACES are given in Table 1 (along with the mean and median for the other comparisons discussed below). The statistics for equipment and structures are reported separately. We find that the mean correlation over industries for equipment is 0.65 and the median is 0.77. For structures, the mean is 0.82 and the median is 0.96. If, in computing an industry's correlation, we weight asset types by their investment share (i.e., the average between the FRTW and ACES shares), the mean for equipment rises to 0.83 and the median rises to 0.97. For structures, the mean rises to 0.88 and the median rises to (virtually) 1. Clearly, weighting helps as for the average (and median) industry, the FRTW and ACES tend to align more closely for asset types that are a larger share of investment. Furthermore, as the high median suggests, there are a fair number of industries with weighted correlations close to one.

Table 1. Summary of within-industry, cross-type correlations			
<u>Correlations between investment shares from:</u>		<u>Mean*</u>	<u>Median*</u>
1998 FRTW & 1998 ACES (raw)	<i>Equipment</i>		
	unweighted correlations	0.653	0.774
	weighted correlations	0.833	0.967
	<i>Structures</i>		
	unweighted correlations	0.816	0.960
	weighted correlations	0.882	0.999
1998 FRTW & 1998 ACES-FRTW hybrid	<i>Equipment</i>		
	unweighted correlations	0.703	0.821
	weighted correlations	0.864	0.971
	<i>Structures</i>		
	unweighted correlations	0.809	0.960
	weighted correlations	0.885	0.999
1997 CFT & 1998 ACES-FRTW hybrid	<i>Equipment</i>		
	weighted correlations	0.835	0.947
	<i>Structures</i>		
	weighted correlations	0.928	1.000

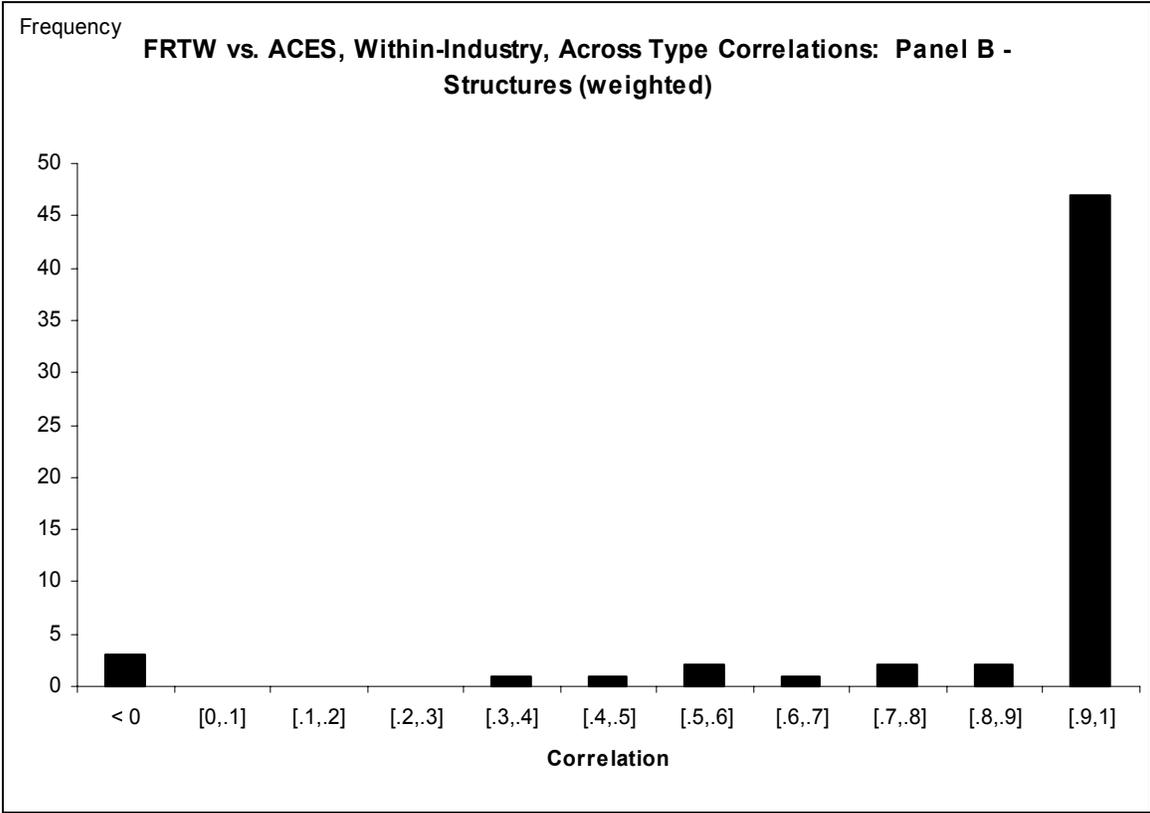
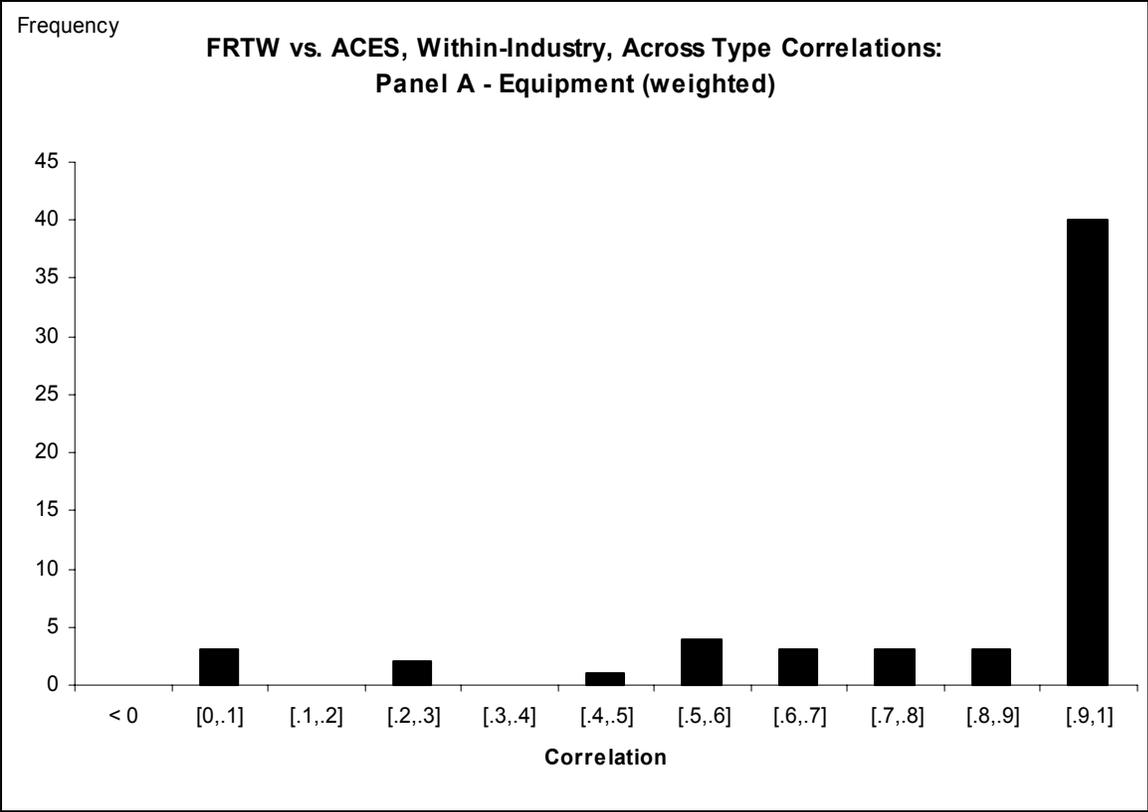
\* Over 59 industries

However, there are also a fair number of industries with very low correlations. This can be seen in Figure 1, which shows two histograms of weighted correlations over industries – one for within-industry correlations across equipment investment shares (Panel A) and one for within-industry correlations across structures shares (Panel B). For the cross-equipment-types correlations, 40 of the 59 industries had a correlation between 0.9 and 1.0. Nonetheless, a few industries had very low correlations: Metal Mining (correlation = 0.03), Petroleum Refining (0.28), Miscellaneous Manufacturing (0.55), Pipelines (0.06), Gas Transmission, Distribution, & Storage (0.05), Nondepository Credit Institutions (0.27), Security & Commodity Brokers (0.58), Insurance Agents, Brokers, & Service (0.43), Personal Services (0.53), and Repair Services (0.56). As for structures, there were fewer industries with very low correlations. Those that did have low correlations were: Public Transportation (-0.07), Water Transportation (-0.11), Transportation Services (0.55), Real Estate Offices (0.47), and Health Services (0.33). Thus, it seems that there are still some substantial discrepancies between the FRTW and ACES.

Looking at the within-type, cross-industry correlations, we find a mean of 0.68 and a median of 0.76. If, in computing a type's correlation, we weight industries by their investment share, the mean rises to 0.79 and the median rises to 0.95. Thus, the FRTW and ACES seem to have lower discrepancies for industries with larger investment (in each asset type). However, as with the within-industry correlations, there are still quite a few within-type correlations that are low. The especially low correlations were for the following types: Mobile Structures (correlation = 0.01), Educational Buildings (0.08), Religious Buildings (-0.02), Other Mining Exploration (0.03), Other Nonfarm Structures (0.15), Electrical Equipment, not elsewhere classified (0.10), Other Nonresidential Equipment (0.64), General Purpose Machinery (0.65). Also, given the wide use of the data on computer investment, it is worth noting that the unweighted correlation across industries for the computer investment share from FRTW and ACES is 0.76 – the weighted correlation for computers is 0.81.

### *Which is right?*

From the results discussed above, we conclude that the BEA's "top-down" FRTW investment matrix and the "bottom-up" matrix derived from the ACES tend to agree on the capital distributions for the most important asset types, but there are serious differences for



**Figure 1**

particular industries and particular asset types. In the face of these discrepancies, the obvious question is which is right?

Both have their advantages and shortcomings. Clearly, the primary advantage of the ACES investment matrix is that it is survey-based – i.e., bottom-up. In contrast, the allocation of asset-type investment to purchasing industries (i.e., the investment shares) in the FRTW is derived from the most recent Capital Flows Table. In turn, the investment shares in the CFT are based on arguably suspect assumptions. Specifically, as described above, the CFT investment shares are based on assumed relationships between capital use of particular asset types and employment in particular occupations. We are aware of little or no empirical support for these relationships.<sup>13</sup>

The fact that ACES is survey-based, however, doesn't mean that its data are necessarily entirely accurate. There are in fact a number of potential sources of reporting error in the ACES. First, due to incomplete records, or lack of effort on the part of the respondent, firms may not break out their investment into every industry in which they operate (as they are instructed to do). Indeed, we know from matching ACES respondents to their corresponding Business Register (BR) records that there is such “industry truncation” - an issue we explore in more depth in Section III.C. An implication of this is that the industry control totals derived from ACES may be incorrect.

Similarly, ACES respondents may fail to fully break out their investment into all of the appropriate asset types. Unfortunately, we have no alternative data source with which to evaluate the extent of this “type truncation” nor do we have any way to treat it (as we do in the case of industry truncation). Third, firms may *expense* some of their expenditures, where BEA would (properly) consider it capital investment. This may be particularly problematic for particular asset types, such as computers and software.<sup>14</sup> Fourth, ACES does not allocate the investment done by non-employers either by industry or by asset type. In 1998, capital expenditure by non-employers accounts for some 10% of nationwide investment. Note that these last three issues should mainly affect the asset-type control totals in the ACES-based investment matrix rather than the industry allocations, though it possible that some industries are more

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<sup>13</sup> In principal, one could match ACES microdata to the Occupation Employment Survey to test the strength of the fixed coefficients implicit in this allocation method.

<sup>14</sup> In 2003, the Census Bureau intends to address this by with a supplemental Information and Communications Technologies (ICT) survey, which elicits information from firms regarding expensing of ICT equipment.

susceptible to these types of reporting errors than others.

The FRTW, on the other hand, may be more accurate when it comes to the asset-type control totals. The FRTW captures economy-wide investment by asset type using the supply-side approach, described above, which is based on micro source data on domestic supply

<b>Table 2. Ratio of economy-wide investment by asset-type</b>			
<u>Asset Type</u>	<u>Ratio of FRTW to ACES investment by type</u>	<u>Share of economy-wide investment in FRTW</u>	<u>Share of economy-wide investment in ACES</u>
<i>Structures</i>			
Other Nonfarm Buildings	0.168	0.007	0.041
Mobile structures	9.034	0.003	0.000
Hotels, Motels, and Inns	1.847	0.068	0.036
Industrial buildings	0.891	0.130	0.143
Office buildings	1.156	0.180	0.152
Other commercial buildings, n.e.c.	0.821	0.137	0.163
Commercial warehouses	1.304	0.048	0.036
Hospital and institutional buildings	0.656	0.057	0.085
Amusement and recreational buildings	1.727	0.029	0.016
Air, Land, and Water Transportation Facilities	0.673	0.021	0.031
Telecommunications Facilities	0.435	0.030	0.068
Electric, Nuclear, and Other Power Facilities	1.454	0.102	0.069
Educational buildings	1.063	0.040	0.037
Religious Buildings	0.696	0.024	0.033
Other Mining Exploration	0.314	0.005	0.015
Petroleum and Natural Gas Wells	1.500	0.106	0.069
Other nonfarm structures	2.107	0.012	0.005
<i>Equipment</i>			
Instruments	1.799	0.053	0.035
Computer and Peripheral Equipment	1.043	0.125	0.142
Office Equipment Except Computers and Peripherals	2.096	0.031	0.017
Communications, Audio, and Video Equipment	1.366	0.121	0.105
Capitalized Software Purchased Separately	4.256	0.072	0.020
Fabricated Metal Products	1.355	0.014	0.012
Metalworking Machinery	0.930	0.051	0.065
Special Industrial Machinery	0.479	0.054	0.134
Ventilation, Heating, Air-conditioning, Refrigeration, and Other General Purpose Machinery	1.425	0.049	0.041
Autos	0.130	0.019	0.174
Trucks, buses, and truck trailers	6.271	0.140	0.026
Aircraft	0.926	0.030	0.039
Other Transportation Equipment	0.458	0.014	0.036
Mining and Oil Field Machinery	0.350	0.006	0.021
Engine, Turbine, and Power Transmission Equipment	0.980	0.007	0.008
Electrical Transmission and Distribution Equipment	3.622	0.034	0.011

Electrical Equipment, NEC	3.805	0.021	0.006
Furniture and Related Products	1.269	0.053	0.050
Agricultural Equipment	3.815	0.009	0.003
Construction Machinery	1.767	0.034	0.023
Service Industry Equipment	2.070	0.022	0.013
Other nonresidential equipment	2.727	0.037	0.016

(shipments minus net exports) combined with measures of government and personal consumption of each asset type. In principal, this approach captures expenditures on an asset-type irrespective of how purchasing firms account for these expenditures.

Note that the supply-side approach is not above reproach: Investment is computed as a residual (i.e.,  $I=Y-NX-C-G$ ). While Y (shipments) may be relatively well measured, measurement error in any of the remaining components will also manifest itself in I. This certainly may impact some asset classes more than others – for example, assets in which personal consumption (C) or government expenditure (G) may be particularly difficult to measure, such as computers. Nonetheless, in this paper, we assume that the BEA’s supply-side asset investment totals are more accurate than the ACES totals, given the shortcoming of ACES described above. However, further research on the accuracy of the supply-side approach would be useful.

It is clear that the asset-type control totals in FRTW and ACES differ greatly. Table 2 shows the ratio of economy-wide investment by asset-type from the FRTW to that of ACES. In most cases, ACES has lower asset-type investment than does FRTW.

As for the FRTW’s (or the CFT’s) industry control totals, for most non-manufacturing industries, the totals are actually based on the ACES micro data, so the industry totals for the FRTW matrix do not differ much from our ACES-based matrix.

### *Creating a hybrid matrix combining the advantages of FRTW and ACES*

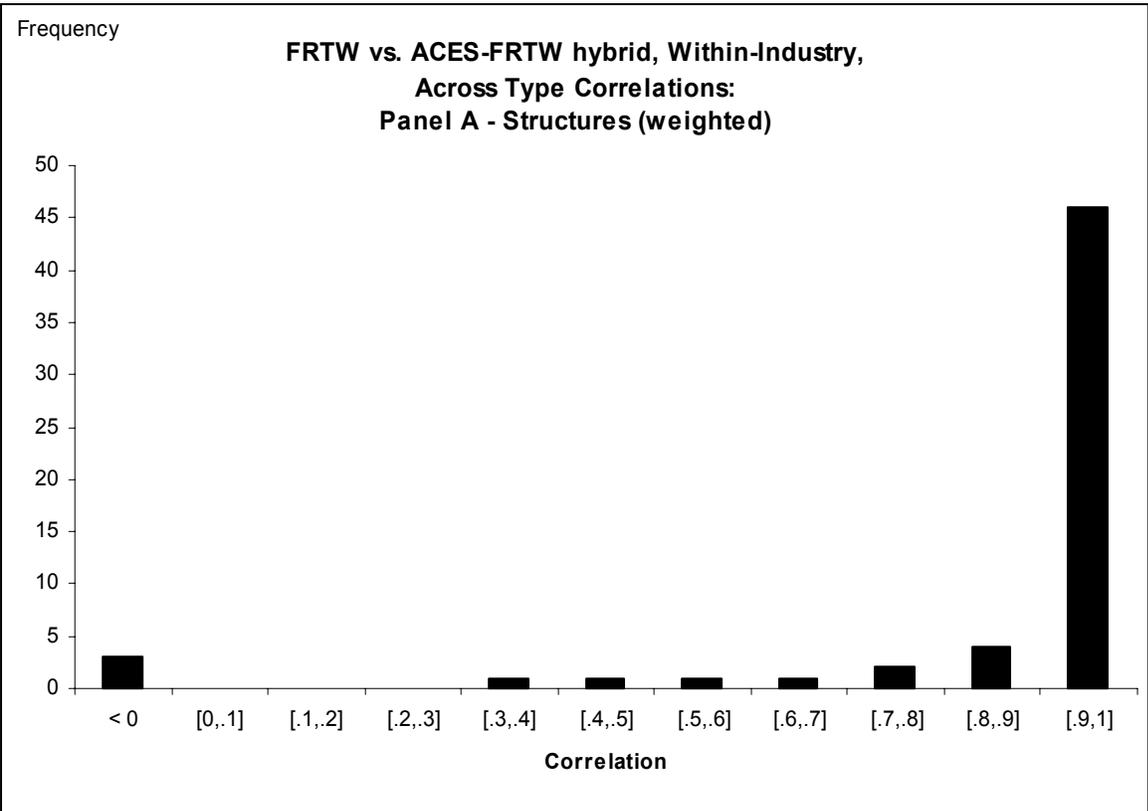
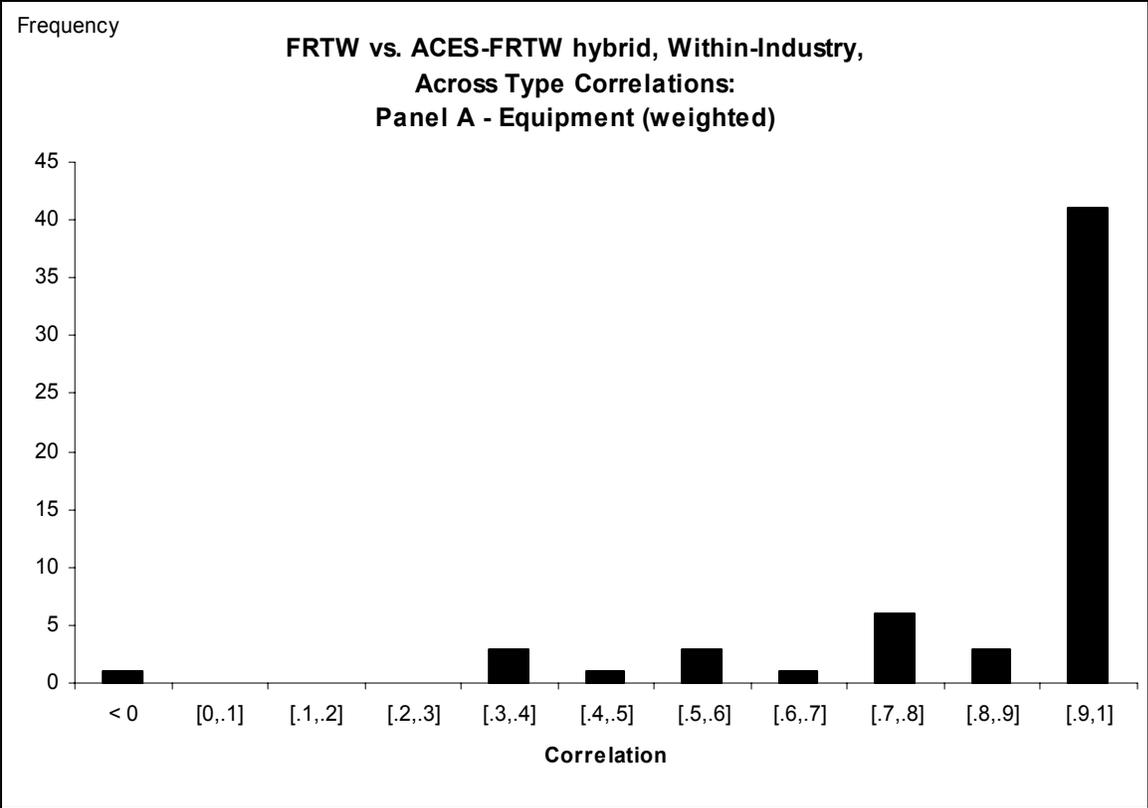
So clearly the ACES and FRTW investment matrices each have some advantages over the other. Can the advantages of each be combined to create a hybrid investment matrix that is conceptually superior to either individually? We believe they can. First, we can re-scale the ACES investment matrix to have the same asset-type control totals as those in FRTW. This should address the last three shortcomings of the ACES investment matrix that we mentioned above – namely, type truncation, expensing, and non-employer investment. And as for industry truncation, we’ve developed a methodology to help treat this problem. This is described below

in Section III.C. These two corrections yield a 1998 ACES/FRTW hybrid that is potentially superior to both.

As earlier, we computed the within-industry, cross-type correlations between the investment shares from the hybrid matrix and those from the FRTW. The correlations are computed separately for equipment types and structures types. The mean and median across industries are reported in Table 1 and the histograms (for equipment and structures, separately) are shown in Figure 2. Not surprisingly, the correlations generally are higher than those between the FRTW and the original ACES matrix. Similarly, the mean and median of the within-type, cross-industry correlations are also higher when comparing FRTW to the hybrid than when comparing FRTW to the original ACES.

The individual correlations for each type and each industry are also generally higher between the FRTW and the hybrid than between it and the original ACES. However, there remain a number of asset types and a number of industries for which there are substantial discrepancies. The industries with the lowest correlations for equipment are: Petroleum Refining (correlation = 0.36); Stone, Clay, Glass, & Concrete (0.58); Pipelines (0.47); Gas Transmission, Distribution, & Storage (-0.01); Nondepository Credit Institutions (0.36); Insurance Agents, Brokers, & Service (0.39). Those with the lowest correlations for structures are: Mining & Quarrying Nonmetallic Minerals (0.35); Tobacco (0.43); Public Transportation (-0.07); Water Transportation (-0.10); Air Transportation (-0.08); and Health Services (0.56). The types with the lowest cross-industry correlations are for these types: Mobile Structures (0.04); Educational Buildings (0.08); Religious Buildings (-0.02); Other Mining Exploration (0.03); Other Nonfarm Structures (0.17); and Electrical Equipment, not elsewhere classified (0.11).

In order to help assess which data source is more accurate, it is useful to look at an independent third source. One possible alternative source is the survey-based investment matrix constructed by Statistics Canada (StatCan). Table 3 shows the investment shares for selected asset-industry pairs from three sources: the FRTW, the FRTW-ACES hybrid, and StatCan. These selected pairs are every possible pair for which a common asset-type and industry aggregate could be obtained (since each of the three sources has its own industry and type classification systems). Of the 82 comparable pairs that we obtained, StatCan was closer to the FRTW-ACES hybrid in terms of industry investment shares in 50 pairs (60%). In terms of asset type investment shares, StatCan was closer to the



**Figure 2**

hybrid in 47 pairs (57%). The sum across all pairs of the absolute difference between StatCan's industry investment shares and those of FRTW turns out to be considerably larger than that between StatCan and the hybrid matrix. However, in terms of asset-type investment shares, the hybrid-StatCan differences are somewhat larger in total than the FRTW-StatCan differences.

Thus, in general, we find StatCan's investment distributions are more similar to the hybrid matrix than the FRTW. This begs the question: Should the BEA use this hybrid instead of the current methodology for constructing FRTW?

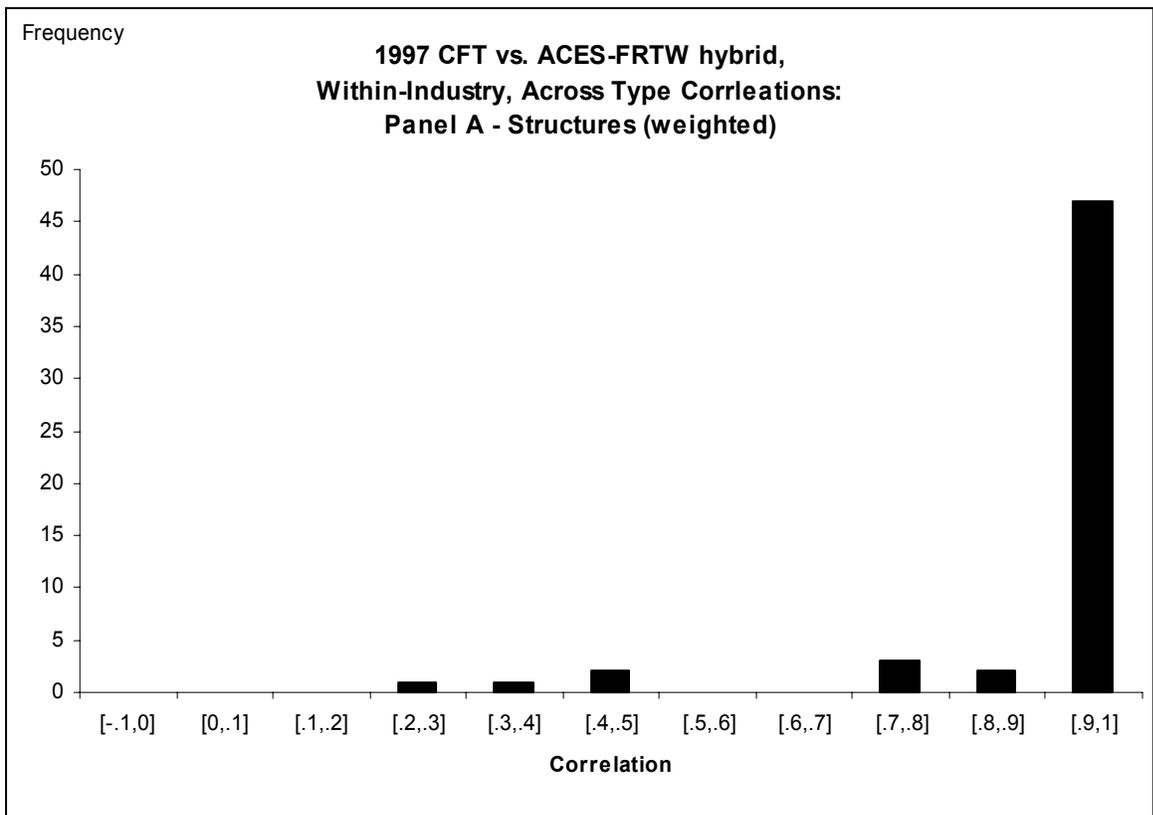
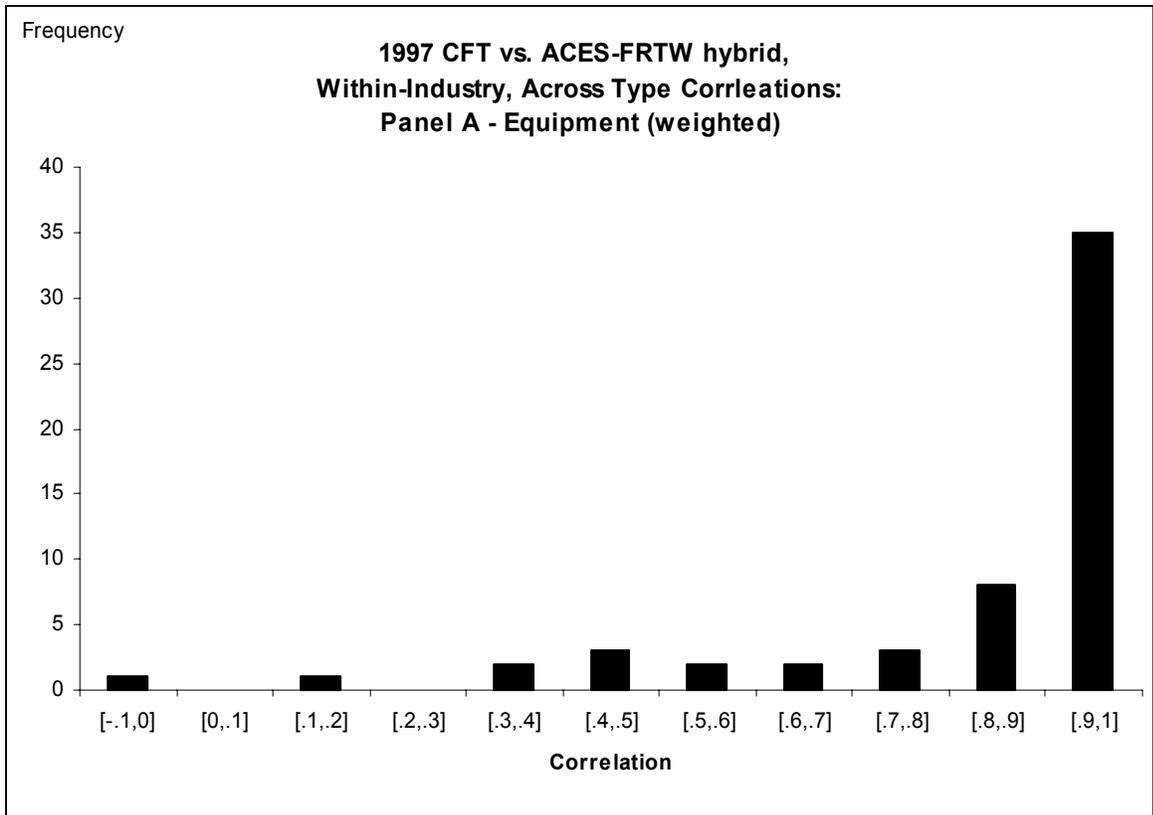
The hybrid still is not immune to the ACES shortcoming of type truncation (which could explain agreement between hybrid and StatCan, since StatCan may also be prone to similar type truncation). But this is arguably a smaller problem than the problems introduced by using occupational employment to allocate investment to industries. In fact, BEA seems to be moving towards this hybrid, as indicated by the changes in methodology introduced in the 1997 CFT. With the 1997 CFT, investment in certain types of structures (covering 35% of structures investment) was allocated to industries according to 1998 ACES distribution. Ideally, we would like to compare this 1998 ACES-FRTW hybrid to a 1998 FRTW matrix that incorporates the 1997 CFT (not just because it uses the ACES distribution for some structures types, but also because it is based on more up-to-date information). Unfortunately, the revised FRTW data are not expected to be published until 2005.

INDUSTRY	ASSET TYPE	SHARE OF INDUSTRY INVESTMENT (within Eqp. Or Str.)			SHARE OF ECONOMY-WIDE INVESTMENT IN THAT ASSET TYPE		
		STATCAN	FRTW	Hybrid	STATCAN	FRTW	Hybrid
			share minus Statcan Share	share minus Statcan Share		share minus Statcan Share	share minus Statcan Share
Business Services	Computers, excluding	80.6	-38.0	-26.9	17.2	-6.5	-5.6
Communications and Other Utilities	Production Process	16.9	-7.1	-8.7	15.3	-9.1	-9.8
Construction		5.0	2.8	-0.4	1.1	-0.1	-0.3
Educational Services		32.6	7.3	18.3	3.2	-3.1	-1.1
Finance and Insurance		11.5	28.3	16.6	23.2	5.7	0.3
Health and Social Services		20.8	-1.3	4.8	2.3	-0.6	3.0
Hotels and Restaurants		9.2	1.8	6.5	0.6	-0.3	-0.1
Manufacturing		4.8	11.5	6.8	8.9	6.5	9.3
Mining and Oil Well		0.6	6.5	4.3	0.2	0.5	0.5
Retail		22.4	3.2	2.0	4.9	1.0	3.2

Wholesale		28.7	18.2	5.2	8.2	8.6	1.7
Business Services		1.7	6.7	4.2	0.6	3.4	1.6
Communications and Other Utilities		53.5	-5.2	16.4	80.1	-22.8	1.2
Educational Services		0.8	24.2	4.7	0.1	0.1	0.3
Finance and Insurance		0.5	6.9	1.5	1.8	8.3	1.1
Health and Social Services		0.7	-0.2	0.5	0.1	0.0	0.4
Hotels and Restaurants		0.1	3.0	1.1	0.0	0.1	0.1
Manufacturing		0.3	3.2	2.4	0.8	5.4	6.4
Retail	Communication equipment	1.5	2.0	0.1	0.6	0.9	0.3
Wholesale		1.7	7.1	-0.3	0.8	5.1	-0.1
Business Services		6.9	-3.7	-4.8	8.6	-5.1	-6.2
Communications and Other Utilities		0.1	2.0	0.3	0.6	5.3	0.8
Educational Services		34.7	-32.7	-23.9	19.8	-19.8	-17.5
Finance and Insurance		0.5	1.8	-0.5	5.9	1.3	-5.7
Health and Social Services		51.4	0.1	11.2	33.4	-14.1	34.7
Mining and Oil Well		1.1	10.7	-0.9	2.2	3.1	-2.0
Wholesale	Instruments	0.8	-0.1	0.2	1.4	-0.3	0.1
Communications and Other Utilities		0.7	1.5	-0.5	2.0	2.8	-1.6
Construction		0.0	4.1	1.6	0.0	1.9	0.6
Manufacturing	Fabricated metal products and metalworking machinery	12.0	11.1	13.5	72.1	4.2	21.7
Mining and Oil Well		0.3	2.5	-0.1	0.3	0.7	-0.2
Wholesale		2.7	0.6	0.2	2.5	1.6	-0.5
Finance and Insurance		0.2	2.9	0.2	3.1	4.1	-1.9
Health and Social Services		4.1	17.1	-2.8	3.4	2.5	-2.4
Manufacturing		1.9	10.8	3.9	26.7	12.3	8.3
Mining and Oil Well		2.6	19.1	-0.6	6.8	0.4	-5.7
Retail	Industrial, energy, electrical and related equipment	3.5	1.3	10.8	5.7	-2.1	12.5
Wholesale		2.6	2.9	15.9	5.4	1.0	15.3
Communications and Other Utilities		0.6	0.0	1.4	0.3	4.1	1.1
Finance and Insurance		66.6	-61.3	-5.3	79.0	-33.3	-25.1
Manufacturing		0.1	0.0	2.3	0.1	1.5	3.9
Mining and Oil Well		1.5	-1.6	0.0	0.3	-0.4	-0.1
Retail		8.6	-6.9	-4.0	1.1	3.6	0.5
Wholesale	Autos	3.1	-5.1	5.1	0.5	-8.9	2.0
Construction		25.0	15.1	-18.1	10.9	-2.3	-3.0
Educational Services		5.0	-4.2	-4.7	1.0	-1.0	-0.9
Manufacturing	Trucks, buses, and truck trailers	0.4	1.9	0.4	1.6	1.9	7.0
Mining and Oil Well		6.6	-2.3	-4.7	4.6	-3.9	-2.8
Communications and Other Utilities		0.2	-0.2		1.4	-1.2	
Manufacturing	Aircraft	0.2	0.0	1.4	3.9	-2.8	7.6
Communications and Other Utilities	Motors,Generators ,Transformers, Turbines and Pumps	1.5	8.0	11.2	9.5	23.7	78.5
Manufacturing		1.3	5.6	-0.9	17.4	18.7	-10.6
Mining and Oil Well		0.9	6.5	-0.3	2.1	2.1	-1.2

Retail		4.3	-3.7	-4.2	6.6	-5.8	-6.3
Wholesale		1.4	1.0	-1.2	2.7	2.0	-2.1
Business Services		6.5	-1.4	-1.0	2.3	3.2	2.1
Communications and Other Utilities		2.0	1.2	-0.3	2.9	5.7	1.2
Construction		10.0	-5.8	-8.9	3.6	-1.2	-2.9
Educational Services		23.6	-15.3	-12.9	3.8	-3.7	-2.2
Finance and Insurance		5.4	1.2	-1.2	17.8	2.7	-4.9
Health and Social Services		21.3	-17.6	-15.7	3.9	-2.5	0.4
Hotels and Restaurants		83.8	-52.0	-22.1	8.7	-5.3	-1.3
Manufacturing		1.5	2.2	-0.4	4.6	10.3	1.6
Retail	Furniture and Related Products	54.8	-37.7	-22.8	19.4	-2.4	19.3
Wholesale		28.7	-24.4	-20.9	13.4	-6.8	-5.1
Construction		60.0	-32.2	-15.4	23.4	-3.8	30.1
Finance and Insurance		1.3	0.9		4.7	3.7	
Manufacturing	Agricultural and Construction Equipment	0.5	0.0	0.1	1.5	1.1	4.8
Mining and Oil Well		17.3	-3.1	-8.4	10.8	-3.0	-1.8
Business Services		34.9	-33.4	-30.1	2.5	-2.3	-2.1
Communications and Other Utilities		0.0	3.1	0.0	0.0	4.1	0.0
Construction		0.0	11.6	21.9	0.0	0.5	0.6
Health and Social Services		1.0	-0.9	-0.8	0.3	-0.3	-0.2
Manufacturing		86.8	-7.5	2.7	93.7	-27.8	-7.7
Mining and Oil Well		0.1	4.0	4.8	0.5	3.2	2.6
Retail	Industrial buildings	0.0	2.3	1.1	0.0	1.4	0.8
Business Services		26.8	29.0	37.2	2.1	4.6	3.5
Communications and Other Utilities		3.5	13.1	-0.5	7.3	8.8	-4.8
Construction		35.0	-4.6	5.1	3.5	-2.6	-2.5
Finance and Insurance		94.0	-45.8	-32.8	28.5	-1.6	17.0
Manufacturing		3.1	4.1	2.4	3.6	0.7	1.3
Mining and Oil Well	Office buildings	0.4	0.2	0.1	2.2	-1.8	-1.9
Retail	Other commercial buildings, n.e.c.	87.3	-3.8	8.8	33.0	4.7	16.6
Mining and Oil Well	Electric, Nuclear, and Other Power Facilities	3.9	-2.5	-3.3	14.3	-12.6	-13.5
TOTAL of absolute differences			794.1	570.6		420.0	489.9

So as an alternative, we can compare the 1998 hybrid matrix directly to the 1997 CFT. The shortcoming of this approach is that 1997 CFT is use-based (where ACES is ownership-based) and covers a different year. Nonetheless, in Table 1 we show the mean and median of the correlations and Figure 3 presents the histograms. Not surprisingly, the correlations for structures are extremely high. In fact, the median correlation for structures is almost exactly 1 (and the mean is 0.93). For equipment, the median correlation is 0.95 and the mean is 0.84. Thus, with the BEA's recent changes in methodology, the industry allocations of detailed asset



**Figure 3**

investment have, in effect, partly switched from a top-down to a bottom-up approach, bringing increased consistency between micro and macro data on capital flows. However, for a fair number of important equipment types, large discrepancies remain between the ACES micro data and the CFT (and FRTW) macro data. Further consideration by the BEA of using the ACES as a source for equipment investment allocations seems warranted.

In the section that follows, we introduce some of the key features of the Annual Capital Expenditures Survey (ACES) and further explore and discuss the issue of industry truncation, which (as we've noted) is an important limitation in using the ACES as a source of information about asset-industry shares and for building aggregate data. We discuss the methodology we've designed to treat the issue of industry truncation and we demonstrate its effect on reallocating capital expenditure across industries and sectors.

### **C. Working with the Annual Capital Expenditures Survey**

#### *The Annual Capital Expenditures Survey (ACES)*

In existence for over a decade, the Annual Capital Expenditures Survey (ACES) is a nationally-representative firm-level survey designed to produce industry-level estimates of capital investment in new and used structures and equipment.<sup>15</sup> Its coverage includes all non-farm sectors of the economy. In particular, prior to 1999, capital expenditure data was collected and published on nearly 100 industries at the two- to three-digit SIC level of detail, and since 1999, data are collected on a NAICS basis, with about 134 three- to four-digit non-farm industries. An additional "industry" is provided for reporting a firm's structures and equipment expenditures that serve multiple industries (e.g., headquarters, regional offices, and central research laboratories).

From 1993-1995, the ACES sample consisted of 27,000-30,000 companies with 5 or more employees, and in 1993 and 1995, an abbreviated survey form (ACES-2) was sent to 15,000 companies with under 5 employees or no employees at all (i.e., non-employers). Since 1996, the sample has consisted of roughly 32,000-44,000 companies with employees and 12,000-15,000 non-employers. The former group receives the long-form version of the survey (ACES-1) while the others receive the abbreviated ACES-2.

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<sup>15</sup> See, for example, U.S. Census Bureau (2000).

Recipients of both these forms are asked their firm-level expenditures on new and used structures and equipment. The ACES-2 form essentially stops there. Firms receiving the ACES-1, however, are also asked to report firm-level totals on the book value of assets, depreciation & retirements, new structures and equipment acquired under capital lease agreements entered into during the survey year, and capitalized interest incurred to produce or construct new fixed assets during the survey year. Most importantly, these firms are asked to provide capital expenditures data *for each industry* in which they had activity and to classify these expenditures as new or used and as structures, equipment, or other.

In certain years, recipients of the ACES-1 are asked to further break down their investment expenditures by type of structure and by type of equipment, in addition to breaking it down by industry. For example, in 1994, firms were asked to provide detail on their structure expenditure, and in 1998, detail on both structure and equipment expenditure was asked. In 1998, ACES recognized 29 distinct categories of structure expenditure and 26 distinct categories of equipment expenditure. The 2003 ACES, which is in the field at the time of this writing, also collects the full structure and equipment detail by industry.

Here (and above) we focus on just the 1998 ACES. Overall, 45,997 firms were sampled in this year, with 33,815 employers receiving the ACES-1 and the 12,182 non-employers receiving the ACES-2. Because we are interested in investment by industry and by asset type, we focus on just the recipients of ACES-1. Unfortunately, as we noted above, the capital expenditure accounted for by non-employers – totaling \$95 billion, or about 9.7% of the national total – is neither allocated to industry or asset type in the ACES, which is an important limitation and an important difference with the BEA estimates.<sup>16</sup> It is also important to note that this missing investment is likely to impact some industries (and probably some asset types) more than others. In any event, of the 33,815 firms that were sent ACES-1 forms, 27,710 (82%) responded with quality data and entered into the published aggregates. The employer universe accounted for \$879 billion of (weighted) capital expenditure. With the \$95 billion of investment by non-employers, the ACES measured \$973.6 billion in total capital expenditure in 1998.<sup>17</sup>

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<sup>16</sup> In 1995, when firms with 1-4 employees also received the ACES-2, almost 18% of national investment was unallocated to industry by ACES.

<sup>17</sup> In contrast, the FRTW recognized \$1,067.1 billion in investment and the CFT \$1,160.7 billion, though it is important to note that the industrial scope and the assets captured are somewhat different between these three sources, in addition to some of the other conceptual differences discussed above.

### *Industry Truncation in the ACES*

Among our earliest discoveries in using the ACES micro data (and we are among the very first researchers to have used these data) is that firms may be providing insufficient industry detail on the ACES — i.e., they “truncate” the list of industries that they record investment for. In particular, we noticed that many firms acknowledged far fewer industries on their ACES form than we observe employment and payroll data for in the Census Bureau’s Business Register (BR).<sup>18</sup> If true, an implication is that ACES may incorrectly distribute total capital expenditures across industries, particularly if some industries are systematically excluded more often than others and the impacts are not perfectly off-setting.

To document this phenomenon, we examine a sub sample of 26,470 ACES-1 reporters.<sup>19</sup> Employing ACES definitions of industries, we find that these firms acknowledged 1.35 industries in the ACES on average, while the same firms had non-zero payroll in 1.85 industries according to the Business Register, or 37% more. The omitted industries however appear to be among these firms’ lesser industries, at least on average. In particular, the unacknowledged industries accounted for just 11.0% of the weighted payroll.<sup>20</sup> Even so, if capital expenditure is distributed identically to payroll (hypothetically), this implies that total investment in the *reported* industries would be 12% too high on average [i.e.,  $1 \div (1 - 0.110) = 1.124$ ].<sup>21</sup> In terms of the 8,122 firms that actually operated in more than one industry (according to the BR), they acknowledged an average of 2.08 industries in the ACES, while the BR had non-zero payroll in

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<sup>18</sup> This observation relies on at least one critical assumption: If a firm had zero investment in an industry, it recorded the industry, reported zero, *and* the Census Bureau actually “keyed in” at least the industry (if not also the zero). We know from other Census Bureau surveys however that zeros are often not keyed into the database (because they do not impact aggregation). By extension, in order to conserve time and resources, the Census Bureau may not key in a line of data from an ACES form if it contributes nothing to the aggregate capital expenditure. That industry entries do sometimes appear in the ACES database with zero investment suggests that the Census Bureau does *sometimes* key in such data. But the prevalence of missing data in the database also suggests that – just like in other surveys – zeros are very often disregarded in the ACES. For our purposes, we assume that if the database shows any trace of an industry associated with a firm then the firm in fact “acknowledged” that industry and we backfill zeros into the missing values as appropriate.

<sup>19</sup> 1,024 firms are excluded from the original sample for various reasons. Most are dropped for not having industries with positive payroll in the BR. Others are dropped for having activity in various out-of-scope industries, such as agricultural production. Including these firms would complicate the analyses. Still other firms are dropped for having establishments in the BR that have insufficient SIC codes and could not be reasonably assigned proper codes. These excluded firms account for 6.4% of the weighted investment in the original sample.

<sup>20</sup> While relatively rare, firms sometime acknowledge industries that are not in the BR. Here, 3.2% of weighted capital expenditure appeared in such industries.

<sup>21</sup> This of course presumes that firms correctly report *firm-level* capital expenditure and distribute it over too few industries. Another possibility is that firms under-report the firm-level total, by omitting the investment in the unacknowledged industries. Given the structure of the ACES survey however, this scenario doesn’t likely.

3.78 industries, or 82% more. Here, the unacknowledged industries accounted for 16.8% of these firms' weighted payroll – suggesting an upward bias in the capital expenditures of the remaining industries of almost 20% on average. Industry truncation, therefore, appears to be a potentially serious concern.

Next, we explore whether certain industries go unreported in ACES more often than others. Table 4 lists the top ten industries in terms of how frequently these 26,470 firms failed to acknowledge them and in terms of the weighted payroll at stake (in billions of 1998 dollars). By either measure, *wholesale trade of durable goods (except motor vehicles)* is the top omitted industry, and the related *wholesale trade of nondurable goods (except groceries and petroleum products)* is not very far behind. This is not an entirely new finding. In their attempt to reconcile why firms responding to both the 1996 ACES and 1996 ASM reported more capital expenditure in manufacturing on their ACES form, Becker and Dunne (1999) found that firms primarily engaged in manufacturing regularly failed to acknowledge their wholesaling activities in the ACES, presumably misallocating that expenditure to their manufacturing industries instead. It seems that any industry that is secondary to a firm's primary activity runs a greater risk of being shortchanged in ACES. And to the extent that some industries are "inherently secondary", they may be systematically shortchanged by ACES. Indeed, some of the other industries in Table 4 might certainly be deemed "support" industries, such as *engineering, accounting, research, and management services* as well as *computer programming, data processing and other computer services*.

A corollary to the above is that some industries may be "inherently primary" and therefore systematically have too much capital expenditure attributed to them. In Table 5, we list the top ten types of firms (according to their primary industry) that are most likely to provide insufficient industry detail on the ACES, as measured by the percent of their collective payroll in industries unacknowledged on their forms. Two things are immediately apparent. First, some of the industries here are also among those in Table 4. This finding suggests that these industries experience off-setting effects – of having unreported capital expenditure by some firms and over-reported expenditure by others. It could also indicate that there is some discrepancies in how these firms classify their primary industry and how the Census Bureau classifies it. Second, more manufacturing industries appear here than in the prior table, and they are relatively high-tech industries at that. And not only do these particular manufacturing firms miss a large portion

of their activities in percentage terms, these activities account for quite a bit of weighted payroll.

Table 4. Industries most often omitted by firms in the ACES

<i>By frequency</i>		
1	Wholesale trade of durable goods (except motor vehicles)	1,301
2	Holding, charitable trusts, and other investment offices	1,251
3	Engineering, accounting, research, and management services	1,137
4	Other retail dealers <sup>a</sup>	851
5	Wholesale trade of nondurable goods (exc. groceries & petroleum products)	748
6	Business services, n.e.c. <sup>b</sup>	646
7	Real estate offices	509
8	Other health care and allied services <sup>c</sup>	399
9	Computer programming, data processing and other computer services	380
10	Social services (including child day care and residential care)	370
<i>By weighted payroll (Billions of 1998 dollars)</i>		
1	Wholesale trade of durable goods (except motor vehicles)	\$31.5
2	Engineering, accounting, research, and management services	24.0
3	Wholesale trade of nondurable goods (exc. groceries & petroleum products)	18.6
4	Business services, n.e.c. <sup>b</sup>	15.6
5	Other retail dealers <sup>a</sup>	15.2
6	Securities and commodity brokers and services	13.3
7	Computer programming, data processing and other computer services	12.2
8	Measuring, analyzing and controlling instruments; etc. <sup>d</sup>	9.9
9	Fabricated metal products (exc. machinery and transportation equipment)	9.2
10	Other health care and allied services <sup>c</sup>	8.7

<sup>a</sup> Excludes retail stores dealing in general merchandise (including department stores), food, apparel & accessories, and shoes

<sup>b</sup> Includes all of SIC 73 except equipment rental & leasing (SIC 735) and computer programming, data processing and other computer services (SIC 737).

<sup>c</sup> Includes medical and dental laboratories, kidney dialysis centers, specialty outpatient facilities n.e.c., and other n.e.c. activities.

<sup>d</sup> SIC 38. Also includes photographic, medical and optical goods, as well as watches and clocks.

Isolating the firms in just these manufacturing industries, we examined the industries that they were least likely to acknowledge in ACES despite having payroll in them (according to the BR). Perhaps not surprisingly, the single industry that these firms failed to report more than all others is *wholesale trade of durable goods*, which was also the top industry in Table 4.<sup>22</sup> The

<sup>22</sup> In fact, these three manufacturing industries account for over 40% of the \$31.5 billion of the uncovered payroll in *wholesale trade of durable goods* seen in Table 4.

point is that manufacturing firms tend not to think of themselves as being engaged in wholesale activity. Other unreported industries high on the list of these high-tech firms are: *holding, charitable trusts, and other investment offices* (SIC 67), *engineering, accounting, research, and management services* (SIC 87), and *computer programming, data processing and other computer services* (SIC 737).

### *Correcting for Industry Truncation*

Having documented the problem of industry truncation and described its potential implications, we now attempt to correct for it. To do so, we first assume that the information in the Business Register reflects a firm's true industrial composition. We then split the sample into two: "Complete reporters" are those firms whose list of industries on the ACES is absolutely identical to their list of industries in the BR. We employ these particular firms' ACES and BR data to compute investment-to-payroll ratios for each asset type and industry pair, simply calculated as total weighted capital expenditure in that industry-asset pair divided by total weighted payroll in that industry-asset. All other firms are designated "incomplete reporters" and their capital expenditures will be reallocated across industries using their industry-level payroll from the BR and the investment-to-payroll ratios computed from the complete reporters.<sup>23</sup>

Specifically, for incomplete reporters with non-zero expenditure in a particular asset type, we sum up their investment in that asset to the firm-level. We then completely replace the industries they recorded on the ACES with the list of industries they have payroll in according to the BR. We then multiply the payroll in these industries by the investment-to-payroll ratios specific to the asset-industry pair. This yields a firm-level capital expenditure that should not be used directly — it is the *implied distribution* of investment across industries that we are interested in however. We use this distribution to allocate the *actual* firm-level capital expenditure in said asset type to the full list of BR industries for the firm. Should this particular methodology fail – as will be the case when the investment-to-payroll ratio is zero for all of a firm's industries – we instead use the distribution of payroll to allocate capital expenditure across

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<sup>23</sup> Actually, we allow firms to cross the boundaries of these groups on an asset-by-asset basis. Suppose, for example, that a firm reports zero investment in metalworking machinery in five industries. And say that the firm in fact truncated its industry detail – it actually operated in those five industries plus three others. Because we assume that firm-level totals are correct, capital expenditure in metalworking machinery in the three omitted industries must also be zero. This firm, and its eight industries, will enter the complete reporter group for at least this one asset type.

Table 5. Types of firms most likely to provide insufficient industry detail on the ACES.

<i>Firm's primary industry</i>		<i>Payroll unacknowledged in ACES</i>	
		<i>Percent</i>	<i>Billions of 1998 dollars</i>
1	Water supply and sanitary service (SIC 494-497)	46.2%	\$3.2
2	**** Suppressed ****	39.0%	—D—
3	Holding, charitable trusts, and other investment offices (SIC 67)	37.9%	4.1
4	Measuring, analyzing and controlling instruments; etc. (SIC 38)	34.0%	12.5
5	Miscellaneous services (SIC 89)	33.5%	1.5
6	Other health care and allied services (SIC 807 & 809)	30.0%	5.1
7	Computer and office equipment (SIC 357)	29.0%	5.3
8	Communications equipment and electronic components & equipment (SIC 36)	24.7%	19.7
9	Other depository institutions (SIC 608 & 609)	21.4%	1.0
10	Wholesale trade of nondurable goods (exc. groceries & petroleum products)	21.1%	10.0

industries. The end result is a new distribution of capital expenditures across industries by detailed asset type, which served as the basis for the hybrid ACES-FRTW matrix we discussed and used in Section III.B.

One can certainly imagine more refined reallocation mechanisms than the one used here. One of the less desirable features of the current algorithm, for example, is that a report of zero investment in a particular asset for a particular industry may be overwritten with a positive value, or a positive value may be replaced with an even larger value. Yet neither of these changes have anything to do with the problem of industry truncation per se. In principle, constraints can be placed on this type of reallocation, but these are rather difficult to implement empirically, for a variety of reasons. We have also experimented with the possibility of imputing zero investment for a particular firm's investment in a particular asset in a particular industry, recognizing that investment is often "lumpy" at the micro-level.<sup>24</sup> This too is quite difficult to implement empirically and if done improperly may lead to unintended biases. So while we acknowledge that more sophisticated methodologies certainly exist, much more understanding of their side effects is necessary. Therefore, for now, we have chosen a simple and (arguably) more benign treatment.

We are also intentionally conservative – along a number of dimensions – in our approach to reallocating capital expenditure. Because we are mainly interested in matching ACES to BEA's FRTW and CFT, we first collapse the ACES data down to the lowest common denominator of industrial classification, reducing the number of industries from some 98 down to 63. One effect of this is that there are *fewer* mismatches between the ACES and the BR.<sup>25</sup> Similarly, we aggregate asset types to the lowest common denominator, which reduces the 55 ACES types to 40.<sup>26</sup> The net effect of both of these actions is large samples in the asset-industry

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<sup>24</sup> In essence, this variation of the algorithm would use the group of complete reporters to compute a *probability* of non-zero investment and an investment-to-payroll ratio *conditional on investment being positive*. This probability and conditional ratio would then be applied to the incomplete reporters. In a further refinement, the probability of investment could be set to one [zero] in cases where the firm already reports positive [zero] capital expenditure. And to remove the element of chance from the resulting estimates, this exercise can be replicated a number of times and an average of the outcomes taken.

<sup>25</sup> For instance, suppose a firm reports its activity in chemicals (SIC 289) on the ACES but not drugs (SIC 283). Because BEA recognizes no distinction within SIC 28, these data are collapsed. Therefore the firm is seen as reporting data in SIC 28, which matches what is found in the (collapsed) BR, and is classified as a complete reporter, where normally it would not have been.

<sup>26</sup> For example, *office, bank, and professional buildings* is combined with *medical offices*. Note that there are also instances in which BEA recognizes more asset detail than the ACES – e.g., the eight different types of *computer &*

cells, resulting in more robust estimates of investment-to-payroll ratios.<sup>27</sup>

For various reasons, we also decided *not* to reallocate capital expenditures in *cars and light trucks*. Like the CFT, ACES measures just the flow of new capital, ignoring the sale of used capital. This is a very important distinction for asset types with extensive resale markets, as is the case with automobiles. To demonstrate the importance of this distinction: ACES tallies over \$98 billion of business investment in automobiles in 1998 (a total that does not include expenditure by non-employers) while BEA's FRTW, which does adjust for resales, recognizes just \$12.8 billion. Surely some industries play more of a role here than others. For example, rental car agencies (SIC 751) invest heavily in automobiles but also sell off a tremendous number, generally after a few years of use. (Automobiles leased by the automakers face a similar fate.) FRTW reports \$4.8 billion of investment in automobiles by all of SIC 75 (Auto Repair, Services, and Parking), while firms in the ACES reported \$27.9 billion of (weighted) automobile investment in this industry – a difference of over \$23 billion.<sup>28</sup> We found that reallocating automobiles needlessly contaminated our analyses (particularly in certain industries) and we therefore left them in their original industries.

#### *The Reallocation of ACES Capital Expenditure*

Despite our rather conservative approach to treating the industry truncation issue, we see some significant reallocation of capital expenditures across industries and sectors. Table 6 shows the reallocation of capital expenditure across broad sectors (in millions of 1998 dollars). Interestingly, the sector that gained the most from reallocation was *wholesale trade*, while *manufacture of durable goods* lost the most. In light of our earlier discussion of industry truncation at manufacturing firms, these findings are not at all surprising. Besides *wholesale trade*, other sectors gaining large amounts of capital expenditure are *transportation, finance*, and *manufacture of nondurable goods*. Other sectors losing large amounts of investment are

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*peripheral equipment*. And there are two asset types that the ACES does not recognize at all: *custom software* and *own-account software*. This will change with the 2003 ACES.

<sup>27</sup> Though not our interest here, if assets were further collapsed into two types – equipment and structures – one could introduce investment-to-payroll ratios that varied by industry and size class. In early work with the 1995 ACES (not reported here), we did exactly that.

<sup>28</sup> Interestingly, firms that are classified as *primarily* in SIC 75 in the ACES reported over \$20 billion in “retirements and dispositions” of capital assets, which presumably includes the sale of used autos. Since this is based on firm-level totals, however, this value may also include any retirement of non-automobile assets as well as the retirement of assets these firms may have had outside of SIC 75. And the retirement of automobiles in this industry by firms *not primarily* engaged in this activity is excluded from this figure. Nonetheless, we see that this magnitude is similar to the \$23 billion gap between FRTW's and ACES's estimates of automobile investment in this industry.

*services, insurance & real estate*, and the ACES category “serving multiple industries.” A virtue of our algorithm is that capital expenditure in the latter is actually allocated to industries.

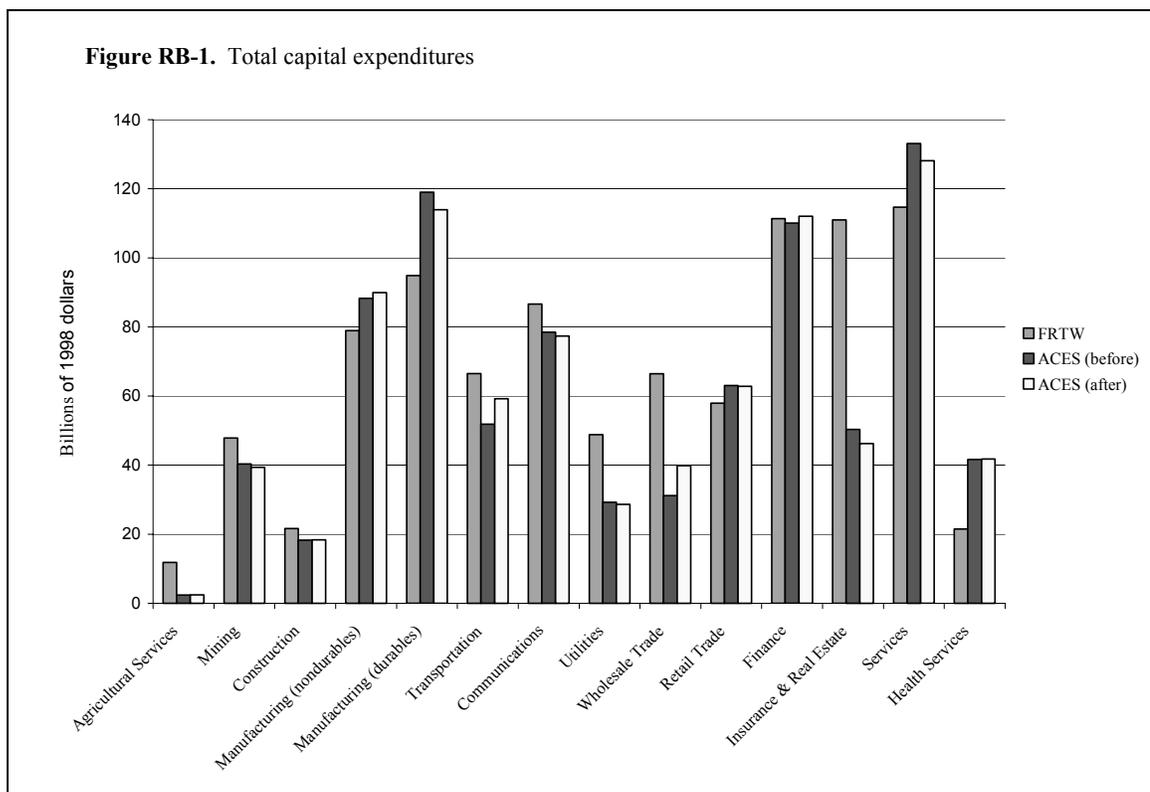
<u>Sector</u>	<u>Millions of 1998 dollars</u>
Agricultural services, forestry, and fishing	+61
Mining	-1,008
Construction	+98
Manufacturing (nondurables)	+1,615
Manufacturing (durables)	-5,074
Transportation	+7,395
Communications	-1,127
Utilities	-609
Wholesale Trade	+8,641
Retail Trade	-252
Finance	+2,000
Insurance & Real Estate	-4,074
Services	-5,013
Health Services	+111
<i>Serving multiple industries</i>	-2,766

Underlying Table 6 is a much larger table by detailed industry and detailed asset type (not presented here). This table reveals that the reallocation of the \$8.6 billion of capital expenditure toward *wholesale trade* is unusually broad, in the sense that nearly every asset type experienced a net gain in expenditure. This sort of robust reallocation does not appear to be the norm in other industries experiencing large net changes.

For example, in terms of the increase in investment in the transportation sector, roughly half of the \$7.4 billion is accounted for by the industry *motor freight transportation & warehousing* (SIC 42), which had most of its increase from non-automobile transportation equipment. In the *finance* sector, *holding, charitable trusts, and other investment offices* (SIC 67), in particular, experienced a large increase in capital expenditure, most of which was in commercial buildings. Meanwhile, in the *manufacture of nondurable goods* sector, the industry experiencing the largest gain was *chemicals and allied products* (SIC 28), mainly in industrial buildings. It is important to note that not all industries in a sector necessarily move in the same direction. *Food and kindred products* (SIC 20), for example, experienced a decrease similar in magnitude to the increase in *chemicals*, chiefly through a loss of miscellaneous equipment.

In terms of the sectors experiencing large losses of capital expenditure as a result of reallocation, *manufacture of durable goods* leads the list. Here we find that *communications equipment and electronic components and equipment* (SIC 36) is the largest of the losers, mostly

in various types of industrial equipment.<sup>29</sup> Again, however, there is heterogeneity within the sector; for instance, *primary metals* (SIC 33) experiences substantial gains. The decline in investment in the *service* sector comes mainly in *business services* (SIC 73) and *automotive repair, services, and parking* (SIC 75), and the vast majority of that is accounted for by a decline in non-automobile transportation equipment. And in the *insurance & real estate* sector, *real estate offices* (SIC 65) is found to lose a large amount of capital expenditure in commercial buildings. In future work, we hope to explore some of these changes in more depth – both at a greater level of asset detail and by examining source-and-destination industry pairs.



**Figure 4.** Total capital expenditures

Finally, in Figure 4 we show how these reallocations affect sectoral totals vis-à-vis BEA’s FRTW. This is done for the assets and industries that ACES and FRTW have in common.<sup>30</sup> We see that our reallocation efforts moved ACES noticeably closer to FRTW totals

<sup>29</sup> Recall that this industry was among the leaders in Table 5.

<sup>30</sup> In particular, ACES does not recognize investment in 2 types of software, nor does it tally capital expenditure for *agricultural production* (SIC 01-02). FRTW, on the other hand, does not contain capital expenditure for *combination electric and gas, and other utility services* (SIC 493), *water supply* (SIC 494), *steam and air-*

in manufacturing (durables), transportation, wholesale trade, and services, but large differences still exist, particularly in insurance & real estate, wholesale trade, health services, utilities, and manufacturing (durables). Part of these discrepancies might be due to remaining conceptual differences. First, recall that capital investment by non-employers (totaling \$95 billion in 1998) are not included in ACES totals, which may certainly explain at least part of the gap seen in an industry like insurance & real estate. Second, ACES does not attempt to adjust for the sale of used capital, which we know from our example above amounts to \$23 billion in just one particular service industry. Third, there may be issues with the expensing of capital expenditure by firms in the ACES. And then there are the issues surrounding leasing. Therefore, while our correction for industry truncation in the ACES may matter, it is not the whole story.

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*conditioning supply* (SIC 496), *irrigation systems* (SIC 497), and *social services* (SIC 83). Neither recognizes the *US Postal Service* (SIC 43), *private households* (SIC 88), and *public administration* (SIC 9). With these restrictions, the FRTW contains \$939.9 billion in capital expenditure in 1998 while ACES contains \$860.1 billion. These totals cannot be easily compared because conceptual differences still remain.

#### **IV. Business-level Capital and Investment: A Bottom Up Approach**

High quality business surveys on capital stocks and flows are critical for building aggregates from the bottom up but also the micro data are critical for understanding the behavior of investment at the micro and the macro levels. The longitudinal business datasets developed in the U.S. have increasingly been used by analysts to study the behavior of productivity, investment, employment, and price and wage dynamics. Part of the motivation for analysts to use such micro data is obvious as the decision making unit is the firm or the establishment. Therefore, testing alternative economic models of business behavior is best achieved with micro data. Aggregate data (at the industry or economy-wide level) can only be used if firms within a given industry are relatively homogenous in their behavior. However, the recent literature using micro data shows that, for investment in particular, micro and macro data provide a very different picture of investment dynamics. Macro investment dynamics are volatile in the sense that investment is highly procyclical but the aggregate data changes over a relatively narrow range of investment rates and in a smooth fashion. In contrast, investment at the micro data is very lumpy – there is a mass of businesses with zero or little investment and a fat right tail of businesses that exhibit what has been denoted an investment spike (see, e.g., Caballero, Engel and Haltiwanger (1995), Doms and Dunne (1998) and Cooper, Haltiwanger and Power (1999)). This recent literature has emphasized that this lumpy micro behavior implies complex aggregation. That is, movements in the aggregates will reflect both intensive and extensive margins with the latter reflecting businesses discretely switching from inaction to action ranges for investment.

In this section, we explore the properties of the micro distribution using the two key business level surveys the statistical agencies (Census) use to collect data on capital stocks and flows (the ASM and ACES). Our primary goal is to illustrate key properties of the micro distribution that highlight the idiosyncratic features of the micro distribution with a particular focus on those features that raise questions about aggregation and aggregate fluctuations. As noted in section II.B, data limitations in these surveys unfortunately make it difficult to apply exactly the same measurement methodology (e.g., perpetual inventory) used in constructing investment rates using aggregate data. Instead, either an adjusted book values or a modified perpetual inventory method is used to construct capital stocks (and in turn act as the denominator

in calculating an investment rate). As such, we also explore the sensitivity of the distributions at the micro level to these measurement issues.

### **A. The Annual Survey of Manufactures**

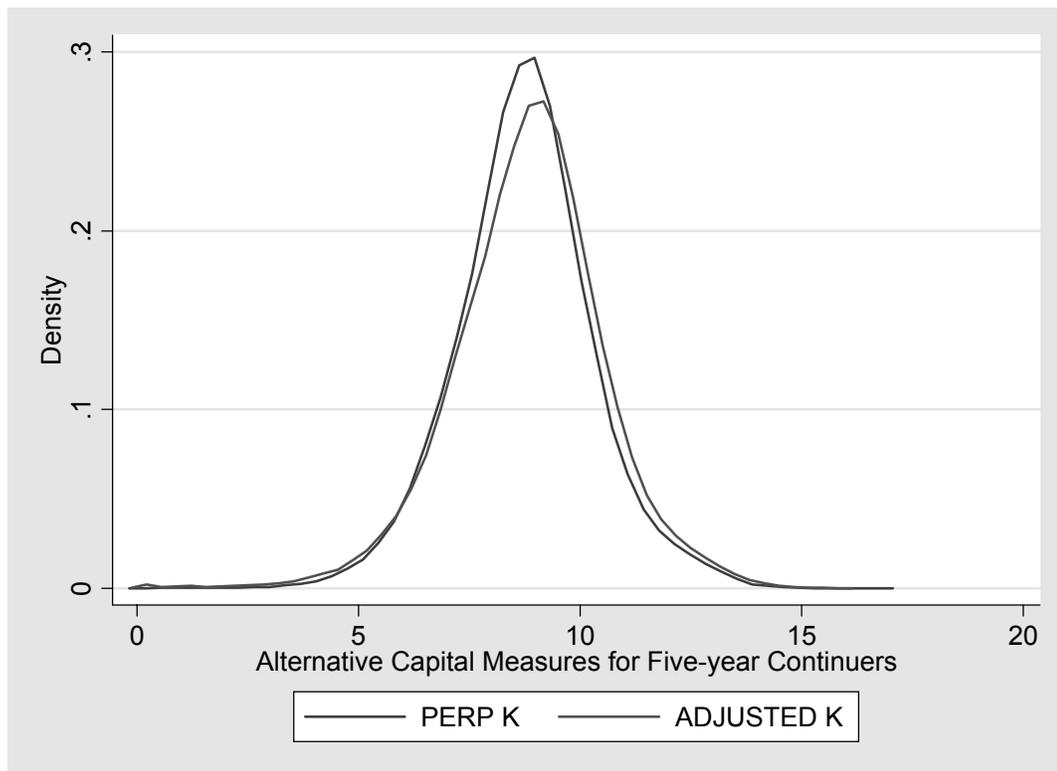
In this subsection, we explore the measurement and properties of business-level capital and investment using the ASM. Our objectives are broadly threefold. First, we explore the limitations of alternative measurement methods outlined in Section II. In particular, we examine the properties of investment and capital measures using the modified perpetual inventory specification given in (2) vs. the adjusted book value specification given in (3). We compare and contrast the properties of the micro and macro capital and investment using these alternative measurement specifications. In addition, we explore the sensitivity of analyses using such alternative capital stock measures – here our metric is the impact that alternative measures have on the measurement of total factor productivity. Second, we summarize and explore key features of the micro distribution of investment. In so doing, we highlight the features of the micro distribution that suggest that having an internally consistent and fully integrated micro/macro measurement of capital would be important for understanding the aggregate fluctuations. Third, we explore basic aggregation issues by comparing and contrasting the properties of the distribution of investment at the establishment and at the firm level. The ASM has the advantage that analysis can be conducted at the establishment level and it is of interest to understand how the properties of business-level investment change as we aggregate data from the establishment to the firm level.

#### *Perpetual Inventory vs. Adjusted Book Values*

The ASM is the only dataset that measures capital stocks and flows at the establishment level. There have, however, been some major changes in the collection of capital data on the ASM. The ASM collected beginning and ending year book values broken out by equipment and structures each year until the 1987 Census of Manufactures (CM). After 1987, the book value question is only asked during a Census year (every five years). In the 1997 CM, only total book value was collected. For these reasons, we can only construct adjusted book values of capital stocks for the period 1972-1987, 1992, and 1997. Fortunately, investment data, broken out by both equipment and structures, has been collected in the ASM continuously for the entire 1972 to 2000 period. Using the detailed investment data along with the book value data to initialize the series,

the modified perpetual inventory method described in Section II.B (equation 2) can be used to construct capital stocks at the establishment level for the vast majority of plants in the ASM.

In what follows, we often compare our measures for all plants and then for a subset of plants that have at least five years of prior continuous plant history. The reason for focusing on the latter subset in this context is that the difference between the capital stocks computed on an adjusted book value basis (equation 3 of Section II.B) and on the modified perpetual inventory basis (equation 2 of Section II.B) will be by construction zero in the year the plant first appears in the ASM and can only grow over time based upon the plant having a different vintage structure of capital relative to the average plant in its 2-digit industry (see the discussion in Section II.B for a more complete discussion). We denote this subset of plants the “five-year continuers” in the analysis that follows.

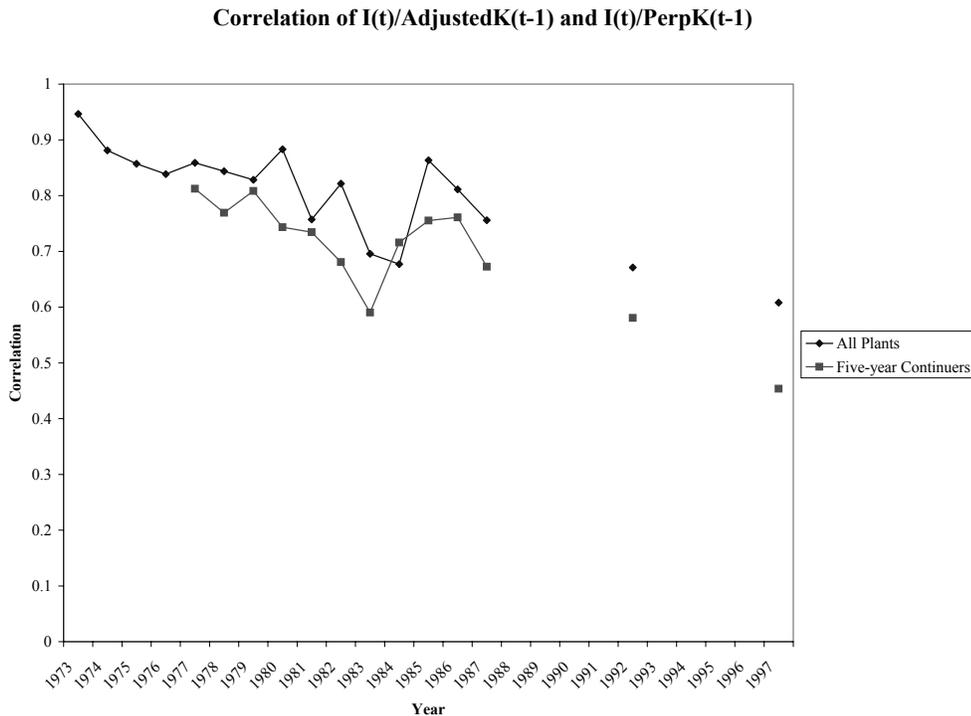


**Figure 5**

Figure 5 provides a comparison of the distribution of adjusted book value capital stock and the modified perpetual inventory capital stock using the five year continuers. We observe the distribution of perpetual inventory capital is slightly to the left of the distribution, with more mass in the center of the distribution. Thus, one difference is that the adjusted book value yields too

high a mean and too high a variance of the capital stock relative to the preferred perpetual inventory measures. However, the distributions are remarkably similar and the correlation at the micro level is above 0.9 (overall and in all years separately).

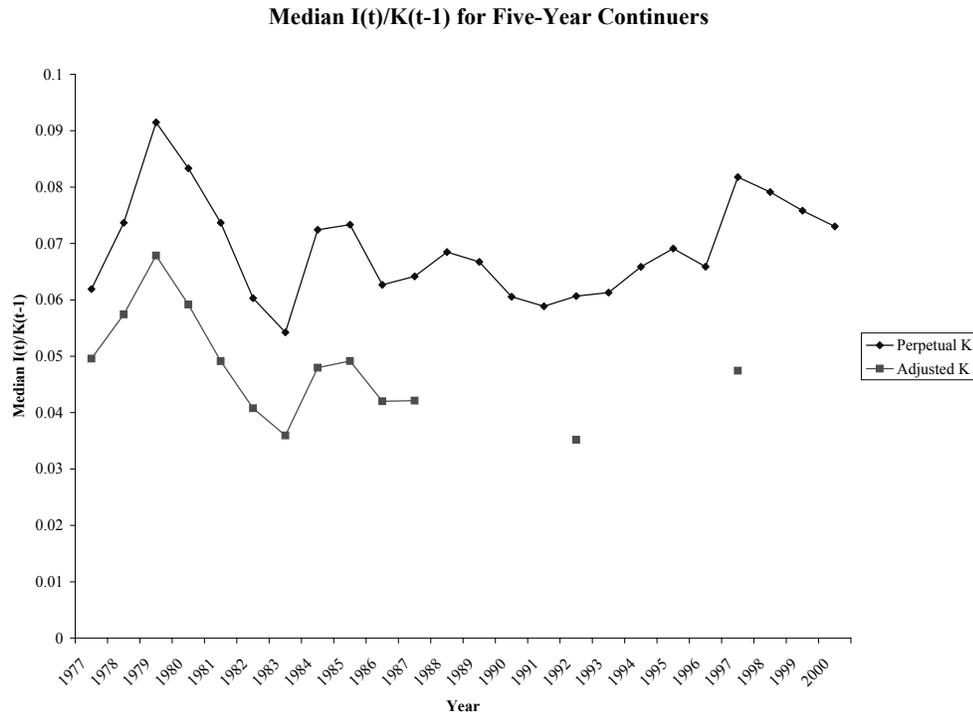
We now turn to properties of the investment rate defined as real investment divided by the beginning of year capital stock in their year. As Figure 6 shows, the correlation of investment rates is also highly correlated. We find that the correlation is generally higher when we include all establishments and is always greater than 0.6. This is sensible considering that the full sample include the years when the capital stocks are initialized in the perpetual inventory method (i.e., when the two measure of capital stocks are equal). When we only look at the five year continuers, we find that the correlation of the two measures is not as strong, but is still relatively high (in the .6 to .8 range) in the period prior to 1987 when the ASM still collected data on capital stocks. In 1992 and 1997 the correlation falls off, but this also would include a set of long lived establishments that would have significantly different measures of capital stocks across the two measures.



**Figure 6**

While these correlations are quite high they are far from one and they are also time varying. These findings thus serve as a caution to the micro data analyst who is studying investment rate

behavior with micro data and only can construct capital stocks using an adjusted book value. Put differently, while the capital stock distributions are very similar the investment rate distributions are apparently less so. In what follows, we explore some of the key features of these distributions to explore these issues further. For the remainder of the analysis, we focus our attention on the five year continuers, since they are the more interesting comparison for this purpose.

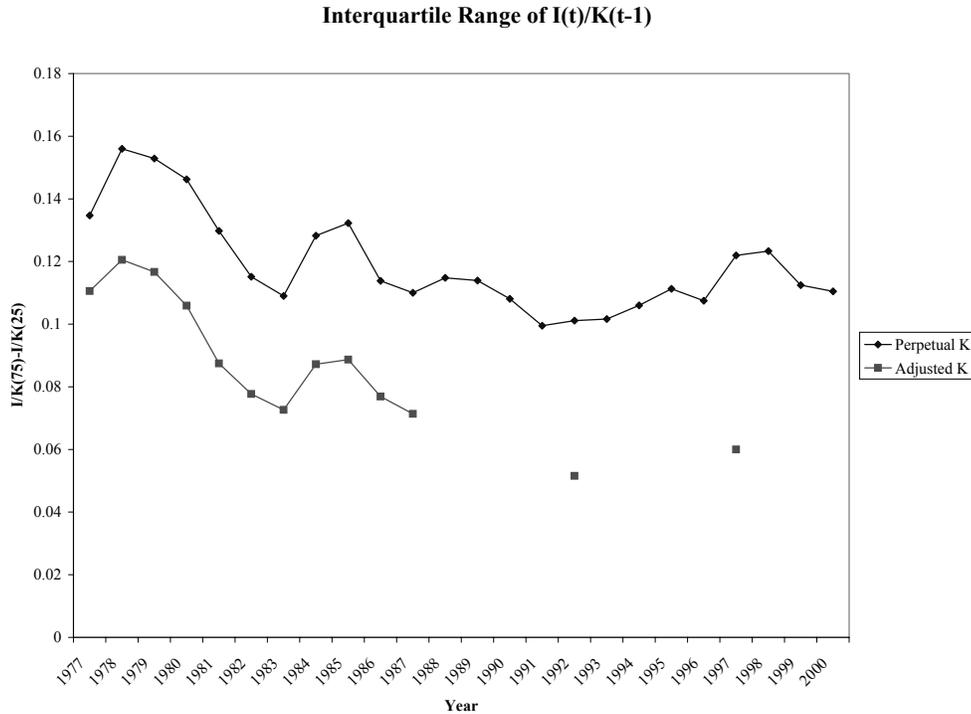


**Figure 7**

In Figure 7, we show the annual time series fluctuations for the median investment rate using the alternative two capital measures. First, we note that the perpetual inventory method yields higher medians. On the low side, the median investment rate ranges from 5.5% of capital in the previous period to just over 9%. The two measures yield the same time series variation, with both series showing increases in median investment rates during the boom periods of the business cycle, and declines during recessionary periods. The median investment rate also exhibits little if any secular trend.

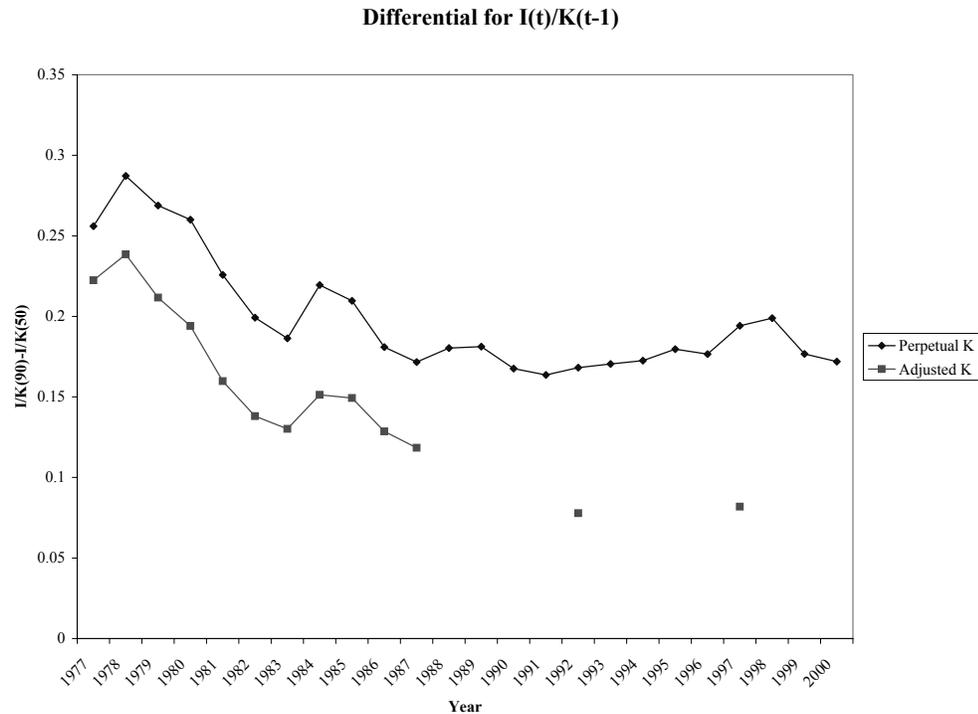
In addition to examining the fluctuations in the median of the micro distributions distribution, we also examine how the shape of the distribution is changing over time. In Figure 8, we show the interquartile range for the investment rate distributions. Interestingly, we find that the interquartile range widens during boom periods and declines during contractionary ones. If we

focus on the boom in the late 1970s, we find that the 75<sup>th</sup> percentile invests roughly 16% more of its capital stock than the 25<sup>th</sup> percentile did. This difference is large given that the median investment rate is roughly 9% at this time.



**Figure 8**

We also look at how the upper tail of the distribution fluctuates over time. In Figure 9, we look at the difference between the median establishment investment rate and the investment rate of the 90<sup>th</sup> percentile. The right tail is more spread out using the perpetual inventory based measure compared to the adjusted book value. We also find that the upper tail of the distribution spreads out in cyclical upturns and this pattern holds for both capital measures. For example, in 1978 (a boom year), the 90<sup>th</sup> percentile of the establishment distribution invests nearly 28% more it's capital stock than the median establishment does while during the recession of the early 1980's, there is a large decline in the 90-50 differential to about 18%. Looking at Figure 7, the change in the median investment rate from peak to trough over this period is roughly 3.5% while the change in the 90-50 differential is about 3 times that large – implying that the change in the 90<sup>th</sup> percentile is much greater than the change in the median in going from peak to trough.

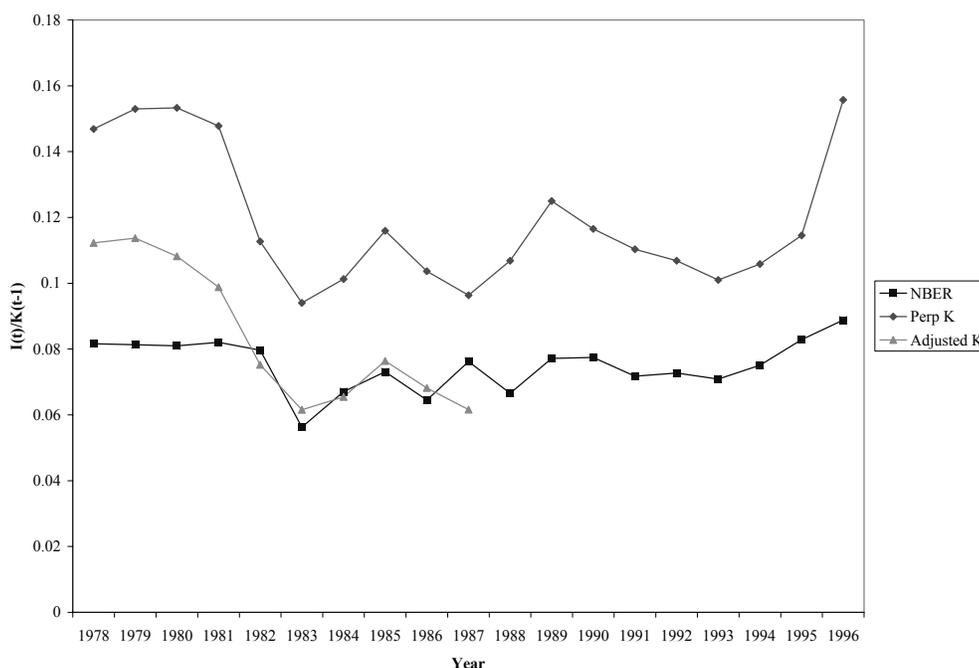


**Figure 9**

Another dimension to check the respective merits of the alternative capital stock measures is to consider the aggregate behavior of the measures at the industry and total manufacturing level. For this purpose, we consider the sample of five year continuers and generate capital stock and flow (investment) aggregates using ASM sample weights. Figure 10 shows the implied aggregate investment rates using this aggregation compared to the aggregate investment rate from the NBER/CES/FRB productivity database. While the latter is based on the ASM data, the capital stock series is generated using a long time series of real gross investment rates and perpetual inventory methods.<sup>31</sup> The perpetual inventory micro data yields a higher average aggregate investment rate than either the NBER or the micro adjusted rate. Both of the aggregates from the micro data are highly correlated with the NBER series (0.76 for the perpetual inventory and 0.75 for the adjusted book value). Figure 11 presents the annual correlation across the 4-digit industry investment rates. For the aggregate perpetual inventory data the correlation averages 0.53 while for the aggregate adjusted book value the correlation averages 0.42. There is volatility in the 4-digit industry correlation that is countercyclical.

<sup>31</sup> While perpetual inventory with a long time series are used in the NBER/CES/FRB dataset, the investment series is from the ASM and thus is not based upon a top down, supply side approach.

**Manufacturing  $I(t)/K(t-1)$**



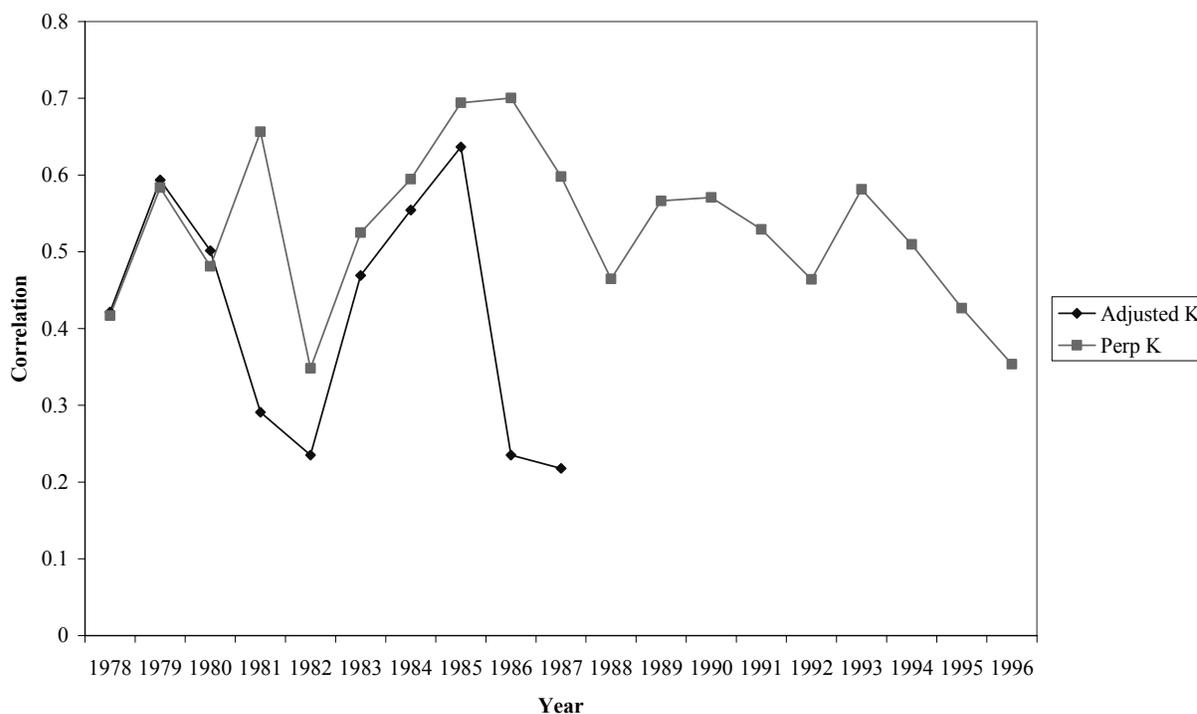
**Figure 10**

As a additional check of the sensitivity of micro patterns to these alternative capital stock measures, we consider how the alternative capital stock measures compare in terms of estimating production functions and measuring total factor productivity. Table 7 presents OLS estimates of production functions using the alternative measures. It is apparent from Table 7 that both capital stock measures yield virtually identical results in terms of factor elasticities. Moreover, the correlation of the implied TFP (the residual) is very high. As a related cross check, we calculated TFP using cost shares but again with the alternative capital stock series. Again, the correlation of TFP is very high using these alternative capital stock measures.

To sum up, the adjusted book value and perpetual inventory capital stocks are highly correlated at the micro level. They perform about the same if the use of the capital stocks is to estimate production functions and TFP. Moreover their aggregate properties are similar and match fairly well and yield aggregate fluctuations at the industry and total manufacturing level similar to those from published aggregates for the manufacturing sector. There are enough differences between them that there are some notable differences in the mean and dispersion of the capital stocks which translate into differences in the mean and dispersion of investment rates. Fortunately, these latter differences while notable are fairly stable over time. These patterns are

reassuring for analysts who are restricted to use micro datasets where the only measure of capital available is the book value.

**Correlation across aggregate industry I/K**



**Figure 11**

**Table 7: Sensitivity of Production Function Estimation to Alternative Capital Measurement**

*Production Function Estimation:*

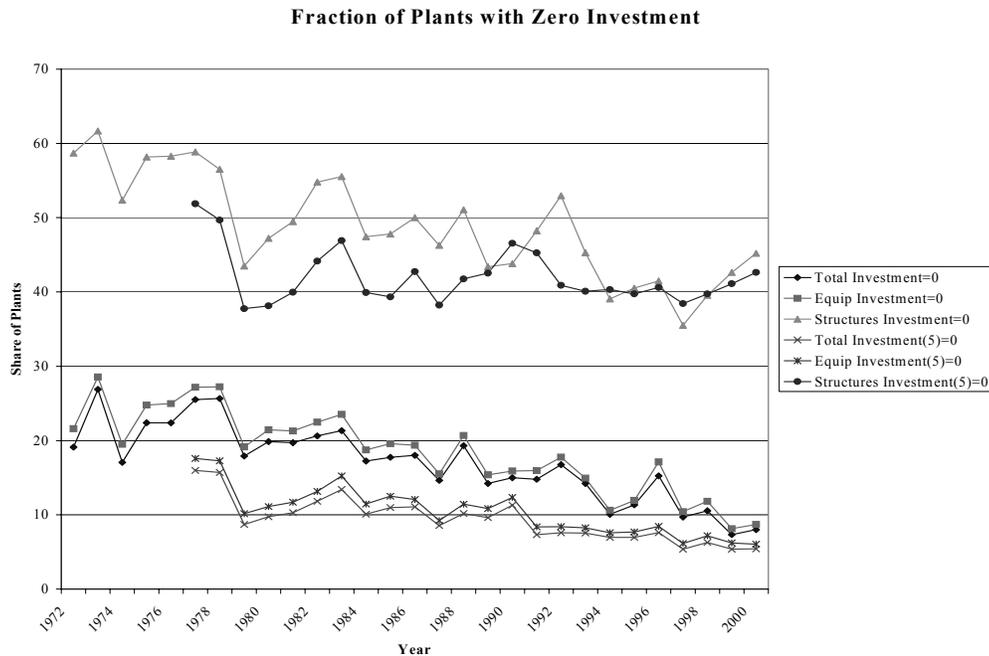
	<u>Perpetual Inventory</u>	<u>Adjusted Book Values</u>
Equipment	0.0365 (0.0007)	0.023 (0.0006)
Structures	0.062 (0.0009)	0.076 (0.0008)
Labor	0.287 (0.0008)	0.284(0.0008)
Material	0.593 (0.0007)	0.597 (0.0007)
Energy	0.016 (0.0007)	0.012 (0.0008)
Correlation of TFP	0.994	
Correlation of TFP (cost shares)	0.995	

Sample: Five-year continuers

### Key Properties of Micro Distribution

The previous section focused on the sensitivity of the distribution of capital and investment rates at the micro level to alternative measures of the capital stock. In this section, we focus on key properties of the micro distribution that are not present in the aggregate data and in turn are likely to be important for both micro studies of investment but also for our understanding of the aggregate dynamics of capital stocks and flows. In particular, in this section, we focus on the lumpy nature of investment as well as the related tremendous dispersion of investment rates at the plant level. From the previous section one could believe that all establishments invest each year, and that in some years their investment is high relative to their capital stock and other years it is low relative to their capital stock. As we will show in this section, that is hardly the case.

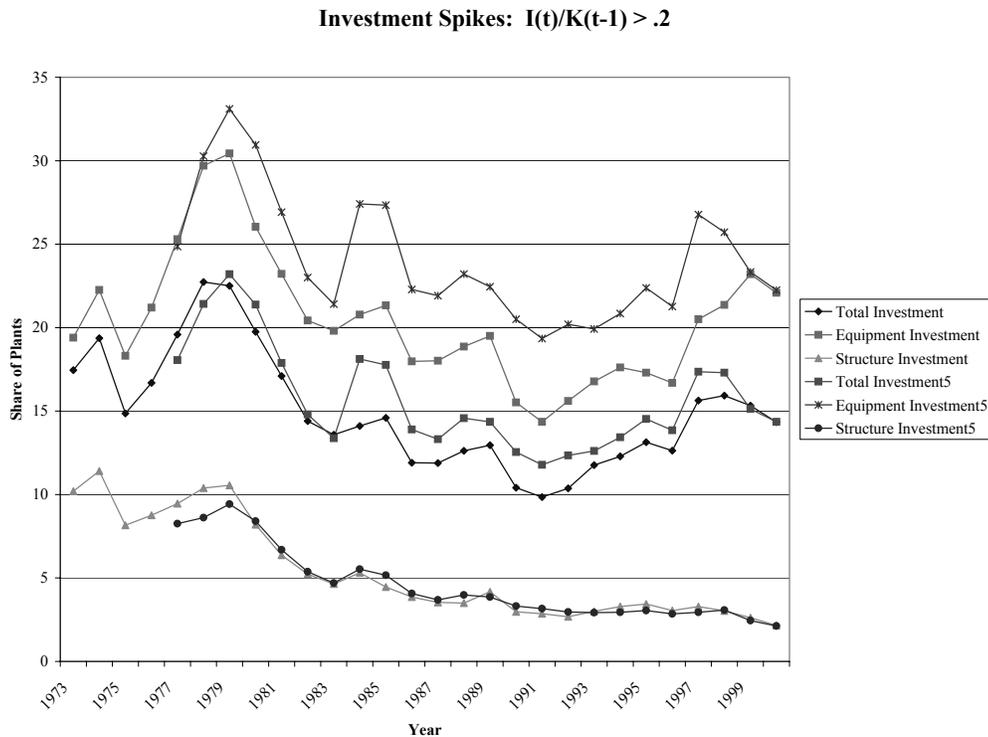
In Figure 12 we show the fraction of establishments that report zero investment in each year, broken out by total investment, equipment, and structures. We look at all establishments and the five year continuers. The share of establishments with zero investment at five year continuers tracks the series with all establishments quite well, but in nearly every case has a smaller share of plants with zero investment. Establishments are much more likely to have zero investment in structures. That share of establishments is as high with zero investment in structures is as 60% in



**Figure 12**

1974, and as low as 38% in 1997. The fraction of establishments with zero total investment varies quite a bit, from nearly 28% of all establishments in 1973 to a low of 9% in 2000. It's also interesting to note the time series pattern to the data. The share of establishments with zero investment shows a secular decline over time, but also is countercyclical (e.g., the correlation between the median investment rate and the fraction of plants with zeroes among the five year continuers is -0.25). The secular trend is somewhat weaker for the five year continuers.

At the other end of the distribution, we are interested in investments spikes, defined here as investment that equals more than 20% of the capital stock. Figure 13 show that investment spikes are highly procyclical (e.g., the correlation between the median investment rate and share of plants with an equipment spikes is 0.48 for the five year continuers). Spike occur much more commonly in equipment investment than they do with structures. Spikes in structures decline in frequency during this time period, but spikes in equipment occur with equally as often in the early 1970's as they do in 2000. As we saw before, five year continuers are less likely to have zero investment. They are also more likely to have investment spikes. During recessionary periods we still observe roughly 15% of all establishments investing over 20% of the value of their entire capital stock.



**Figure 13**

As evidenced by the large fraction of zeros and the large fraction of investment spikes, it is clear that investment at the establishment level is quite lumpy. In order to quantify this in more detail, we construct the share of cumulative investment that is due to the largest year for two samples of establishments, five year continuers and a panel of long lived establishments that have been in the ASM from 1972 to 2000 continuously. For the group of five year continuers in each year, we find that (on average across all years from 1977 to 2000) that the largest year of investment over any given five year period accounts for over 40% of investment in terms of both total investment and investment in equipment. In general, these two numbers have been monotonically decreasing over time, from the 47% range in the mid-1970's to roughly 39% in 2000. A similar pattern shows up in the data for structures, but on average the largest year of structures investments accounts for a much larger fraction of cumulative investment for the five year continuers, over 60% in the average year, and the decline in the average is much less pronounced than in the total and equipment investment.

In addition to looking at the five year continuers, we also look at a panel of long lived establishments. As Table 8 shows, for these establishments roughly 17% of their total investment in the past 30 years comes in just one year, and the three year total is roughly twice that or 32%. At least 5% of investment comes from the largest year of investment, and in some cases, all investment comes in one year. While the results are quite similar for equipment, the results for structures are even more striking. On average, 32% of structures investment comes from the largest year of investment, and the largest three year average is nearly 60% of the cumulative investment in structures. At least 16% of cumulative investment in structures at these establishments comes from the largest single year of investment.

The findings on lumpy investment indicate that understanding investment dynamics at the micro level require understanding both intensive (how much investment) and extensive (invest or not invest) margins. The finding that the extensive margin is so procyclical, and in a related fashion that the fraction of spikes is so procyclical suggests that understanding the procyclicality of investment at the micro level requires understanding the forces that cause plants to change from inaction to action. As has been highlighted in the recent theoretical and empirical literature, the class of models that can account for these dynamics are models where there is some type of nonconvexity in the adjustment costs. The latter models inherently have a range of inaction and also have the interesting feature that aggregate dynamics depend critically on the entire distribution

of micro behavior because it is critical to know how many plants are close to their extensive margin thresholds to understand how aggregate behavior responds to aggregate shocks.

**Table 8. Share of Cumulative Investment**

<i>Time Period</i>	<i>Variable</i>	<i>Mean</i>	<i>Min</i>	<i>Max</i>
Last five years	The largest total investment/cumulative total investment*	.414	.389	.475
Last five years	The largest equipment investment/cumulative equipment investment*	.414	.391	.467
Last five years	The largest structures investment/cumulative structures investment*	.627	.608	.675
Twenty-nine years	The largest total investment/cumulative total investment**	.169	.056	1
Twenty-nine years	The largest equipment investment/cumulative equipment investment**	.167	.053	1
Twenty-nine years	The largest structures investment/cumulative structures investment**	.325	.064	1
Twenty-nine years	The largest three years of total investment/cumulative total investment**	.362	.162	1
Twenty-nine years	The largest three years of equipment investment/cumulative equipment investment**	.362	.157	1
Twenty-nine years	The largest three years of structures investment/cumulative structures investment**	.594	.171	1

\*distribution across all years 1977-2000 for five year continuers.

\*\*distribution across all establishments in the 29 year balance panel with approximately 6,600 observations.

We now turn to another key property of the micro distribution of investment. As is evident from the characterization of the distribution of investment in the prior section, there is substantial dispersion in investment rates across businesses. There are a large fraction of zeros and a large fraction of spikes. Those with zero investment are, given depreciation, experiencing a decline in their capital stock. Those with spikes are, even taking into account depreciation, experiencing large increases in their capital stock. Thus, one inference that immediately emerges from the distribution of investment rates is that there are considerable changes in the allocation of capital across establishments all the time. In addition, what is not evident in the results presented thus far is that another potentially important source of capital reallocation is the entry and exit of establishments. Entry and exit rates in U.S. manufacturing are not as large as they are in other sectors but still it is of interest to consider the role of entry and exit in the reallocation of capital across establishments. A related issue that we explore in more depth in the next section is that the exit of establishments (or firms) may not be properly accounted for in the measurement of depreciation used to build aggregate capital stocks. That is, the standard measurement of depreciation is based upon the service life of an asset. The latter does not explicitly consider

whether the exit of a firm or establishment changes the useful service life of an asset. Instead, implicitly efficiency or depreciation schedules implicitly assume that the capital from an exiting business is still in use – put differently, it is implicitly assumed that the capital from an exiting business is transferred to another business (presumably through the secondary market for capital).

To explore these issues, we use the capital stock measures (perpetual inventory based) for the ASM from 1972 to 1998 along with longitudinal identifier links created by Davis, Haltiwanger and Schuh (1996), extended by Haltiwanger and Krizan (1999) and Foster, Haltiwanger and Kim (2003) as well as longitudinal identifiers created from the Business Register by Jarmin and Miranda (2002). These identifiers permit us to take any pair of consecutive years and classify plants as being entrants, exits, or continuers.

Using this classification, we compute the growth rate of the capital stock at each plant as:

$$gk_{et} = (K_{et} - K_{et-1}) / X_{et} \text{ where } X_{et} = .5 * (K_{et} + K_{et-1}) \quad (6)$$

Where  $K_{et}$  is the real capital stock for establishment  $e$  at time  $t$ . For this purpose, we used the real capital stocks computed using the modified perpetual inventory method and since we are interested in entry and exit we use all plants.<sup>32</sup> This growth rate measure mimics the growth rate measure used in the job creation and destruction literature (see, Davis, Haltiwanger and Schuh (1996)). It has the desirable feature that it is symmetric like a log first difference (indeed it can be shown that this is a second order approximation to a log first difference) but unlike the log first difference it incorporates establishment entry and exit. Using this growth rate measure, aggregate gross capital creation and destruction measures are defined respectively as:

$$POSK_{et} = \sum_{gk_{et} \geq 0} (X_{et} / X_t) g_{ket} \quad (7)$$

$$NEGK_{et} = \sum_{gk_{et} < 0} (X_{et} / X_t) |g_{ket}| \quad (8)$$

Using these measures note that by definition the aggregate net capital stock growth rate is equal to  $POSK_{et} - NEGK_{et}$ .

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<sup>32</sup> Note that our neglect of retirement/sales implies that we are potentially missing an important part of the gross capital destruction for continuing establishments. Caballero, Engel and Haltiwanger (1995) find that the average gross investment rate (not net investment rate) for businesses with *negative gross real investment* is around 3 percent. We are missing that three percent in this analysis in part although it may be partly captured in the depreciation rates we are using. See Caballero, Engel and Haltiwanger (1995) for further discussion.

Figure 14 depicts the capital creation, construction and net growth rates from the mid-1970s to the late 1990s for equipment investment.<sup>33</sup> The net growth rate in capital is on average much smaller than the gross capital creation and destruction rates calculated in this manner. Not surprisingly gross capital creation is procyclical and gross capital destruction is countercyclical. However, the cyclical patterns vary considerably across cycles. That is, the boom in the late 1970s is driven more by a fall in capital destruction while the booms in the 1980s and 1990s are driven more by a rise in capital creation. One way of viewing these findings is that they illustrate that the changes in the aggregate capital stock in the manufacturing level at cyclical frequencies varies in terms of what part of the micro distribution is changing. In the late 1970s, those businesses that were exiting and/or had very low gross investment (so the net capital stock was falling) decreased their capital destruction and this led to a rise in the net capital stock. In contrast in the booms of the 1980s and 1990s the boom was driven more by either entrants and/or businesses whose gross investment was considerably larger than depreciation so that their net capital stocks grew substantially. It is also interesting to note that like net job creation in manufacturing, net capital growth in manufacturing is driven more by fluctuations in capital destruction than capital creation. The standard deviation of capital destruction is 1.5 times the standard deviation of capital creation (although this appears to be driven primarily by the cyclical variation in the 1970s and early 1980s).

An obviously interesting question here is the role of entry and exit. Figure 14 shows the components of gross capital creation accounted for by continuers (businesses that are present in year t-1 and t) and entrants (businesses not present in period t-1 but present in period t) as well as the components of gross capital destruction accounted for by continuers and exits (businesses present in year t-1 but not present in year t). Figure 14 shows that the contribution of entry and exit is quite modest in this setting although the share of capital creation accounted for by entry and the share of capital destruction accounted for by exit both exceed 20 percent in specific years. Part of the reason that the contribution of entry and exit is modest in this case is that as a share of the capital stock in any given year, entering and exiting plants account for a very small share (less than 1 percent each). This is because entering and exiting plants tend to be younger and smaller plants.

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<sup>33</sup> We exclude the first year of each ASM panel (1974, 1979, 1984, 1989 and 1994 since the ASM does not have a representative sample of entrants and exits in those years. This is somewhat unfortunate since many of these years (1974 excluded) are boom years so we miss some of the story on what happens during booms. This also yields the average net growth to be considerably lower than it would be if these years were included. Note that we use all plants in the ASM that are identified to be either an entrant, exit or a continuer and we also use sample weights.

However, the latter suggests that these annual calculations may be somewhat misleading regarding the contribution of entry and exit. As we will explore in the next section, the investment rates of young businesses (e.g., less than 10 years old) are very high so the cumulative contribution of entry taking into account the immediate post-entry growth is substantially higher. Still, it is striking that Figure 14 shows that most of the fluctuations in gross capital creation and destruction rates are from continuers. For example the large decline in capital destruction which is associated with the boom of the late 1970s is entirely driven by a decline in capital destruction by continuers.

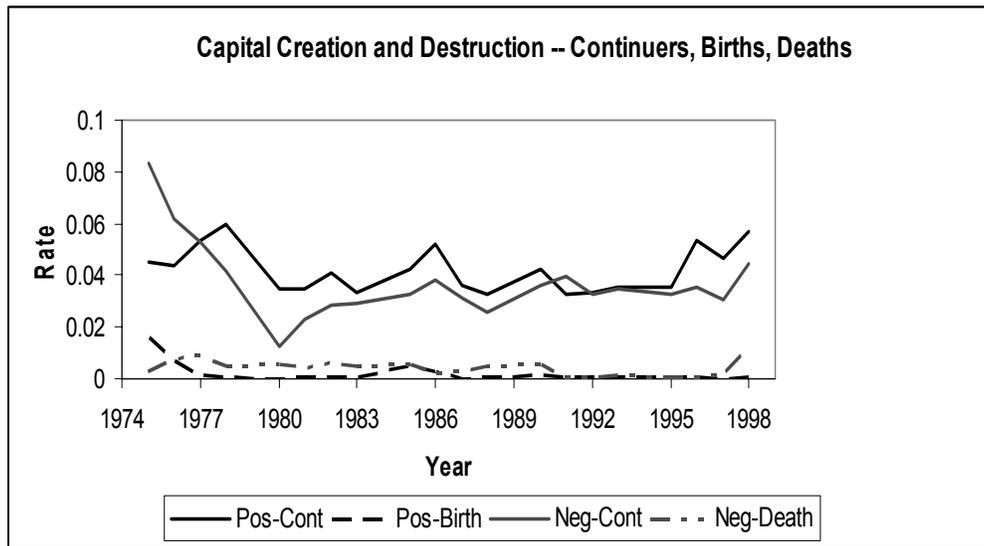


Figure 14

To sum up our plant-level evidence on the properties of the micro distributions, we emphasize two key points. First, the micro distribution of investment is very lumpy and second the micro distribution is very heterogeneous with some businesses rapidly expanding their capital stocks through large gross investments and others contracting their capital stocks either by depreciation or exit.

*Firm vs. Establishment Micro Properties*

As the only dataset that collects measure of investment and capital at the establishment level, the ASM is a unique dataset that permits exploring the differences between establishment level data and data aggregated to the firm level. For this analysis, we restrict the analysis to those plants that are classified as five-year continuers. The median of the firm distribution exhibits that

same overall time series pattern as the establishment level data, but with the median firm investment rate being slightly higher than the establishment investment rate. The correlation of our two measures of capital, perpetual inventory and adjusted book value, show that the two measures are also highly correlated at the firm level, ranging from .6 to .8 and exhibiting a slight trend upwards during this period. The correlation at the firm level is slightly lower than at the establishment level, and the series shows less variation over time. The interquartile range and difference between the 90<sup>th</sup> percentile and median show exactly the same time series patterns and are roughly identical in terms of levels. In terms of the micro properties of the firm series, the fraction of firms with zero investment is somewhat lower for equipment and total investment, but the fraction of firms with zero investment in structures is significantly lower than the fraction of establishments with zero investment. Investment spikes in structures exhibit the same patterns and levels at the firm and establishment level, but the incidence of spikes in equipment and total investment are much lower for firms than for establishments. These last two points suggest that firm investment is somewhat less lumpy than plant investment, smoothing structures investment across the firm but concentrating investment at particular plants within the firm. Equipment and total investment also exhibit smoother investment patterns, with slightly fewer zero investment firms and fewer investment spikes. While the results for the ASM establishment versus firm level are roughly equivalent, some differences do exist. In the following section, we describe the micro properties of another firm level dataset, the ACES.<sup>34</sup>

## **B. Investment Dynamics At The Micro Level For The Entire Economy**

In this section, we look at patterns of the distribution of investment across firms and in this case for firms in all sectors of the economy. For this purpose we use the ACES data on gross investment at the firm level along with the book value information<sup>35</sup>. The ACES is now the

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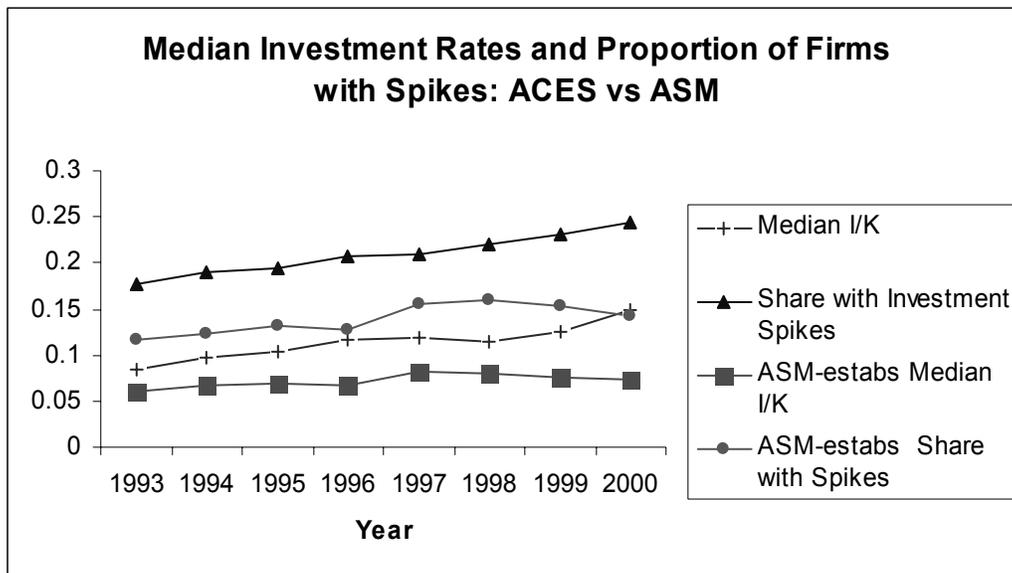
<sup>34</sup> In future drafts we will examine the firm vs. establishment distinction more completely. For the analysis reported here we are using the distributions across plants vs. the distributions across firms without weighting by some measure of activity (in this case the most appropriate weight would probably be capital). It turns out that most firms are single units (i.e., have one plant) so the micro distributions of firms and plants are quite similar. However, while most firms are single-units, multi-unit plant firms account for a large fraction of activity. Thus, it would be interesting to explore the activity-weighted distributions. Put differently, it would be interesting to focus some attention on the large, complex multi-units who have many establishments. The behavior of the latter at the firm level is likely to look quite different than the plant-level data.

<sup>35</sup> As of this draft, we have not yet constructed real investment flows and capital stocks with the ACES data. Many large firms in the ACES span many industries which somewhat complicates the choice of appropriate deflators for constructing real values for investment flows and capital stocks. Most of the calculations using ACES in this paper

primary source of data on business investment in the U.S. statistical system. To date, however, it has been used sparingly by researchers looking at investment dynamics. This is partly due to its relatively recent introduction and to researchers' unfamiliarity with the survey. We hope to shed light on the usefulness of the ACES for understanding investment dynamics and to suggest ways the survey can be changed to improve its utility in the area. Before moving on to this analysis, it's useful to briefly compare the ACES to the ASM on some key measures.

*Comparing the ACES and ASM*

Differences in the sampling units and survey design make comparisons between the ACES and ASM difficult. Both surveys sample larger units (manufacturing establishments in the case of the ASM and firms in the case of the ACES) with certainty. The surveys differ markedly in how they handle the uncertainty cases. The ASM selects a sample of smaller establishments that it follows in a five year panel. This allows the use of the perpetual inventory methods discussed in the last subsection. The ACES, on the other hand, selects a new probability sample each year. Thus, perpetual inventory methods can be used to construct firm level capital stocks only for the largest ACES firms.



**Figure 15**

are within year. In addition, we don't construct perpetual inventory capital stocks using ACES. Therefore, deflating ACES investment and capital stocks was not a high priority for this draft.

Despite the differences between the two surveys it is possible to compare various statistics computed from each. Here we focus on the investment rates and the share of firms experiencing spikes in investment. Figure 15 compares the median investment rate ( $I/K$  - computed as total capital expenditures divided by total fixed assets) and share of businesses with investment rates exceeding .2 (i.e., those experiencing spikes) across ACES firms and ASM establishments. The differences in units and industry focus notwithstanding, we see that the results are broadly consistent. Firms in the ACES have slightly higher investment rates than the manufacturing establishments in the ASM and have larger proportion experiencing investment spikes. While measurement differences could play a role (for instance we believe the capital stock measure available for the ASM are more reliable than the book value information collected but not published on the ACES), the differences between the ACES and ASM seen in Figure 15 may stem largely from higher investment rates in the non-manufacturing sector over the 1990's. All of the series trend up over the 1990's following the business cycle.

Now we turn our attention to the contribution of entry and exit and also to a closely related idea raised in the prior subsection – the contribution of young businesses to investment. We focus on these issues in this context because in the non-manufacturing sectors entry and exit are much more important in accounting for the reallocation of outputs and inputs and for growth (see, e.g., Foster, Haltiwanger and Krizan (2001, 2002)). As mentioned in the introduction, one of the limitations of aggregate data on capital stocks and flows is that it is difficult to capture the contribution of young vs. mature businesses or the contribution of entry and exit. It is also the case that typical business surveys (including ACES) have some limitations when it comes to capturing the roles of entry and young businesses, as often the focus of these surveys is on large, mature businesses. Accordingly, the analysis in this section serves the purpose of both illustrating the importance of considering the age distribution of businesses (and entry and exit) but also of highlighting some of the limitations in trying to assess the contribution of these factors given the traditional emphasis in data collection on the large, mature businesses. Another reason to be particularly interested in the investment behavior of young firms is that we believe they are among the first to adopt new technologies and business practices. This may have been particularly true over the period covered by the ACES: the 1990's.

### *Incorporating age information into the ACES*

The ACES is not designed to provide statistics on investment by firm age. However, the ACES can be easily linked to the Census Bureau's Longitudinal Business Database (LBD; see Jarmin and Miranda (2002)). The LBD contains longitudinally linked establishment level data with firm ownership information from 1975 to present. The LBD contains two sources of information on firm age. First, one can use the first year a firm's numeric identifier (FIRMID) is observed in the LBD. However, numeric firm identifiers in the LBD are not intended for longitudinal analysis. Events such as merger and acquisitions can result in changes to numeric firm identifiers for continuing businesses. An alternative measure of firm age is the age of the oldest establishment owned by the firm. While this measure is not ideal either, it yields a much more plausible age distribution of firms than that which results from using only numeric firm identifiers.<sup>36</sup>

### *Basic facts about investment and firm dynamics by firm age*

Table 9 provides information on the distribution of employment across the firm age distribution for 1998. The LBD contains the universe of firms with paid employees and thus provides the benchmark to compare with those employer firms covered in the ACES. The first column in the table shows the 1998 distribution of employment in the LBD. Note the mass point at age 23. This results from the fact that the LBD extends only back to 1975. Thus, all firms owning establishments born on or before 1975 have the same age. These older firms tend to be large and, therefore, account for large portion of overall economic activity.

The second and third columns of Table 9 show the unweighted and weighted percentages of total LBD employment by age for ACES firms. The table clearly shows that young firms are under sampled in the ACES. For example, good responses for the 1998 ACES were received from firms accounting for only 1.5% of all employment at age one firms. Using ACES sample weights, these firms represent only 15% of age one employment. Recall, however, that ACES is not stratified by firm age. Coverage is much better for the more mature firms that account for a lot of economic activity. Thus, ACES is representative of total investment spending.

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<sup>36</sup> Work is currently underway at the Center for Economic Studies to create firm level longitudinal linkage in the LBD. Once completed, this work will allow researchers to construct more sophisticated measures of firm age.

Figure 16 looks at investment rates over the age distribution. Because there are limited observations on young firms within each year, we use pooled data to construct the figure. That is, each age category (below 25) is made up of observations from multiple years.<sup>37</sup> The figure clearly shows that investment rates, measured as the ratio of total capital expenditures to fixed assets decline with firm age. Younger firms invest much more intensively than do older firms. In addition, younger firms pursue more varied investment strategies relative to older firms as shown in the decline of 90-10 differential in investment intensity as firms age.

**Table 9. Distribution of Paid Employment by Firm Age - 1998**

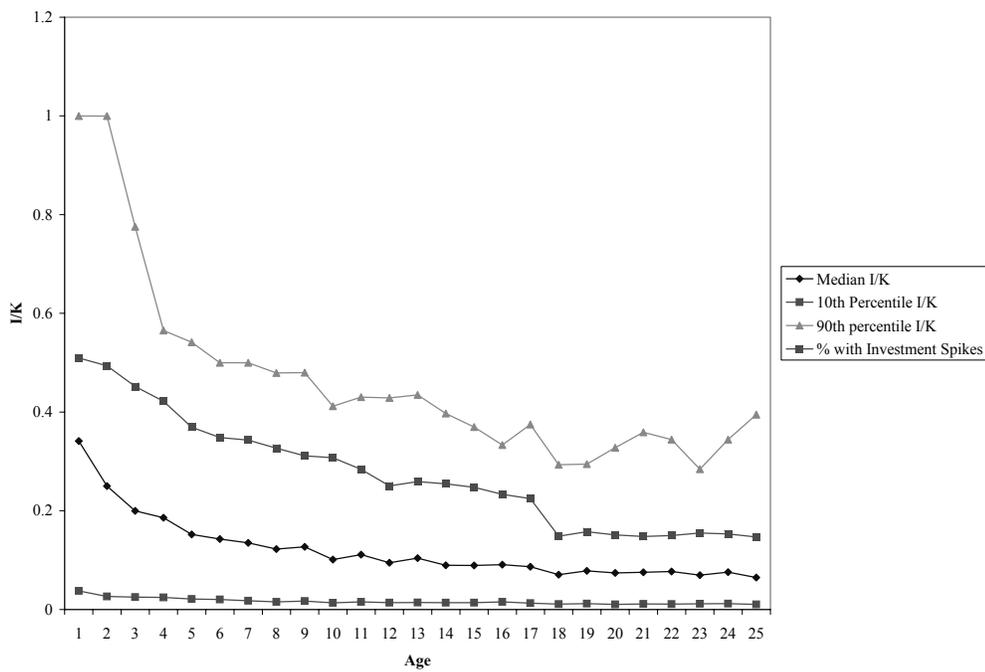
<i>Firm Age</i>	<i>Employment</i>	<i>ACES Coverage</i>		<i>Age Share of Total ACES</i>		
	<i>LBD</i>	<i>un-weighted</i>	<i>weighted</i>	<i>LBD</i>	<i>(un-weighted)</i>	<i>ACES (weighted)</i>
0	1,452,603	D	D	1.31%	D	D
1	3,146,743	1.50%	15.02%	2.85%	0.10%	0.55%
2	3,193,107	2.99%	47.21%	2.89%	0.20%	1.76%
3	2,711,276	2.80%	45.47%	2.45%	0.16%	1.44%
4	2,551,283	3.76%	45.14%	2.31%	0.20%	1.34%
5	2,377,135	5.13%	51.89%	2.15%	0.25%	1.44%
6	2,553,304	7.44%	54.91%	2.31%	0.39%	1.63%
7	2,315,490	5.71%	53.51%	2.09%	0.27%	1.44%
8	2,006,223	5.11%	54.66%	1.81%	0.21%	1.28%
9	2,174,030	9.95%	63.45%	1.97%	0.44%	1.61%
10	2,263,811	12.95%	65.44%	2.05%	0.60%	1.73%
11	2,584,330	14.43%	59.58%	2.34%	0.76%	1.80%
12	2,671,816	8.31%	48.36%	2.42%	0.45%	1.51%
13	2,296,896	13.55%	66.72%	2.08%	0.64%	1.79%
14	2,078,559	12.69%	63.81%	1.88%	0.54%	1.55%
15	1,648,923	14.60%	60.48%	1.49%	0.49%	1.16%
16	2,376,955	21.71%	78.26%	2.15%	1.06%	2.17%
17	1,558,257	18.20%	66.93%	1.41%	0.58%	1.22%
18	1,386,752	16.09%	70.97%	1.25%	0.46%	1.15%
19	1,410,778	22.09%	77.46%	1.28%	0.64%	1.27%
20	1,376,125	18.92%	69.44%	1.24%	0.53%	1.11%
21	2,453,113	39.00%	84.61%	2.22%	1.96%	2.42%
22	2,019,449	65.59%	154.43%	1.83%	2.71%	3.64%
23	59,953,493	70.43%	92.98%	54.23%	86.38%	65.00%
Total	110,560,451	44.21%	77.57%			

An alternative way to examine investment behavior across the age distribution of firms is to follow a cohort of firms over time. This is difficult with the ACES as there is no explicit

<sup>37</sup> Note that the oldest firms in the LBD (i.e., those born or owning establishments born before 1975) dominate the age categories from 18 on up

panel nature to the survey. The ACES does a good job of longitudinally tracking only larger certainty case businesses. These, of course, are mostly all old. Young firms are mostly small and are, therefore, only observed in the ACES once over the 1993 to 2000 period (111,446 out of 141,605 ACES-1 firms observed over the 1993 to 2000 period are observed only once). Thus, the only way to follow a cohort over time is to construct a synthetic cohort of firms that were all born in the same year, but where the composition of the observed cohort changes over different survey years.

**Firm Age Distribution of I/K (ACES-1 Firms)**



**Figure 16**

Table 10 looks at a synthetic cohort of 1993 births over the period covered by the ACES. The first four columns of the table highlight the small share of total activity accounted for by any given birth cohort (the payroll and employment shares in the first two columns are based on universe information from the LBD). It's interesting to note that young firms account for a smaller share of investment and assets than they do payroll and employment. This is true even though they invest more intensively than do more mature firms.

Table 10. Share of Activity for the 1993 Birth Cohort

<u>Year</u>	<u>Share of Payroll</u>	<u>Share of Employment</u> <i>t</i>	<u>Share of TCE (I)</u>	<u>Share of Fixed Assets</u> <i>(K)</i>	<u>Relative Share(TCE)</u>	<u>Relative Share (FA)</u>	<u>Median I/K</u>
1993	1.38%	1.12%	D	D	D	D	D
1994	2.04%	3.02%	0.48%	0.30%	15.89%	9.93%	19.63%
1995	1.93%	2.79%	1.13%	0.86%	40.50%	30.82%	18.54%
1996	1.82%	2.58%	1.10%	0.80%	42.64%	31.01%	20.57%
1997	1.64%	2.36%	1.18%	0.62%	50.00%	26.10%	25.00%
1998	1.72%	2.15%	1.35%	0.53%	62.79%	24.65%	16.36%
1999	1.74%	2.06%	0.71%	0.59%	34.47%	28.64%	14.89%
2000	1.12%	1.97%	0.73%	0.57%	37.06%	28.93%	19.08%

The behavior of investment intensities for this synthetic cohort is not as clean as that depicted in Figure 16. Within a year, we generally find that the mean and median investment intensities are higher for younger firms. Figure 16 essentially pools statistics across time and shows the downward trend in investment intensity as firms age. However, since the ACES does not track individual young firms over an extended period of time, its difficult to make inferences about the behavior of a given cohort since the composition of the sample changes from year to year. Obviously, the sample in out years would only contain successful entrants, which most likely invest more intensively that did the unsuccessful ones that were in the sample in previous periods. This may explain why we don't see the same patterns for a synthetic cohort as we do across the age distribution within a given year.

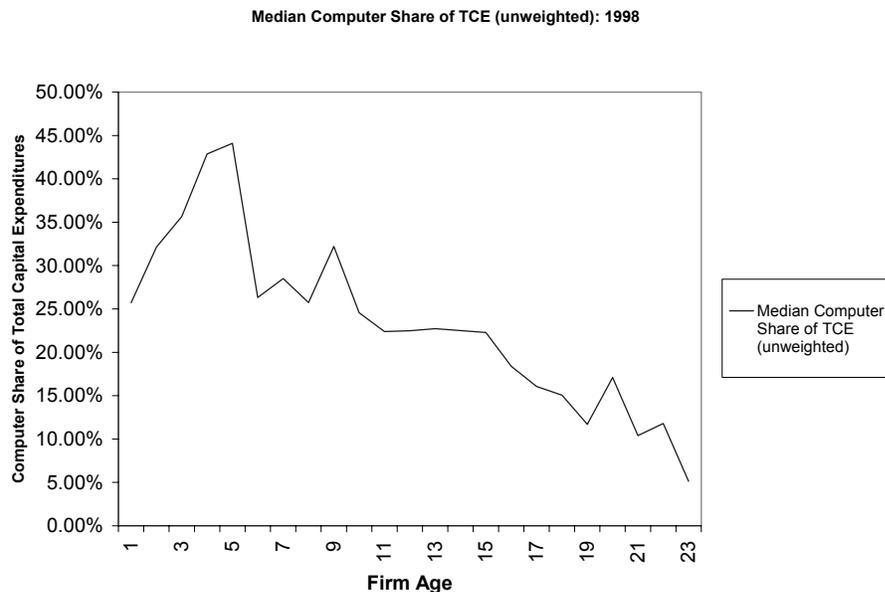


Figure 17

Another reason to be interested in understanding the investment behavior of young firms is that they may chose a different mix of capital than more mature firms. New firms are often to be more likely to experiment with new technologies. Figure 17 looks at this issue by comparing the share of total capital expenditure accounted for by information technology (IT) equipment in 1998 across the firm age distribution. Here we see that older firms devote a smaller share of their investment budgets on IT equipment. This is admittedly a very limited analysis. The small number of observations in the ACES for younger firms limits our ability to control for other factors such as industry and size and we only have one year with detailed asset information.<sup>38</sup> Nevertheless, Figure 17 demonstrates that asset mix is a function of firm age.

We compare the share of different measures of economic activity at young firms across the 1990's in Table 11. The table shows that the share of employment accounted by firms less than 4 year old is roughly constant, over the 1990's, at just under 10%. Table 11 gives some indication that this was indeed the case. The contribution of young firms to net employment growth is much larger as most age cohorts usually experience reductions in employment.

Table 11. Share of Activity at Young Firms over the 1990's								
<i>Share of Total ACES-1 Investment</i>								
<i>Firm Age</i>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>
0	D	D	D	D	D	D	D	D
1	0.39%	0.48%	0.21%	0.37%	0.65%	0.84%	2.54%	1.80%
2	0.81%	1.00%	1.11%	2.50%	1.01%	1.04%	2.46%	1.96%
3	0.68%	0.77%	0.96%	1.10%	0.65%	0.96%	1.53%	1.10%
Total	1.88%	2.25%	2.29%	3.97%	2.31%	2.85%	6.52%	4.85%
<i>Share of LBD Employment</i>								
<i>Firm Age</i>	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>
0	1.12%	1.11%	1.24%	1.59%	1.31%	1.31%	1.24%	1.39%
1	3.02%	3.02%	3.01%	2.93%	3.20%	2.85%	2.69%	2.87%
2	3.01%	2.84%	2.79%	2.76%	2.71%	2.89%	2.65%	2.89%
3	2.53%	2.75%	2.64%	2.58%	2.55%	2.45%	2.71%	2.55%
Total	9.67%	9.72%	9.68%	9.86%	9.77%	9.50%	9.29%	9.70%
<i>Contribution to Net Employment Growth</i>								
<i>Firm Age</i>	<u>1994</u>	<u>1995</u>	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>	<u>2000</u>	
0	61.50%	35.23%	61.29%	38.28%	33.78%	123.97%	58.95%	
1	103.93%	54.31%	66.49%	48.70%	40.81%	139.17%	70.65%	
2	-6.42%	-3.47%	-6.66%	-3.58%	-4.85%	-17.12%	-1.59%	
3	-11.16%	-3.00%	-5.49%	-3.45%	-3.94%	-14.84%	-1.64%	
Total	147.86%	83.06%	115.63%	79.95%	65.80%	231.18%	126.37%	

<sup>38</sup> Questions on investment by detailed asset type are available only for 1998.

The striking feature of Table 11 is the low share of total investment accounted for by young firms. These firms account for nearly 10% of total employment (at firms with paid employees) yet only account for, on average, 3% of total investment. New firms seem to enter the ACES with some lag. For instance the ACES has very limited coverage of age 0 and 1 firms. It's possible if we imputed missing ACES investment for age 0 and 1 firms in 1997 and 1998, we would see more investment by younger firms in these years as well.

### *The Contribution of Exit*

As discussed above, we are also interested in the contribution of entry and exit to capital and investment dynamics. However, the results and discussion in the prior subsection make clear that ACES is not well-suited to study of the contribution of entry since new firms seem to enter ACES with a lag. However, ACES can be used to study the contribution of exit to capital destruction. However, since we cannot adequately measure entry in this context we do not adopt the capital creation and destruction measures used in our plant level analysis. Rather we undertake a more limited analysis and simply try to quantify the extent of assets that are impacted by what we might consider to be firm exit.

Since we are looking at firm exit here rather than plant exit, we need to think about alternative types of firm exit. Using the LBD we can differentiate between firms that disappear from the data, but whose establishments (or subset of those establishments) continue to operate under a different firm, and firms whose establishment cease to be active. We call the latter cases Pure Deaths and the former FIRMID Deaths.

Table 12 shows the current dollar value of fixed assets for both Pure and FIRMID deaths from 1993 to 1999. These numbers give us the fixed assets from ACES for the last year the firm operated. FIRMID deaths can include mergers and other activities that result in the disappearance of an active FIRMID in the LBD with little or no real consequences for the operating establishments the firm controlled. The table shows that the total capital stock at firm classified as FIRMID deaths far exceeds that at Pure Death firms.

	<u>1993</u>	<u>1994</u>	<u>1995</u>	<u>1996</u>	<u>1997</u>	<u>1998</u>	<u>1999</u>
Pure Deaths	10	26	9	20	26	32	22
Firmid Deaths	138	150	166	281	291	256	341
Year t+1 Used Capital Expenditures	30	35	34	31	34	42	63

To put these numbers into perspective and also to raise a related measurement issue we compare the assets that are associated with firm deaths with the reported expenditures on used expenditures. In this regard, it is important to note ACES instructs firms to include assets acquired through M&A activity in their used capital expenditures. As such, it should be the case that if all of the assets impacted by firm deaths remain in use then in principle we should observe these assets transferred to other firms and this should be reflected in the used expenditures numbers in ACES. The last row of Table 12 shows the total used capital expenditures in the ACES for the year following the year of death of the firms (that is we should see deaths in year t be reflected in increased assets in year t+1 for the firms acquiring the assets). We see that reported used expenditures are well below the sum of the first two rows which could be taken to represent the stock of used assets available. There are several measurement issues to deal with here (e.g., valuation of fixed assets stock vs. the cost of acquiring them), but these findings suggest that either used expenditures are poorly reported (especially with regard to M&A activity) or the secondary market for capital for firms going through exit may be much weaker than is implicitly assumed in our treatment of depreciation.<sup>39</sup> In either case, statistical agencies should focus more attention on the disposition of assets of exiting businesses at both the micro and aggregate levels.

### *Summing Up Firm-level Evidence*

This brief exploration of the micro properties of the distribution of firm level investment yields a number of insights. First, it is difficult to apply perpetual inventory measurement and in a related fashion difficult to use ACES as a panel dataset given the annual panel rotation.

<sup>39</sup> We also need to look into the possibility that the assets from the exporting firms are exported. Note further that we can conduct some further micro analysis on how well the transfer of assets associated with mergers and acquisitions are measured in ACES. We can identify specific mergers and acquisitions in the micro data and for firms involved in such transactions quantify exactly the treatment of assets (in terms of used expenditures in particular) in this context.

Second, ACES appears to get entrants with a lag. Third, there are dramatic differences in the patterns of investment by firm age. Young businesses have much greater investment rates than do mature businesses. This latter pattern mimics the patterns of employment growth. However, unlike for employment growth, young businesses account for a relatively small fraction of gross investment. This finding is partly because young businesses have much smaller capital stocks than more mature businesses so even high gross investment rates contributes relatively little to aggregate gross investment. Moreover, for employment growth we tend to find mature businesses exhibiting little growth while for capital we still find that mature businesses exhibit robust positive gross investment. Finally, we find that there are substantial assets associated with firm exit (either via exit of all plants or acquisition). The latter finding is interesting in its own right but also we find that used expenditures do not come close to matching the assets at risk from firm death. The latter finding raises interesting questions about the nature of secondary capital markets for firms that are undergoing some form of exit.

## **V. Concluding Remarks**

Micro/Macro data integration should be an objective of economics measurement as it is clearly advantageous to have internally consistent measurement at all levels of aggregation (firm, industry and aggregate). Such internal consistency permits transparent accounting of the sources of changes in aggregates whether due to economic factors or problems of measurement and it permits micro level analysis in a context where the aggregate implications can be clearly investigated. There are a rich range of firm characteristics over which recent research suggests it is useful to decompose aggregate changes such as age and size of business as well as decomposing the contribution of continuing, entering and exiting businesses. In spite of these apparently compelling arguments, there are few measures of business activity that achieve anything close to micro/macro data integration. The measures of business activity that are arguably the worst on this dimension are capital stocks and flows. In this paper, we have documented and quantified the widely different approaches to the measurement of capital from the aggregate (top down) and micro (bottom up) approaches.

Capital stock and flow aggregates are based on a top down, supply side approach. Measures of the domestic production, exports and imports of capital goods yields reasonably accurate measures of domestic supplies of these commodities. These supply totals are the strength of the

top down approach. Somewhat more challenging is to allocate the domestic supply across personal consumption, government consumption and fixed business investment by detailed asset class since there are limited data available by these categories by detailed asset class. Still, the top down approach arguably yields reasonably accurate measures of aggregate capital stocks and flows by detailed asset classes (to be cautious, there are inherently difficult problems with measuring investment deflators for capital goods and depreciation given both data limitations and difficult conceptual problems).

The weakest link in the top down approach is not the capital stocks and flows by asset class but the capital stock and flows by detailed asset type and by industry. Currently, this latter allocation is based upon indirect methods and very strong assumptions about the relationship between asset use by industry and the occupational distribution of an industry. These problems are most severe for allocating equipment investment – for example, in the most recently released 1997 capital flows table, about 85 percent of the total value of equipment investment is allocated across industries based upon the occupational distribution of employment.

The core problem has been the lack of direct measures of detailed asset use by industry. Recently, there have been some improvements in the collection of capital expenditures at the firm level for all sectors with the development of the ACES. However, data from the ACES are only beginning to be used in the national accounts. We have taken advantage of these new data in our analysis in this paper to explore the limitations of the top down approach for measuring capital stocks and flows by industry.

In exploring the new ACES data, we have learned about the many limitations of building up capital expenditures data from the bottom up. For one, firms that are asked to break out their assets by industry too often truncate the set of industries for which they report (where we know from other sources that the firms are engaged in activity in those industries). For another, expensing and leasing issues plague measurement of capital expenditures by firms, particularly for some types of assets.

In this paper, we develop a hybrid approach to allocating assets by industry which attempts to take advantage of the strengths of both the top down and bottom up approach and also minimizes (or at least adjusts for) the limitations of each of the approaches. We believe our hybrid approach has promise for improved measurement of capital stocks and flows by asset and industry. Moreover, our hybrid methodology has the promise of making the micro and the

macro data more internally consistent so that there is a greater ability to conduct internally consistent analyses of capital stocks and flows at the micro and the macro levels. Our actual implementation of this hybrid methodology has numerous limitations of its own that could be improved upon by further study as well as by improved source data and improved integration of the business data at the Census Bureau.

A closely related objective of this paper is to characterize the state of economics measurement for micro level capital stocks and flows. Measurement from the bottom up is important for improving the aggregates as discussed above but is also important in its own right. Analysts have increasingly been using longitudinal business level datasets to study business dynamics even when the objective is to understand aggregate fluctuations in business activity.

Creating a data infrastructure that permit permits high quality analysis at the micro level poses many challenges. Panel rotation of surveys makes measurement of capital stocks by perpetual inventory methods difficult. Moreover, the data collected are quite sparse at the micro level on an annual basis – at best data are collected by broad asset class annually. Amongst other things, this makes generating investment price deflators and depreciation rates that are firm-specific difficult if not impossible. There has also unfortunately been some deterioration in the collection of capital stocks and flows at the establishment level for the manufacturing sector in the ASM. The deterioration of the ASM capital data is unfortunate since the ASM has successfully been linked longitudinally permitting a rich range of analysis of business dynamics. As we have emphasized, while ACES has yielded an improvement on some dimensions, ACES has many limitations as a longitudinal micro dataset given the sampling procedures used for ACES (e.g., the annual sample rotation and the under-representation of entrants and young businesses).

In spite of these measurement challenges at the micro level, the facts that emerge from the micro analysis are quite striking. Investment activity at the business level is very lumpy and in turn very heterogeneous. A large fraction of businesses in any given year have literally zero investment while a small fraction of businesses have large investment spikes. These investment spikes account for a large fraction of aggregate investment and also account for a large fraction of the cumulative investment of the individual business over a long period of time. All of this lumpiness implies that some businesses are shrinking their capital stocks (via depreciation primarily) while others are expanding their capital stocks substantially. The implied

heterogeneity of capital growth rates across businesses implies that the allocation of capital across producers is constantly in a state of flux. Moreover, the entry and exit of businesses yields important and additional contributions to this reallocation of capital inputs across production sites. A related dynamic is that young businesses have high failure rates but conditional on survival have very high average investment (and output and employment) growth rates. Putting all of these factors together suggests that the aggregate dynamics are driven by a complex set of factors and that understanding the aggregates requires decomposing the aggregate changes into the contribution of businesses with zero vs. spike investment, the contribution of entry and exit, and the contribution of young vs. more mature businesses. Moreover, our findings suggest that the contribution of these factors is time varying both across cycles and across secular episodes. For example, the investment boom in the late 1970s is more associated with a fall in what we denote as gross capital destruction (capital contraction by continuing and exiting businesses) than gross capital creation while the investment booms in the 1980s and 1990s are more associated with increases in gross capital creation.

In addition to raising interesting questions about the driving forces for micro and macro investment dynamics, our preliminary findings raise an interesting question about the treatment of plant and firm exits in the measurement of capital. The standard treatment of the service life of an asset ignores plant and firm exit issues. That is, the service life is given by the technological use of the asset. There is some attempt to incorporate the impact of secondary markets on the efficiency schedules but at the end of the day the useful service life ignores exit. This treatment is appropriate if assets from exiting plants and firms are kept in use through secondary markets. However, a quick and simple exercise from the micro data raises doubts in this regard – we find that the value of assets at risk from firm exit far exceed the used expenditures purchases recorded in the data. While there are a number of measurement limitations of our quick exercise, we believe this issue deserves further attention and also highlights the importance of micro/macro data integration.

We believe these micro properties provide prima facie evidence that understanding aggregates requires the micro/macro internal consistency. However, we clearly recognize that our analysis of the properties of the micro distributions have limitations given the limitations in the micro data (and the associated measures at the micro level) so that these inferences should be treated with appropriate caution.

An open question is what can be done to improve micro/macro data consistency – in general and in particular for the case of capital. From our vantage point, considerable progress could be made if (i) there is a concerted effort to develop the type of hybrid methodology proposed here to integrate the micro and the macro approaches to capital measurement and (ii) the survey design for the collection of the data on capital stocks and flows (primarily by the ASM and ACES) clearly recognized that one of the uses of the data is for micro data analysis and closely related micro/macro data integration. As such, statistical agencies should consider changes to surveys of business investment, such as the ACES, that put increased attention on entrants and young business and rethink sample rotation strategies to enhance longitudinal analysis.

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