CONSTRUCTING PRICE AND QUANTITY INDEXES FOR HIGH TECHNOLOGY GOODS

by

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ABSTRACT

In most markets for high technology goods, the life of a specific product variety is short, and many varieties are bought and sold at once. Using data for computers and semiconductors that are very disaggregate and available at a high frequency, we find that matched-model superlative price indexes capture the rapid pace of quality change in these goods. Our results contrast with the widely held view that the hedonic function is needed to capture quality change in high technology goods.

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1. INTRODUCTION

In recent years, the measures of high tech industry output in the Federal Reserve's industrial production index have been improved. An aspect of this work has involved the construction of price indexes for computers and semiconductors, the subject of this paper.

The accurate measurement of high technology goods such as computers and semiconductors is important because of their growing importance in the economy and their role in its productivity performance (Oliner and Sichel 2000, Jorgenson and Stiroh 2000). Constructing price and quantity indexes for these goods presents special challenges, however. An important feature of their markets, as well as those for related goods undergoing rapid technological change, is the presence of product heterogeneity. New varieties are steadily introduced, and, at a given point in time, product-level output and sales statistics are composed of data on a blend of entering, exiting, and continuing models or devices.

The literature has offered various approaches to address the problem of product turnover in constructing product-level price indexes for high tech goods. Researchers, practitioners, and reviewers of price estimating methods have most frequently advocated the use of the hedonic function to capture quality change in new varieties of these goods (eg., Griliches 1961, Cole *et*. *al*.1986, Dulberger 1989, Triplett 1989, Boskin *et*. *al*. 1997, Grimm 1998, Moulton 2000). The more recent literature on welfare-based indexes suggests that alternative methods are needed to capture fully the effects of quality change in periods of sharp changes in technology (eg., Trajtenberg 1989, Pakes, *et*. *al*. 1993, Hausman 1999).

In this paper, we address the index number problems presented by product heterogeneity in high technology goods by constructing price and quantity indexes using data that are very disaggregate along both product and time dimensions. The primary data on high technology goods that we use are for personal computers and computational microprocessors: They are at a high frequency (quarterly), and they include observations on both prices and quantities for homogeneous models or devices sold in each period. Using these data, which are for the 1990s, we find that conventional index number methodology can be used for the construction of constant-quality price indexes for these goods.

The applicability of a conventional approach for the construction of price indexes—specifically, a matched-model price index compiled using a superlative index number formula—rests in large part on the availability of a panel of overlapping observations on prices and quantities. The nature of competition in most markets for high technology goods lends itself to this framework and these data. Moreover, these same data would be required to determine the welfare gain, or “exact” price change, in the wake of a marked advance in technology. By contrast, there is a great deal of ambiguity in how one constructs an index number by applying the hedonic technique to a panel of overlapping observations on prices (Berndt and Griliches 1993). Moreover, the technique and its data are insufficient for analyzing distinctly new varieties of a product.

This paper attempts to sharpen our understanding of the applicability and the quantitative distinction between the hedonic and matched-model approaches for the construction of price indexes for high technology goods. We first review known results in the conventional and welfare-based index number literature, drawing implications for the data and conditions that are required for the matched-model approach to yield price measures that approximate exact indexes. We then review the applicability of several prominent variants of the hedonic approach (Triplett 1989). Price indexes are calculated for each approach using the same dataset, and the results are compared and analyzed.

We find that both the matched-model and hedonic-based indexes yield broadly similar trends for quality-adjusted prices of high technology goods. For some hedonic variants, the period-by-period differences between the matched-model and hedonic-based indexes are noticeable and large. We find that these differences stem, in large part, from differences in weighting—not differences that arise from the hedonic’s explicit treatment of new varieties—and conclude that matched-model indexes compiled using a superlative aggregator are more precise measures of price change.

2. DATA REQUIREMENTS FOR EXACT PRODUCT LEVEL PRICE INDEXES

In the economic approach to index numbers, a price index is “exact” if it equals the change in the cost of producing or obtaining a given level of output or utility (Diewert 1976, 1978; see also Diewert 1987). This literature is unambiguous that the construction of an exact price index requires price and quantity information.

Superlative aggregators, such as the Tornqvist or Fisher, will approximate an exact price index provided the calculation is based on data for items that are (a) not changing in quality and (b) available in adjacent periods. At the lowest level of aggregation—the construction of a product level or "elementary" price index—such data are ideally given by the unit value and the total quantity sold (Diewert 1995, Balk 1998).

A Tornqvist price index, which we use for exposition, is a weighted geometric mean of price ratios in two periods using an average of each item's revenue share in the two periods as weights; in logs the aggregate price, P*, from t-1 to t is expressed as:

$$(1) \qquad \ln P^*_t - \ln P^*_{t-1} = \Sigma_m \; s_{m,t} \, (\ln P_{m,t} - \ln P_{m,t-1}) \, ,$$

$$s_{m,t} = \tfrac{1}{2} \, [PQ_{m,t} / \Sigma_m \, PQ_{m,t} + PQ_{m,t-1} / \Sigma_m \, PQ_{m,t-1}] \; .$$

$P_{m,t}$, $PQ_{m,t}$, and $s_{m,t}$ are the price, revenue, and revenue share, respectively, for the m^{th} item or model ($m = 1, \ldots, N$) in period t ($t = 1, \ldots T$). A time series for P^*_t is obtained by cumulating the results of (1) for the T successive periods. Thus, according to this formula, the measurement of aggregate price change requires price and revenue data for the N homogeneous items in T adjacent periods.

Strictly speaking, (1) cannot be calculated when there is entry or exit among the items being aggregated. If an item disappears or a new/improved one is introduced, N, the number of homogeneous items, changes between t and t-1, and some of the price relatives needed in (1) are unobservable. Economic theory suggests than an unobserved shadow price for a new variety should be imputed for the period prior to introduction and used in (1). The appropriate shadow prices for the entering varieties are Hicksian reservation prices (Fisher and Shell 1972), that is, those prices that just induce the demand for the new item equal to zero in the period prior to introduction. A similar principle applies to the determination of the unobserved shadow price for exiting varieties in the period following retirement.

The calculation of the appropriate Hicksian reservation prices requires knowledge of indifference surfaces or cost functions, however (Diewert 1980). In the literature, three methods have been used to address the problem of product turnover and new varieties in the construction of product-level price indexes:

(a) Matched-model indexes – compute price indexes using only the data for items available in adjacent periods;

(b) Hedonic-based indexes – impute unobserved prices using predicted values from a hedonic regression; and

(c) Welfare-based indexes – specify a functional form for utility or expenditure function and obtain an explicit expression for the change in welfare under product turnover.

Under each approach, data on buying patterns as well as prices are required. Both the matched-model and hedonic-based price indexes need to be compiled using a variant of (1) to account accurately for substitution effects, and the welfare-based generalizations use information on market shares of new (or disappearing) varieties to infer the influence of product turnover on the price change between two periods. Thus, data on quantities or revenues as well as prices are necessary both for the appropriate treatment of new goods and for calculating measures free of substitution bias.

Although the welfare-based methods invariably introduce other restrictions and involve the estimation of one or more parameters of the underlying cost or utility function, they will approximate an exact price index. A feature of the matched-model approach, though, is that it retains one of the more remarkable advantages of (1) – the price index does not depend on the unknown parameters of the underlying cost or utility functions. The matched-model approach and the conditions and data under which it yields a reasonable approximation to an exact price index for high technology goods are reviewed in the next section.

3. MATCHED-MODEL PRICE INDEXES

When there are nontrivial sets of overlapping varieties from one period to the next, an aggregate price index can be compiled by successively applying (1) only to those items for which prices are observed in adjacent periods. The result is a form of matched-model index. Denote the number of homogeneous varieties produced and sold in each period as M_t, the number produced and sold in adjacent periods as $M_{t/t-1}$, (that is, $M_t \cap M_{t-1}$), and summation over the $M_{t/t-1}$ "matched" models as $\Sigma_{m\in Mt/t-1.}$ The matched-model Tornqvist price index is expressed as:

(1') $\quad ln\ P^{MT}_{t} - ln\ P^{MT}_{t-1} = \Sigma_{m\in Mt/t-1}\ s_{m,t}\ (ln\ P_{m,t} - ln\ P_{m,t-1})$,

where $\quad s_{m,t} = ½\ [PQ_{m,t} / \Sigma_{m\in Mt/t-1}\ PQ_{m,t} + PQ_{m,t-1} / \Sigma_{m\in Mt/t-1}\ PQ_{m,t-1}]$.

When the results of (1') are chained together over T periods, the price index will be exact for periods before and after changes in the composition of $M_{t/t-1}$ (Diewert 1987).

The implicit assumption in (1') is that an unobserved price change is equal to the aggregate of the observable price changes in the same period. Consider a new variety (call it model "Z") that was introduced at time t, and, hence, has a missing price at time t-1. Therefore, the implicit unobserved price under the matched-model approach, $ln\ \underset{\sim}{P}_{Z,t-1}$, is assumed to obey the following relationship:

(2) $\quad ln\ P_{Z,t} - ln\ \underset{\sim}{P}_{Z,t-1} = ln\ P^{MT}_{t} - ln\ P^{MT}_{t-1}$, or,

(2') $\quad ln\ \underset{\sim}{P}_{Z,t-1} = ln\ P^{MT}_{t-1} + [ln\ P_{Z,t} - ln\ P^{MT}_{t}]$.

This relationship will be generally valid under competitive market conditions and if new models or varieties are perfect or near-perfect substitutes for existing ones. Under these conditions, the matched-model Tornqvist is an exact price index in all periods because, in essence, when new varieties are perfect substitutes for existing ones, welfare is unchanged by their introduction.

In markets for high technology goods, for example, (2') states that observable prices of incumbent models or devices must be nearly instantaneously bid down to reflect a performance-adjusted price differential between them and the new, more powerful substitute.[1] This differential thus includes an assessment by purchasers of the degree to which a new variety's introductory price over- or under compensates for its performance advantage relative to the overall market.

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1. The implicit relationship for an exiting item (call it model "X") that retires at time t-1, and, hence, has a missing price at time t is

$$ln\ \underset{\sim}{P}_{X,t} = ln\ P^{MT}_{t} + [ln\ P_{X,t-1} - ln\ P^{MT}_{t-1}] ,$$

which states that the implicit price of an exiting item in period t, the period following retirement, preserves the performance-adjusted price differential that prevailed in t-1.

Explicit treatment of new varieties. A generalization of (1) to account for product turnover can be obtained for the CES and translog aggregator functions (Feenstra 1994, Feenstra and Shiells 1997). The result, an explicit relationship between (1) and (1'), suggests somewhat looser conditions under which a superlative matched-model index approximates an exact index. In the CES function, which we use for exposition, the demand for an item approaches zero only as its price approaches infinity; thus, Hicksian reservation prices are infinity when costs or utility are governed by the CES function.

Define ϕ_t as the revenue share of the $M_{t/t-1}$ varieties relative to that of the M_t varieties in period t; similarly, define ϕ_{t-1} as the revenue share of the $M_{t/t-1}$ varieties relative to that of the M_{t-1} varieties in period t-1. Alternatively, ϕ_t measures one minus the market share of entering products in period t, $(1- s_{Z,t})$, and ϕ_{t-1} measures one minus the market share of exiting products in period t-1, $(1- s_{X,t-1})$. Under CES costs or preferences, the relationship between the exact price index and the matched-model Tornqvist can be expressed as follows:

$$(3) \qquad \ln P^*_t - \ln P^*_{t-1} = [\, \ln P^{MT}_t - \ln P^{MT}_{t-1} \,] + [\ln \phi_t - \ln \phi_{t-1}] \,/\, (\sigma - 1)\,, \quad \sigma > 1$$

where σ is the CES elasticity of substitution parameter. (See Feenstra 1994, pp. 176, for the derivation of this result.)

This result states the introduction of new or improved products will *lower* the change in the exact price index relative to the change in the matched-model index. Similarly, the retirement of products will tend to *raise* the change in the exact price index relative to the change in the matched-model index. Thus, the entry of new varieties may induce an upward bias to a matched-model price index, but the simultaneous exit of varieties that may have become "niche" products near retirement will induce the opposite effect.

The quantitative magnitudes of these effects depend on the size of the revenue shares of entering and exiting varieties and the elasticity of substitution among the varieties that are being aggregated. If σ is high, so that $1/(\sigma-1)$ approaches zero (the case of perfect substitution), a superlative matched-model index will be numerically close to an exact index (the result suggested in the previous section). At the other extreme, as σ

approaches one, the matched-model approach will significantly misstate price change – but only when the ϕ_t and ϕ_{t-1} shares, on net, are significantly less than one. In short, a sufficient condition for the matched-model approach to produce an accurate measure of price change is when the revenue shares of the entering and exiting varieties are small and/or largely offsetting.[2]

The revenue share of a new variety is likely to be small the larger is its own-price elasticity of demand and the greater is the degree to which it substitutes for continuing items, as emphasized in the literature on the welfare-based approach to price indexes (see earlier references). However, this work abstracts from the time frequency, and at a high frequency, those conditions need not be met—and will not when new goods are not very much like existing goods. Rather, the introductory revenue share for a new good or variety with a low own-price elasticity and/or one that is a strong complement with other goods or services is likely to be small simply because the data are at a high frequency.[3]

In conclusion, it is generally not necessary to impute Hicksian reservation prices for the construction of constant-quality, exact price indexes under the following conditions: First, the available data must be at a high frequency and otherwise meet the conditions discussed above (that is, the data should be composed of observations on the prices and revenue of physically similar varieties of the good). Second, those data must indicate that the revenue share weights for entering (exiting) items are small in the introductory (retirement) period.

Revenue shares—the evidence. Quarterly statistics on the revenue shares of new varieties of computational microprocessors and personal computers confirm these propositions.[4] The row stubs of table 1 list the computational processor units (CPUs) produced by Intel for desktop computers from 1993Q1 to 1999Q2, and the columns show the quarterly revenue shares of each of these devices during this period. Each of the 45 rows of the table pertains to a physically distinct device: the CPUs listed differ by speed (shown in the row captions measured in MHz) as well as other characteristics (cache

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2. Under these conditions, *ln* $\phi_t \approx -s_{Z,t}$ and *ln* $\phi_{t-1} \approx -s_{X,t-1}$, and the bias in the superlative matched-model estimate of price change, $-(s_{Z,t} - s_{X,t-1})/(\sigma - 1)$, approaches zero as both $s_{Z,t}$ and $s_{X,t-1}$, or their difference, approaches zero.
3. One can think of exceptions, of course, such as the market share of a new CD in the initial days or weeks following its release.
4. Information on the data sources and the concepts they measure found in section 5.

memory capacity, for example, which is not shown). As may be seen, the quarterly revenue shares of each of the entering and exiting microprocessors in their introductory and retirement periods tend to be very small. Table 2 reports the average per period revenue share for all entering and exiting devices: as may be seen, over all periods shown, the revenue share for entering devices (column 1) is about 6 percent and the average exiting share is about one percent (column 4). Statistics for the revenue shares of Intel's other processor products, not shown, also display a similar pattern.[5]

The upper portion of table 3 shows revenue share statistics for desktop (or desk side) models of personal computers (PCs) containing Intel microprocessors during the same period. As may be seen, the product cycles mirror those for the microprocessors shown in table 1, and, not surprisingly, the revenue shares of entering and exiting items according to this grouping are quite small. However, the data as shown do not meet the homogeneity condition: the statistics in each row are for PCs that are similar only in terms of the speed and brand of its microprocessor. From 1993 to 1998, PC purchasers faced about 20 brands of personal computers, on average, that contained an essentially identical CPU device, including those with non-Intel computational devices.

The statistics in the bottom portion of table 3 show the average per period revenue shares of these nearly 1,400 distinct models of a desktop (or deskside) PC according to whether they were continuing, entering, or exiting models in a given quarter. Here, too, the relevant shares tend to be small: the average revenue share of entering personal computer models is 9 percent per quarter and the average exiting share is 3 percent per quarter. Statistics for notebook computers and for workstation/server computers, not shown, also display these same patterns.

4. HEDONIC PRICE INDEXES

Hedonic regressions capture the tangency between prevailing attribute demand and supply relationships, which restricts the extent to which hedonic-based price indexes capture welfare gains in periods of sharp changes in technology (Trajtenberg 1989).

5. Since the mid-1990s, Intel has segmented its processor products into three groups—desktop, mobile, and workstation/server. However, Intel's products continue to be developed from only a few processor "cores" at any point in time ("cores" have names such as Deschutes, Katmai, or Coppermine). The cores

Once that point is well understood, it is natural to ask, What is the advantage of the hedonic approach for constructing price indexes for high technology goods? Given the typical nature of the competition in these markets, the answer lies in the availability of data. If one only has very low frequency price data on varieties of these goods, then price relatives for homogeneous observations cannot be formed. Under these circumstances, which are dictated by data availability, a stack of cross-sectional data on prices must be aggregated, and the hedonic technique operates uniquely as a constant-quality aggregator.

With a panel of overlapping observations of prices and quantities, however, there are alternative methods. Because the hedonic approach will generally yield numerically different results than those yielded by a matched-model approach, this section reviews the algebra of those differences to sharpen our understanding of the relative merits of the two approaches. We examine two variants of the hedonic approach, the dummy variable method and the imputation method (or "composite" approach; see Cole *et.al.* 1985, Grimm 1998).

The typical hedonic regression expresses the prices of varieties of a good in terms of the quantities of characteristics contained in each variety and dummy variables in time. When there are nontrivial sets of overlapping varieties from one period to the next, and the data are organized so that each model represents a homogeneous variety, the hedonic regression can be expressed as a fixed-effects model. Each of the technologically distinct models (m = 1, … N) is assigned a dummy variable that captures the average value of its unique characteristics on its price. In semi-logarithmic form, this relationship is:

(4) $$\ln P_{m,t} = \Sigma_m \Phi_m MD_m + \Sigma_t \delta_t TD_{m,t} + \varepsilon_{m,t}$$

where $MD_{m,t}$ = 1 if the price is for model m, and = 0 otherwise.

$TD_{m,t}$ = 1 if a price for model m is observed at time t, and = 0 otherwise.

are varied both within and across the product segments according L2 cache size, cache speed, and bus speed, and the variation yields a multitude of Intel processor products on the market at any point in time and where Φ_m, δ_t, and $\varepsilon_{m,t}$ denote econometric estimates. This specification allows for the "brand effects," or model-specific values for coefficients on characteristics, that many researchers have found important in empirical work using the hedonic technique.[6]

The dummy variable method. Because the $\Sigma_m \Phi_m MD_m$ terms control for differences in the qualities of each variety of the good, the regression delegates all other influences on prices to the time dummies and the residuals. The time dummy terms, $\Sigma_t \delta_t TD_{m,t}$, capture the average value of the other influences, and the coefficients of the time dummies are the constant-quality price measures for the aggregate good. Thus, noting that a time dummy for period t has M_t nonzero entries, the dummy variable (DV) hedonic measure of aggregate price change from t-1 to t (in logs), $\delta_t - \delta_{t-1}$, can be expressed in terms of observed prices and the parameters of the hedonic regression that account for quality differences in the varieties being aggregated:

$$(5) \qquad \delta_t - \delta_{t-1} = \Sigma_{m \in Mt} (\mathit{ln}\, P_{m,t} - \Phi_m) / M_t - \Sigma_{m \in Mt-1} (\mathit{ln}\, P_{m,t-1} - \Phi_m) / M_{t-1} .$$

This measure of price change is the difference between two geometric means of price levels: the mean of quality-adjusted prices for varieties bought and sold in period t and the mean of quality-adjusted prices for those bought and sold in period t-1.

The DV treatment of unobservable price relatives can be illustrated by considering a single new variety (call it model "Z") that is introduced at time t, and, hence, has a missing price at time t-1. Rearranging the terms in (5) between those associated with continuing varieties and the term associated with the new variety, the dummy variable estimate of aggregate price change can be expressed as:

$$(6) \qquad \delta_t - \delta_{t-1} = (M_{t-1} / M_t) [\Sigma_{m \in Mt,t-1} (\mathit{ln}\, P_{m,t} - \mathit{ln}\, P_{m,t-1}) / M_{t-1}]$$
$$+ (1 / M_t) [(\mathit{ln}\, P_{Z,t} - \Phi_Z) - \Sigma_{m \in Mt-1} (\mathit{ln}\, P_{m,t-1} - \Phi_m) / M_{t-1}] .$$

6. That is, the typical hedonic regression that explains the price of a variety in a period in terms of the variety's characteristics in the period ($C_{k,m,t}$, k = 1, …K),

$$\mathit{ln}\, P_{m,t} = \Sigma_m \Sigma_k \beta_k C_{k,m,t} + \Sigma_t \delta_t TD_{m,t} + \varepsilon_{m,t}$$

is equivalent to (4) when there are a nontrivial number of overlapping varieties, when the observations are for models are that are homogeneous over time (so that $\Sigma_k \beta_k C_{k,m,t} = \Sigma_k \beta_k C_{k,m,t-1} \ldots = \Sigma_k \beta_k C_{k,m}$ in all periods that model m is bought and sold), and when the coefficients on each characteristic are allowed to vary by model (so that $\Phi_m = \Sigma_k \beta_{k,m} C_{k,m}$).

This results states that, in the presence of turnover, the DV measure is a weighted average of a price measure for continuing varieties and a price measure for the turnover variety, where the weights are shares of observations. For continuing varieties, the measure is a geometric mean of observable price relatives, a form of a matched-model price index.[7] For the turnover variety, the price relative is given as the difference between the quality-adjusted price for the new variety in period t and the average of quality-adjusted prices for all varieties bought and sold in period t-1.

When the number of turnover observations is small, the DV measure will be dominated by the first term—a price index that imposes restrictions on the degree of substitutability across the varieties that are being aggregated. When the number of turnover observations is relatively large, the DV results may be distorted for a related reason, especially in turnover periods when there are substantial discrepancies between the observation share and the revenue share of turnover varieties: The impact of a new (exiting) variety in a period on the econometric estimate of the DV price index for the period, δ_t (the time dummy coefficient), is proportional to its share in the total number of varieties bought and sold in the period. Its appropriate weight, in a Tornqvist index for example, is ½ of the revenue share in the introductory (retirement) period.[8]

The imputation method. The imputation method refers to the practice of using predicted values from a hedonic regression to form the unobservable price relatives required in index number calculations. According to the literature (Triplett 1989, Griliches 1990), this is the preferred hedonic variant because it nests an explicit treatment of new varieties within conventional methodology.

The implicit assumption for the unobservable price relative used in the imputation method can be isolated by again considering a single new variety introduced in period t. Its imputed price in the previous period is obtained from the estimated parameters of the hedonic regression,

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7. In the absence of turnover, the DV measure is simply a geometric mean of available price relatives. Note that this result holds exactly (not in expectation) and requires only that (1) the regression techniques be ordinary least squares, (2) the dependent variable is specified in logs, and (3) the time dummy variables are specified without interactions with the characteristics.

8. Note that the weights in (1) are not appropriate to use in a weighted least squares variant of (4) or (or the expression in footnote 5) because they include current period expenditure shares and, therefore, are endogenous variables (Feenstra 1995). Viewed from this perspective, the DV's econometric estimates are inefficient.

(7) $ln\ P_{Z,t-1} = \delta_{t-1} + \Phi_Z$.

Using the fact that the price of the new good (Z) in period t is, by definition,

(7') $ln\ P_{Z,t} = \delta_t + \Phi_Z + \varepsilon_{Z,t}$

the imputed price relative for the entering variety "Z" is given by:

(8) $ln\ P_{Z,t} - ln\ P_{Z,t-1} = \delta_t - \delta_{t-1} + \varepsilon_{Z,t}$

This states that the imputed price relative for "Z" is the DV price change for the aggregate good, plus a residual that measures the extent to which the new variety fits the regression in its introductory period.

As frequently noted in the hedonic literature (eg., Berndt and Griliches, 1993), the residuals indicate whether a particular variety is over- or under priced relative to the overall market. The role of the residual in (8) is thus viewed as a key feature of the imputation method – it captures an important dimension noted in context of (2), the implicit price relative in the matched-model approach.

Combining expressions (6) and (8) yields the imputed price relative for the new variety expressed in terms of observed prices and the estimated hedonic quality adjustments:

(8') $$ln\ P_{Z,t} - ln\ P_{Z,t-1} = (M_{t-1} / M_t)\ [\ \Sigma_{m\in Mt,t-1} (ln\ P_{m,t} - ln\ P_{m,t-1}) \ /\ M_{t-1}\ ]$$
$$+\ (1 / M_t)\ [(ln\ P_{Z,t} - \Phi_Z) - \Sigma_{m\in Mt-1} (ln\ P_{m,t-1} - \Phi_m) \ /\ M_{t-1}\ ]$$
$$+\ \varepsilon_{Z,t}\ .$$

Ignoring the residual, if the number of turnover observations is small, then most of the movement in the imputed price relatives for turnover varieties will stem from the change in a matched-model geometric mean aggregate price index for the good – the imputation method does not fully correct this deficiency of the DV measure. Although under these circumstances the inclusion of (8') in (1) will tend to carry a small weight, there is no basis in index number theory for choosing (8') as the missing price relative. Moreover, as suggested above, the hedonic regression will not necessarily generate efficient estimates of the residual in (8') if the importance of turnover varieties is misrepresented owing to large differences between the turnover observation share and the turnover revenue share.

5. DATA AND CALCULATIONS

Detailed data at a high frequency, at least quarterly, are an essential ingredient for this inquiry. Guided by theory, we have argued that appropriate measures of price change for high tech goods such as computers and semiconductors can be obtained using a matched-model superlative index, provided the data are sufficiently granular in both the product and time dimensions and composed of unit values and total quantity sold (or the total sales revenue).

Computer data. Quarterly estimates of unit sales and factory revenues for approximately 2,800 computer models marketed in the United States from 1993Q1 to 1998Q4 are the primary data used to study computer prices. These data are composed of about 1,400 models of desktop (or desk side) personal computers (PCs), nearly 600 models of notebook/laptop computers, and about 800 varieties of workstations and servers. These data are from *Dataquest* (DQ), a respected market research firm.

DQ's primary source for the computer data are the computer manufacturers. The manufacturers provide DQ with statistics on the unit shipments of each computer model that they produce. DQ then estimates an average selling price for each of these models based on information provided by the manufacturers, major computer resellers, and the trade press. The prices are for a "typical configuration" of the model, which is held constant during the (short) product life of the model. DQ employs two cross checks on its estimates. First, they compare their revenue figures with publicly available reports, such as 10Ks. Second, DQ exploits detailed input-output relationships and its related data on the industries that produce the major inputs to computers, hard drives and microprocessors, to ensure that their figures for computer sales are consistent with their information and statistics on the production of these components.[9] Data are compiled and issued 6-10 weeks after the close of a quarter.

Computational microprocessor data. Quarterly data on factory shipments and unit prices for Intel's computational microprocessors are from *MicroDesign Resources* (MDR), also a well-respected market research firm. MDR obtains figures on the list prices of Intel processors and adjusts these prices for volume discounts offered to their

9. DQ estimates worldwide computer sales by major regions; the figures used in this paper are sales in the United States.

major customers, the computer manufacturers. MDR obtains figures for the company's total unit shipments and revenue from microprocessors based on Intel's 10K reports and the data reported in the monthly release *World Semiconductor Trade Statistics* (WSTS), available from the Semiconductor Industry Association (SIA). MDR then estimates the unit shipments of each type of microprocessor produced by Intel, based in part on engineering relationships for capacity production at each of Intel's 18 semiconductor plants. Data are compiled twice a year, including figures/forecasts for the current year, which are subject to revision.

During the 486 generation, only clock speed (and price) differentiated one Intel processor from another, and PC system makers had to create differentiated products from the same processors. However, Intel began to design specific processors for PC market segments that were growing in popularity – notebook computers and high-end systems. The company introduced its first mobile CPU line in 1995 and a high-end line for workstation and servers in 1996. In 1998, Intel further segmented the desktop market by introducing a processor product—the Celeron—specifically developed for the "basic" desktop PC market, defined as a system selling for $1000 or less (sans monitor). Previously, Intel supplied the low end PC market solely by reducing the prices of its mainstream processors.

The MDR statistics are thus composed of observations on 91 varieties of Intel processors sold worldwide from 1993Q1 to 1999Q4: 51 desktop processors (performance and Celeron), 32 mobile processors (performance and Celeron), and 8 processors for workstations and servers. Processors aimed for the performance desktop PC market accounted for about 75 percent of the revenue from all processor products in 1998 and 1999 and for the bulk of total processor revenue earlier in the 1990s. MDR estimates Intel's share of the total computational microprocessor market at 93 percent in 1999.

MOS memories data. Quarterly estimates of unit sales and factory revenues sold worldwide from 1990Q1 are also from *Dataquest*. The methods used to obtain these estimates are similar to those described above. Product-level figures, eg. DRAM, SRAM, etc., according to the basic geometry of the chip are crosschecked with comparable detail reported in the WSTS data.

The WSTS Data. The WSTS survey has collected detailed statistics from virtually all semiconductor producers since the early 1990s.[10] The statistics provide measures of worldwide unit sales and factory revenues for more than 110 types of semiconductors on a monthly basis. The annualized figures, in nominal terms, are shown in table 4. As may be seen, MOS memories comprise nearly 25 percent of the total market for integrated circuits (ICs), and Intel computational microprocessors, the bulk of nonembedded MPUs, comprise nearly 20 percent of the total IC market. The semiconductor industry is extremely diverse, of course, but the products we cover in this study are among the more dynamic in the industry.

Matched-model indexes. Matched-model price indexes for computers (desktop PCs, notebooks, servers and workstations, and total), computational microprocessors (desktop, mobile, server and workstation, and total), and MOS memories (DRAM and other) are shown on tables 5-13.

The first column of each table shows a matched-model price index compiled using a Fisher formula, and the second column shows changes in that index at a annual rate. Columns 3 and 4 report the same results for a geometric means price index using the same data. All indexes are set equal to 100 in the first period of the data for a product.

The memo items present calculations useful for interpreting and analyzing the properties of these indexes. The construction of a price index using a superlative aggregator decomposes the change in an aggregate average unit price for the product into a change in a constant-quality price and a change in product quality.[11] These components

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10. These statistics go back earlier; the survey was initiated by the SIA and has covered most U.S. producers of semiconductors since its inception. Since the early 1900s, the survey has been co-sponsored with semiconductor industry trade associations in all major semiconductor-producing countries, and the monthly statistics cover firms whose shipments make up over 95 percent of global semiconductor sales.

11. To see this, note that a superlative aggregator yields price and quantity measures with the property that the change in aggregate nominal output is the sum of the change in the price index and the change the quantity, or real output, index. The change in product quality, $ln\ V^*_t - ln\ V^*_{t-1}$, may be defined as the difference between the change in the real output index, $ln\ Q^*_t - ln\ Q^*_{t-1}$, and the change in the aggregate number of units sold, $ln\ Q_t - ln\ Q_{t-1}$:

(1) $$ln\ V^*_t - ln\ V^*_{t-1} = (ln\ Q^*_t - ln\ Q^*_{t-1}) - (ln\ Q_t - ln\ Q_{t-1})\ .$$

Noting that the change in nominal output can also be decomposed into the change in the average price per unit sold, $ln\ P_t - ln\ P_{t-1}$, and the growth in the number of units sold,
yields the identity

of a price index have common interpretations: average prices reflect production costs and quality change reflects design improvements (Griliches 1961, Raff and Trajtenberg 1997). Thus, a price index can fall when production economies or process improvements lower average selling prices (costs) and when design improvements improve quality. The average unit price for each table's aggregate is shown in columns 5 and 6, and the change in quality, calculated as the change in the Fisher index less the change in the average price per unit is shown in column 7.

Column 8 of each table reports the percentage point difference between the geomean and Fisher matched-model price indexes. The differences indicate the substitution bias in geomean price measure, which plays a role in analyzing the results of hedonic price measures.

Hedonic price indexes. The dummy variable hedonic price index, calculated from the estimated parameters of the time dummies using equation (4), is shown on tables 14-16 for selected products. Each table shows results for two products, and a total of 8 columns are shown on each table. The first of the four columns for a product shows the DV index and the second column reports its annualized percent changes. The third and fourth columns show percentage point differences of the changes in the DV price index from changes in the geomean and superlative matched-model price indexes, respectively.

6. DISCUSSION OF RESULTS

For desktop personal computers, from the beginning of 1993 to the end 1998, the Fisher matched-model constant-quality price index falls from 100 to 14, a decline that averaged about 29 percent per quarter at an annual rate (table 5, column 2). The DV hedonic price index for desktop PCs declines at about the same rate, on average (table 16, column 4).

From 1993 to 1996, the average annual rate of decline in constant-quality prices for desktop personal computers as measured by the Fisher matched-model index was about 23 percent, but in 1997 and 1998 the rate of decline accelerated to 39 percent.

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(2) $$\ln P^*_t - \ln P^*_{t-1} = (\ln P_t - \ln P_{t-1}) - (\ln V^*_t - \ln V^*_{t-1}) .$$

Equation (2) expresses the change in a price index from t-1 to t as the difference between the change in the aggregate average price per unit sold less the change in product quality. Given that $\ln P^*_t$ is a

According to the decomposition of the index, since the fourth quarter of 1996 – a period that covers the advent of the "sub $1000 PC" – the acceleration in the rate of decline of the constant-quality price index was more than accounted for by a large drop in the average selling price of a personal computer. As a result, the implied growth of aggregate quality slowed by 10 percentage points during 1997 and 1998 (table 5, column 7)

Table 6 reports matched-model price indexes for notebook computers from 1993 to 1998. As may be seen, constant-quality prices of notebook computers fell at an average annual rate of 23 percent per quarter; and the decomposition of price declines over the sub-periods of the 1990s yields similar results to those discussed above for desktop PCs. The hedonic price index for notebook computers also falls at about the same rate, on average, as the matched-model Fisher index during this period (table 16, column 8).

For Intel's desktop computational microprocessors, from the beginning of 1993 to 1999, the Fisher matched-model constant-quality price index falls from 100 to 0.21, a decline that averaged nearly 60 percent per quarter at an annual rate (table 9, column 2). The price index for all Intel processors declines at a slower rate, about 50 percent over the same period (table 12, column 2), owing to the noticeably slower rate of decline in constant-quality prices of processors designed for high-end systems (table 11, column 2). For desktop CPUs (including Celeron), the rate of decline in constant-quality prices accelerated noticeably in 1995. Since then desktop CPU prices have declined at an average annual rate of more than 65 percent.

For computers and computer processors, the differences between the Fisher and geomeans matched-model price indexes are generally small, on average (see the all-periods average shown at the bottom of column 8 on the tables). However, these differences, which reflect the substitution bias in the geometric means index, are not uniform in sign, and the averages mask large period-to-period differences that bounce around significantly.

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constant-quality index and as inspection of (2) suggests, the quality change aggregate defined by (1) mirrors mix shifts in the composition of varieties sold.

For desktop computer processors, a geometric means price index slightly understates the rate of decline in prices (table 8, column 8) while for PCs, a geometric means index slightly overstates the decline (table 5, column 8). Although these differences are small, they occur in our data, which we wish to underscore are for the 1990s, because the price profiles of each computer model or CPU device were approximately log-linear with similar slopes during this period. This finding is not a general characteristic of high technology goods prices: Prices for individual DRAM devices, for example, do not exhibit simple log-linear patterns (Flamm 1993, Irwin and Klenow 1994, and Grimm 1998), and we find that, on average, from 1992 to 1998, the matched-model geometric means price understates the decline in DRAM prices by 8 percentage points per year (table 13, column 8). And, the price declines for servers and workstations are significantly overstated by the geometric means price index (table 11, column 8), while, on balance, the all Intel microprocessor geometric means price index falls at an identical rate to that of the Fisher index for the period shown (table 12, column 8).[12]

The large period-by-period differences between the geometric mean and Fisher matched-model indexes show through in the period-by-period differences between the DV hedonic and Fisher matched-model indexes. To see this, we view the differences between the DV hedonic and Fisher matched-model indexes as composed of two terms: (1) the differences between the DV hedonic and the geomean MM indexes and (2) the differences between the geomean and Fisher MM indexes.

For desktop CPUs, for example, 15 of the 27 observations show large (greater that 4 percentage points in absolute value) differences between the DV hedonic and Fisher MM index (table 14, column 8). Of these, 12 are nearly identical in size and sign to the differences between the geomean and Fisher MM indexes (table 8, column 8) and thus owe to differences in weighting. For desktop PCs, 8 of the 23 observations shown large differences between the DV hedonic and Fisher MM index (table 16, column 4). Of these, 6 are largely explained by differences in weighting.

12. For high-end processors, the geomeans estimator for 1999Q1 is dominated by a 42 percent decline in the price of the 400MHz Xeon (PII) processor, one of only a few continuing devices in that quarter.

The differences between the DV hedonic and geomean MM indexes isolate the effect of the hedonic treatment of turnover items. For desktop CPUs (table 14, column 7), the DV hedonic falls, on average, about 2 percentage points per year faster than the geomean MM index. As may be seen, this average difference is dominated by several observations that show large negative differences, including 1993Q2, 1994Q1, 1995Q4, and 1996Q4. The differences occur in quarters with high entry rates measured in terms of observation shares. For the majority of these occurrences, the observation share greatly overstates the entry rate measured in terms of revenue shares.[13]

For desktop PCs (table 16, column 3), the DV hedonic falls, on average, about 2 percentage points per year slower than the geomean MM index, a result dominated by a discrepancy for single observation (1994Q1) that may be traced to an overstated turnover rate.

5. CONCLUSION

In most markets for high technology goods, the life of a specific variety of a product is short and many varieties are bought and sold at once. When very disaggregate data on prices and quantities of these products are available at a high frequency, matched-model price measures compiled using a superlative index formula will generally capture the rapid pace of quality change in these goods. This finding rests on both the nature of markets for most high technology goods as well as the simple fact that, in high frequency data, the market share of turnover varieties tends to be small.

The logical conclusion of our findings is that high frequency data on both prices and quantities of high technology goods should be collected in a single survey instrument. Unfortunately, such survey instruments are rare in official statistics, especially at a high frequency and at the level of detail required by (1). Under both the conventional and welfare-based approaches to price measurement, however, such data are

13. Table 3, introduced earlier, compares the observation share and the revenue share for entering and exiting Intel computational desktop processors. As may be seen, the shares differ substantially in most of the turnover periods. The average revenue share of the entering devices, as noted earlier, is 6 percent. Averaged only over periods of entry, the entering revenue share is a bit higher, 8 percent, but the observation share of entering varieties averages 19 percent for the same periods. For exiting varieties in periods of exit, the revenue share averages 2 percent, while the observation share averages 15 percent. The discrepancies are quite large for most of the quarters with exit and many of the quarters with entry.

required for the accurate measurement of prices indexes for high technology goods such as computers and semiconductors, and, by implication, the productivity performance of the aggregate economy.

A comparison of the matched-model indexes compiled using a superlative index number formula with those generated using a hedonic regression technique suggests that the hedonic approach yields noisy and imprecise period-by-period measures of price change. That said, our results for personal computer prices are interesting because the estimated trends are both consistent with those established in the hedonic literature and generally in line with figures issued by the BLS. The methods used to compile our indexes, which are replicable and independent of econometrically estimated parameters, thus provide support for published data that indicate an acceleration in the rate of decline in computer prices in the late 1990s.

BIBLIOGRAPHY

Balk, Bert M., "On the Use of Unit Value Indices as Consumer Price Subindices," in *Proceedings of the Fourth Meeting of the International Working Group on Price Indices,* ed., Walter Lane. (Washington D.C.: U.S. Department of Labor, Bureau of Labor Statistics, 1998), pp. 112-120.

Berndt, Ernst R. and Zvi Griliches, "Price Indexes for Microcomputers: An Exploratory Study," in *Price Measurements and Their Uses*, ed. Murray Foss, Marilyn Manser, and Allan Young. (Chicago: The University of Chicago Press, 1993), pp. 63-93.

Boskin, Michael J., Ellen R. Dulberger, Robert J. Gordon, Zvi Griliches, and Dale Jorgenson, "The CPI Commission: Findings and Recommendations," *American Economic Review, Papers and Proceedings* 87 (May 1997), pp.78-83.

Cole, Rosanne, Y.C. Chen, Joan A. Barquin-Stolleman, Ellen Dulberger, Nurhan Helvacian, and James H. Hodge, "Quality-Adjusted Price Indexes for Computer Processors and Selected Peripheral Equipment," *Survey of Current Business 66* (January 1986), pp. 41-50.

Diewert, W. E., "Exact and Superlative Index Numbers," *Journal of Econometrics* 4 (May 1976), pp. 115-45.

Diewert, W.E., "Superlative Index Numbers and Consistency in Aggregation," *Econometrica* 46 (July 1978), pp. 883-900.

Diewert, W.E., "Aggregation Problems in the Measurement of Capital," in *The Measurement of Capital*, ed., Dan Usher. (Chicago: University of Chicago Press, 1980), pp. 433-528.

Diewert, W.E., "Index Numbers", in *The New Palgrave: A Dictionary of Economics*, Volume 2, J. eds., Eatwell, M. Milgate and P. Newman. (London: Macmillan, 1987), pp. 767-780.

Diewert, W.E., "Axiomatic and Economic Approaches to Elementary Price Indexes," Discussion Paper 95-01. (Vancouver: Department of Economics, University of British Columbia, 1995).

Dulberger, Ellen R., "The Application of a Hedonic Model to a Quality-Adjusted Price Index for Computer Processors," in *Technology and Capital Formation*, ed. Dale W. Jorgenson and Ralph Landau. (Cambridge, Mass: MIT Press, 1989), pp. 37-75.

Dulberger, Ellen R., "Sources of Price Decline in Computer Processors: Selected Electronic Components," in *Price Measurements and Their Uses*, ed. Murray

Foss, Marilyn Manser, and Allan Young. (Chicago: The University of Chicago Press, 1993), pp. 103-124.

Feenstra, Robert C, "New Product Varieties and the Measurement of International Prices," *American Economic Review* 84, no. 1 (March 1994), pp. 157-177.

Feenstra, Robert C., "Exact Hedonic Price Indexes," *The Review of Economics and Statistics*, 1995, pp. 634-653.

Feenstra, Robert C. and Clinton R. Shiells, "Bias in U.S. Import Prices and Demand," in *The Economics of New Goods*, eds., T. F. Breshnahan and R. J. Gordon. (Chicago: The University of Chicago Press, 1997), pp. 249-273.

Fisher, Franklin M. and Karl Shell, *The Economic Theory of Price Indices* (New York: Academic Press, 1972).

Flamm, Kenneth, "Measurement of DRAM Prices: Technology and Market Structure," in *Price Measurements and Their Uses*, ed. Murray Foss, Marilyn Manser, and Allan Young. (Chicago: The University of Chicago Press, 1993), pp. 157-197.

Griliches, Zvi, "Hedonic Prices for Automobiles: An Econometric Analysis of Quality Change," in *The Price Statistics of the Federal Government*. (New York: NBER, 1961).

Griliches, Zvi, "Hedonic Price Indexes and the Measurement of Capital and Productivity," in *Fifty Years of Economic Measurement*, eds., E.R. Berndt and J.E. Triplett. (Chicago: University of Chicago Presss, 1990), pp. 185-202.

Grimm, Bruce T., "Price Indexes for Selected Semiconductors, 1974-96," *Survey of Current Business* 78 (February 1998), pp. 8-24.

Hausman, Jerry, "Cellular Telephone, New Products, and the CPI," *Journal of Business and Economic Statistics* 17 (April 1999), pp. 188-194.

Irwin, Douglas A. and Peter J. Klenow, "Learning-by-Doing Spillovers in the Semiconductor Industry," *Journal of Political Economy*, 102, no 6. (December 1994), pp. 1200-1227.

Moulton, Brent, "Getting the 21st Century GDP Right: What's Underway," paper. (Washington DC: U.S. Department of Commerce, Bureau of Economic Analysis, 2000).

Oliner, Steven D. and Daniel E. Sichel, "The Resurgence of Growth in the Late 1990s: Is Information Technology the Story?" FEDS paper 2000-20. (Washington D.C.: Board of Governors of the Federal Reserve System, 2000).

Pakes, Ariel, Steve Berry and James Levinsohn, "Price Indexes and the Analysis of Environmental Change," *American Economic Review*, 83 (May 1993), pp. 240-46.

Raff, Daniel M.G. and Manuel Trajtenberg, "Quality-adjusted Prices for the American Automobile Industry: 1906-1940," in *The Economics of New Goods*, eds., T.F. Breshnahan and R.J. Gordon. (Chicago: The University of Chicago Press, 1997), pp. 71-101.

Trajtenberg, Manuel, "The Welfare Analysis of Product Innovations, with an Application of Computed Tomography Scanners," *Journal of Political Economy* 97, no. 2 (April 1989), pp. 444-479.

Triplett, Jack E., "The Economic Interpretation of Hedonic Methods," *Survey of Current Business* 66 (January 1986), pp. 36-40.

Triplett, Jack E., "Price and Technological Change in a Capital Good: A Survey of Research on Computers," in *Technology and Capital Formation*, ed. Dale W. Jorgenson and Ralph Landau. (Cambridge, Mass: MIT Press, 1989), pp. 126-213.

Table 1. Revenue Shares for Intel Desktop Computational Microprocessor Chips, 93Q1-99Q4

		93Q1	93Q2	93Q3	93Q4	94Q1	94Q2	94Q3	94Q4	95Q1	95Q2	95Q3	95Q4	96Q1	96Q2	96Q3	96Q4	97Q1	97Q2	97Q3	97Q4	98Q1	98Q2	98Q3	98Q4	99Q1	99Q2
486SX	25 MHz	2.3%	2.7%	3.5%	2.5%	1.6%	0.8%	0.4%	0.2%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
486SX	33 MHz	3.2%	4.5%	6.7%	5.9%	5.8%	3.6%	2.5%	1.3%	0.4%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
486SX2	50 MHz	-	-	-	-	4.4%	7.6%	7.3%	5.2%	3.3%	1.4%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
486DX	33 MHz	39.8%	36.4%	32.5%	32.5%	30.0%	21.4%	12.8%	4.1%	1.8%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
486DX2	50 MHz	29.0%	29.8%	30.5%	28.1%	25.2%	22.7%	18.7%	12.3%	5.3%	1.7%	0.4%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
486DX3	66 MHz	25.7%	24.6%	24.0%	25.8%	25.0%	19.7%	16.5%	14.6%	16.4%	8.5%	3.6%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
486DX4	75 MHz	-	-	-	-	0.1%	1.8%	4.0%	8.2%	6.2%	4.0%	2.3%	0.5%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
486DX4	100 MHz	-	-	-	-	0.1%	1.4%	3.2%	6.6%	7.5%	8.3%	8.0%	5.7%	2.1%	-	-	-	-	-	-	-	-	-	-	-	-	-
PI	60 MHz	-	1.9%	2.7%	4.1%	4.9%	5.2%	3.9%	3.2%	1.6%	0.6%	0.3%	0.2%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PI	66 MHz	-	0.2%	0.2%	1.2%	2.3%	3.8%	4.7%	4.1%	2.5%	0.9%	0.5%	0.2%	-	-	-	-	-	-	-	-	-	-	-	-	-	-
PI	75 MHz	-	-	-	-	-	-	-	8.1%	7.5%	13.1%	13.8%	12.9%	4.1%	1.0%	0.4%	-	-	-	-	-	-	-	-	-	-	-
PI	90 MHz	-	-	-	-	0.5%	7.9%	19.5%	23.0%	21.9%	15.9%	11.6%	9.3%	5.1%	1.4%	0.4%	-	-	-	-	-	-	-	-	-	-	-
PI	100 MHz	-	-	-	-	0.3%	4.0%	6.6%	9.2%	23.5%	21.3%	16.6%	16.0%	10.5%	5.5%	3.0%	1.7%	0.4%	-	-	-	-	-	-	-	-	-
PI	120 MHz	-	-	-	-	-	-	-	-	-	-	-	-	2.9%	4.9%	6.2%	5.0%	3.8%	2.0%	0.6%	-	-	-	-	-	-	-
PI	120 MHz	-	-	-	-	-	-	-	-	2.2%	19.1%	25.9%	21.6%	13.0%	6.5%	1.9%	0.6%	-	-	-	-	-	-	-	-	-	-
PI	133 MHz	-	-	-	-	-	-	-	-	-	5.3%	17.0%	17.3%	22.2%	26.0%	23.9%	21.0%	10.6%	2.4%	0.8%	-	-	-	-	-	-	-
PI	150 MHz	-	-	-	-	-	-	-	-	-	-	-	4.8%	10.5%	13.6%	15.4%	12.4%	5.8%	1.4%	0.4%	-	-	-	-	-	-	-
PI	166 MHz	-	-	-	-	-	-	-	-	-	-	-	8.1%	17.3%	25.8%	28.2%	25.2%	14.4%	4.9%	1.6%	0.7%	-	-	-	-	-	-
PI	200 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.1%	9.4%	8.0%	4.0%	2.2%	1.8%	-	-	-	-	-	-
MMX	166 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.8%	26.9%	29.1%	17.9%	10.1%	5.5%	1.5%	-	-	-	-
MMX	200 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.1%	16.9%	27.4%	20.5%	18.2%	9.5%	2.8%	0.6%	-	-	-
MMX	233 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.7%	11.2%	17.2%	10.3%	5.1%	1.3%	-	-	-
Pro	150 MHz	-	-	-	-	-	-	-	-	-	-	-	1.6%	4.0%	3.2%	1.1%	0.0%	-	-	-	-	-	-	-	-	-	-
Pro	180 MHz	-	-	-	-	-	-	-	-	-	-	-	1.4%	5.4%	6.8%	4.1%	2.8%	2.2%	0.6%	0.0%	-	-	-	-	-	-	-
Pro	200 MHz	-	-	-	-	-	-	-	-	-	-	-	0.4%	2.8%	5.3%	7.2%	8.0%	11.1%	7.7%	4.2%	1.6%	-	-	-	-	-	-
PII	233 MHz	-	-	-	-	-	-	-	-	-	-	-	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	10.7%	17.5%	10.4%	4.4%	1.2%	0.3%	-	-	-
PII	266 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.0%	14.5%	18.8%	18.4%	10.8%	3.4%	0.3%	-	-
PII	300 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	8.5%	8.2%	7.6%	4.6%	3.4%	0.2%	-	-
PII	300 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	7.9%	20.9%	24.7%	16.2%	6.2%	-	-
PII	333 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5.2%	18.4%	21.9%	23.9%	18.2%	6.6%	0.9%
PII	350 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	3.4%	16.2%	25.5%	28.1%	19.5%	4.8%
PII	400 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.7%	8.2%	12.6%	22.2%	23.1%	18.9%
PII	450 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.6%	13.4%	18.3%	12.6%
PII	450 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	11.6%	15.7%
PIII	500 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.9%	24.0%
PIII	550 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6.8%
Celeron	266 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.0%	1.0%	0.0%	0.0%	0.0%
Celeron	300 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.9%	2.4%	3.1%	0.3%	0.0%
Celeron	300 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.4%	4.0%	1.0%	0.3%
Celeron	333 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2.5%	3.6%	2.1%	1.3%
Celeron	366 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0.7%	4.6%	2.4%
Celeron	400 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	4.4%	5.3%
Celeron	433 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.5%	5.1%
Celeron	466 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1.8%
Total		100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100

Source: Authors calculations based on proprietary data from Micro Design Resources.

Table 2. Entry and Exit Shares for Intel Desktop CPUs (including Celeron)

	Entering devices (t)			Exiting devices (t-1)			
	Revenue Share (percent) (1)	Number (2)	Observation Share (percent) (3)	Revenue Share Share (percent) (4)	Number (5)	Observation Share (percent) (6)	Net Entry Share (percent) (7)
Date							
93Q2	2.1	2	28.6	0.0	0	0.0	2.1
93Q3	0.0	0	0.0	0.0	0	0.0	0.0
93Q4	0.0	0	0.0	0.0	0	0.0	0.0
94Q1	5.3	5	41.7	0.0	0	0.0	5.3
94Q2	0.0	0	0.0	0.0	0	0.0	0.0
94Q3	0.0	0	0.0	0.0	0	0.0	0.0
94Q4	8.1	1	7.7	0.0	0	0.0	8.1
95Q1	2.2	1	7.7	0.4	1	7.7	1.8
95Q2	5.3	1	8.3	0.4	1	7.7	4.9
95Q3	0.0	0	0.0	1.4	1	8.3	-1.4
95Q4	16.4	6	40.0	4.0	2	18.2	12.4
96Q1	3.0	1	7.7	0.9	3	20.0	2.1
96Q2	0.0	0	0.0	3.0	1	7.7	-3.0
96Q3	0.0	0	0.0	0.0	0	0.0	0.0
96Q4	13.8	2	15.4	0.8	2	15.4	13.0
97Q1	0.0	0	0.0	0.6	2	15.4	-0.6
97Q2	9.7	2	18.2	0.0	1	9.1	9.7
97Q3	8.5	1	9.1	0.0	0	0.0	8.5
97Q4	13.0	2	18.2	1.8	4	30.8	11.2
98Q1	5.1	2	20.0	4.1	3	27.3	1.0
98Q2	2.9	2	16.7	0.0	0	0.0	2.9
98Q3	9.5	3	21.4	2.0	1	8.3	7.5
98Q4	8.3	1	8.3	2.1	3	21.4	6.2
99Q1	24.4	4	30.8	6.7	3	25.0	17.7
99Q2	8.6	2	13.3	0.0	0	0.0	8.6
93-99	5.8		12.5	1.1		8.9	4.7

Source: Authors calculations based on proprietary data from Micro Design Resources.

Table 3. Revenue Shares for Desktop Personal Computers, 93Q1-98Q4

A. Models with an Intel CPU

		93Q1	93Q2	93Q3	93Q4	94Q1	94Q2	94Q3	94Q4	95Q1	95Q2	95Q3	95Q4	96Q1	96Q2	96Q3	96Q4	97Q1	97Q2	97Q3	97Q4	98Q1	98Q2	98Q3	98Q4
486SX	25/33 MHz	32%	33%	34%	32%	31%	26%	20%	14%	7%	3%	1%	0%	0%	-	-	-	-	-	-	-	-	-	-	-
486SX2	50 MHz	12%	8%	5%	3%	1%	1%	0%	0%	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
486DX	33 MHz	39%	38%	36%	31%	19%	11%	6%	4%	1%	0%	0%	0%	0%	-	-	-	-	-	-	-	-	-	-	-
486DX2	50/66 MHz	18%	21%	22%	27%	35%	43%	45%	43%	31%	18%	9%	3%	1%	1%	0%	0%	-	-	-	-	-	-	-	-
DX4	75/100 MHz	-	-	-	-	-	1%	3%	5%	10%	10%	9%	6%	3%	0%	1%	0%	-	-	-	-	-	-	-	-
PI	60/66 MHz	-	-	-	-	2%	3%	4%	3%	16%	13%	4%	1%	0%	0%	0%	0%	-	-	-	-	-	-	-	-
PI	5/90/100 MHz	-	0%	3%	8%	12%	15%	22%	30%	35%	53%	68%	75%	56%	32%	15%	5%	1%	0%	0%	-	-	-	-	-
PI	120/133 MHz	-	-	-	-	-	-	-	-	0%	3%	9%	15%	30%	43%	44%	36%	29%	19%	11%	1%	0%	-	-	-
PI	150/166 MHz	-	-	-	-	-	-	-	-	-	-	-	-	9%	22%	30%	36%	37%	34%	25%	19%	10%	2%	-	-
PI	180/200 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	4%	11%	17%	23%	26%	26%	18%	10%	1%	1%
PI	233/266 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	8%	11%	16%	14%	6%	2%
Pro	150/166 MHz	-	-	-	-	-	-	-	-	-	-	-	0%	1%	2%	1%	1%	2%	3%	1%	0%	0%	-	-	-
Pro	180/200 MHz	-	-	-	-	-	-	-	-	-	-	-	-	0%	1%	5%	11%	14%	19%	15%	16%	5%	0%	0%	-
Pro	233/266 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	0%	0%	1%	-	-	-
PII	233/266 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2%	13%	20%	27%	40%	16%	8%
PII	300/333 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1%	6%	23%	22%	23%	14%
PII	350/400 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	9%	39%	40%
PII	450/500 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5%	21%
Celeron	233/266 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2%	3%	2%
Celeron	300/333 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1%	5%	10%
Celeron	350/400 MHz	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1%
Total		100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%	100%

B. All Models

	93Q1	93Q2	93Q3	93Q4	94Q1	94Q2	94Q3	94Q4	95Q1	95Q2	95Q3	95Q4	96Q1	96Q2	96Q3	96Q4	97Q1	97Q2	97Q3	97Q4	98Q1	98Q2	98Q3	98Q4
Continuing models	-	98.2	96.2	95.8	75.4	94.7	95.0	94.7	73.8	91.2	85.5	98.0	82.9	94.1	82.0	96.5	86.8	88.9	82.5	92.0	86.2	77.4	84.2	72.9
Entering models (t)	-	1.5	3.3	3.6	13.3	5.1	4.4	4.6	21.4	7.5	12.8	1.2	15.6	4.7	17.5	1.3	7.6	10.5	15.0	6.6	5.7	17.0	10.4	16.3
Exiting models (t-1)	-	0.3	0.5	0.6	11.2	0.2	0.6	0.7	4.9	1.3	1.8	0.8	1.5	1.2	0.6	2.2	5.6	0.6	2.4	1.4	8.1	5.6	5.4	10.8
Net entry		1.3	2.8	3.0	2.1	4.8	3.8	3.9	16.5	6.2	11.0	0.3	14.1	3.5	16.9	-0.9	2.0	9.9	12.6	5.1	-2.4	11.4	5.0	5.4

Source: Authors calculations based on proprietary data from Dataquest.

Table 4. Nominal Worldwide Semiconductor Billings
(Millions of Dollars, NSA)

	1991-95 Average	1996	1997	1998	1999
Total	87,613	131,966	137,203	125,612	149,379
Integrated circuits (ICs)	73,951	114,499	119,179	109,071	130,218
MOS Memory	26,849	36,018	29,335	22,993	32,286
DRAM	18,504	25,132	19,798	14,011	20,714
Other	8,345	10,886	9,537	8,982	11,572
MOS Microcomponents	19,900	39,828	47,767	47,341	51,701
Microprocessors (MPUs)	8,160	18,530	23,467	24,776	27,191
Nonembedded MPUs	--	16,626	20,854	22,646	24,769
Embedded MPUs	--	1,904	2,612	2,129	2,422
Microcontrollers	7,134	11,435	12,623	12,116	14,083
Microperipherals	4,606	9,862	11,677	10,450	10,427
Other Logic	13,152	20,126	21,047	18,564	23,158
General purpose	1,545	2,106	2,370	1,904	2,171
Gatearray	3,368	4,813	3,960	3,022	2,464
Standard cell	2,153	5,006	6,334	5,382	7,333
Field programmable	970	1,795	2,043	2,174	2,900
Other	5,116	6,406	6,340	6,082	6,022
Other ICs	14,051	18,528	21,029	20,173	23,072
Analog	11,594	17,044	19,789	19,073	22,082
Bipolar	2,457	1,484	1,240	1,100	990
Opto-Discretes	12,648	17,025	17,671	16,541	19,161
Discretes	9,657	12,879	13,165	11,923	13,383
Optoelectronics	2,991	4,147	4,506	4,617	5,778
Memo: Total (SA)	87,437	131,981	136,937	125,478	148,956

Source: Semiconductor Industry Association

Table 5. Matched-model Price Indexes for Desktop Personal Computers

	Fisher formula		Geomean formula		Memos: Average Price per unit		Memos: Quality Change	Memos: Geomean Subs.
	Index 93Q1=100	Percent change (annual rate)	Index, 93Q1=100	Percent change (annual rate)	Dollars	Percent change (annual rate)	(6)-(2) Percentage points, annual rate	Bias, (4)-(2) Percentage points, annual rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
93:1	100.0	--	100.0	--	1,946	--	--	--
93:2	95.3	-17.4	94.9	-18.9	1,897	-9.7	7.7	-1.5
93:3	88.2	-26.6	86.2	-31.8	1,807	-17.7	9.0	-5.2
93:4	83.0	-21.8	82.1	-18.0	1,795	-2.6	19.2	3.8
94:1	77.1	-25.4	73.0	-37.4	1,871	17.9	43.4	-12.0
94:2	69.3	-34.9	67.2	-28.1	1,814	-11.5	23.4	6.8
94:3	65.5	-20.0	63.7	-19.4	1,875	14.1	34.1	0.6
94:4	60.9	-25.4	57.8	-32.3	1,840	-7.4	18.0	-6.9
95:1	57.6	-19.8	54.2	-22.4	1,930	21.2	41.0	-2.6
95:2	52.6	-30.3	49.1	-32.9	1,952	4.5	34.8	-2.6
95:3	49.9	-19.1	46.7	-18.2	1,988	7.5	26.6	0.9
95:4	47.9	-15.6	44.3	-18.5	2,041	11.2	26.8	-2.9
96:1	43.5	-31.9	39.7	-35.5	2,029	-2.4	29.5	-3.7
96:2	41.0	-21.3	37.2	-23.4	2,111	17.2	38.5	-2.1
96:3	39.5	-13.8	35.7	-14.6	2,155	8.8	22.5	-0.8
96:4	37.8	-16.1	34.1	-16.6	2,250	18.8	34.9	-0.6
97:1	36.2	-15.3	33.5	-7.6	2,267	3.0	18.3	7.7
97:2	30.3	-51.3	28.5	-47.4	2,003	-39.0	12.3	3.9
97:3	28.1	-25.8	26.5	-25.3	1,947	-10.7	15.2	0.6
97:4	25.3	-34.0	23.9	-34.3	1,875	-14.1	19.9	-0.3
98:1	21.4	-48.5	20.7	-43.0	1,694	-33.3	15.2	5.5
98:2	19.2	-35.1	18.1	-41.8	1,620	-16.4	18.7	-6.6
98:3	16.9	-39.9	15.6	-45.4	1,602	-4.3	35.6	-5.5
98:4	14.1	-52.1	12.6	-57.1	1,364	-47.4	4.7	-5.0
93-98		-28.9		-30.3		-6.0	22.9	-1.4
93-96		-22.9		-24.9		4.0	26.8	-2.1
97-98		-38.9		-39.2		-22.2	16.8	-0.3

Source: Authors calculations based on proprietary data from *Dataquest.*

Table 6. Matched-model Price Indexes for Notebook Computers

	Fisher formula		Geomean formula		Memos: Average Price per unit		Memos: Quality Change	Memos: Geomean Subs.
	Index 94Q1=100	Percent change (annual rate)	Index, 94Q1=100	Percent change (annual rate)	Dollars	Percent change (annual rate)	(6)-(2) Percentage points, annual rate	Bias, (4)-(2) Percentage points, annual rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
93:1	100.0	--	100.0	--	2,501	--	--	--
93:2	98.1	-7.2	96.9	-11.8	2,487	-2.3	4.9	-4.5
93:3	95.0	-12.2	91.4	-21.0	2,469	-2.7	9.5	-8.8
93:4	91.6	-13.5	87.7	-15.2	2,442	-4.3	9.1	-1.7
94:1	83.2	-31.9	77.1	-40.3	2,405	-5.9	26.0	-8.5
94:2	77.9	-23.2	71.8	-24.8	2,413	1.3	24.5	-1.6
94:3	74.8	-15.0	68.2	-18.4	2,691	54.8	69.7	-3.4
94:4	68.7	-29.0	63.1	-26.8	2,572	-16.7	12.3	2.2
95:1	65.5	-17.5	59.9	-18.8	2,629	9.3	26.8	-1.3
95:2	61.4	-22.7	56.5	-20.9	2,558	-10.4	12.4	1.8
95:3	57.6	-22.7	53.7	-18.2	2,625	10.9	33.6	4.6
95:4	54.2	-21.4	50.6	-21.6	2,642	2.6	24.0	-0.2
96:1	49.5	-30.3	45.4	-34.9	2,765	19.9	50.2	-4.6
96:2	45.7	-27.7	42.6	-22.6	2,962	31.7	59.4	5.1
96:3	45.2	-3.5	41.5	-9.8	3,131	24.9	28.4	-6.3
96:4	43.6	-13.6	39.6	-17.3	3,162	4.1	17.7	-3.8
97:1	43.1	-4.6	39.1	-4.8	3,358	27.2	31.8	-0.2
97:2	37.6	-42.0	34.6	-38.7	3,051	-31.9	10.1	3.3
97:3	36.1	-15.3	33.6	-11.4	2,895	-18.9	-3.6	3.9
97:4	33.6	-25.0	31.0	-27.7	2,908	1.9	26.8	-2.7
98:1	30.4	-32.6	27.7	-36.0	2,761	-18.7	13.9	-3.4
98:2	29.4	-12.5	26.6	-15.2	2,769	1.1	13.6	-2.7
98:3	27.0	-29.2	24.1	-32.2	2,672	-13.3	15.9	-3.0
98:4	22.1	-55.0	19.2	-59.4	2,287	-46.3	8.7	-4.4
93-98		-23.1		-24.9		-1.5	21.5	-1.8
93-96		-19.8		-21.9		6.5	26.3	-2.1
97-98		-28.8		-30.3		-15.0	13.8	-1.5

Source: Authors calculations based on proprietary data from *Dataquest.*

Table 7. Matched-model Price Indexes for Servers and Workstations

	Fisher formula		Geomean formula		Memos: Average Price per unit		Quality Change	Geomean Subs.
	Index 94Q1=100	Percent change (annual rate)	Index, 94Q1=100	Percent change (annual rate)	Dollars	Percent change (annual rate)	(6)-(2) Percentage points, annual rate	Bias, (4)-(2) Percentage points, annual rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
94:1	100	--	100	--	26,792	--	--	--
94:2	94.41	-20.6	97.04	-11.3	29,699	51.0	71.5	9.2
94:3	93.07	-5.6	94.2	-11.2	31,148	21.0	26.6	-5.6
94:4	92.35	-3.1	90.64	-14.3	31,035	-1.4	1.6	-11.2
95:1	81.81	-38.4	80.56	-37.6	26,765	-44.7	-6.3	0.8
95:2	81.26	-2.7	78.21	-11.2	25,522	-17.3	-14.7	-8.5
95:3	77.07	-19.1	76.5	-8.5	23,333	-30.1	-11.1	10.6
95:4	74.16	-14.3	74.67	-9.2	23,515	3.2	17.4	5.0
96:1	70.08	-20.3	69.78	-23.7	23,804	5.0	25.3	-3.5
96:2	66.74	-17.7	66.82	-15.9	21,230	-36.7	-19.0	1.8
96:3	64.8	-11.1	65.12	-9.8	21,811	11.4	22.5	1.3
96:4	61.12	-20.9	62.1	-17.3	17,441	-59.1	-38.3	3.6
97:1	58.36	-16.9	58.11	-23.3	19,271	49.0	65.9	-6.5
97:2	55.78	-16.5	55.02	-19.6	17,926	-25.1	-8.6	-3.1
97:3	53.35	-16.3	52.48	-17.2	16,994	-19.2	-2.9	-0.9
97:4	50.67	-18.6	47.78	-31.3	14,733	-43.5	-24.9	-12.7
98:1	45.49	-35.0	43.67	-30.2	14,770	1.0	36.1	4.8
98:2	40.57	-36.7	38.64	-38.7	12,962	-40.7	-4.0	-2.0
98:3	37.15	-29.7	32.99	-46.9	13,506	17.9	47.6	-17.2
98:4	33.27	-35.7	29.48	-36.2	11,887	-40.0	-4.3	-0.6
94-98		-20.7		-22.7		-15.7	5.0	-2.0
94-96		-16.4		-15.9		-14.5	1.9	0.5
97-98		-26.2		-31.1		-17.4	8.8	-4.9

Source: Authors calculations based on proprietary data from *Dataquest.*

Table 8. Matched-model Price Indexes for All Computers

	Fisher formula		Geomean formula		Memos: Average Price per unit		Quality Change	Geomean Subs.
	Index 94Q1=100	Percent change (annual rate)	Index, 94Q1=100	Percent change (annual rate)	Dollars	Percent change (annual rate)	(6)-(2) Percentage points, annual rate	Bias, (4)-(2) Percentage points, annual rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
94:1	100.0	--	100.0	--	2,868	--	--	--
94:2	92.0	-28.4	94.6	-19.8	2,977	16.1	44.5	8.6
94:3	88.6	-14.1	90.7	-15.6	2,981	0.5	14.6	-1.5
94:4	83.7	-20.3	84.7	-24.0	2,919	-8.0	12.2	-3.7
95:1	78.1	-24.2	78.1	-27.7	2,893	-3.5	20.6	-3.6
95:2	73.5	-21.4	73.2	-22.6	3,004	16.2	37.6	-1.2
95:3	69.6	-19.6	70.4	-14.7	2,842	-19.9	-0.3	5.0
95:4	66.6	-16.1	67.5	-15.6	2,857	2.2	18.3	0.5
96:1	61.0	-29.6	61.2	-32.4	2,949	13.4	43.0	-2.8
96:2	57.5	-21.4	57.7	-20.7	3,029	11.3	32.8	0.8
96:3	55.8	-11.1	55.9	-12.0	2,997	-4.1	7.1	-0.9
96:4	53.3	-16.8	53.4	-16.9	3,029	4.2	21.0	-0.2
97:1	51.4	-13.8	51.6	-12.4	3,142	15.9	29.7	1.4
97:2	44.8	-42.0	46.0	-36.9	2,908	-26.7	15.3	5.0
97:3	42.2	-21.4	43.5	-19.9	2,707	-24.8	-3.5	1.5
97:4	38.7	-29.5	39.5	-32.3	2,626	-11.5	18.0	-2.8
98:1	33.6	-42.9	35.0	-38.6	2,405	-29.7	13.2	4.3
98:2	30.5	-32.4	31.3	-35.7	2,364	-6.6	25.8	-3.3
98:3	27.3	-35.6	27.2	-42.7	2,266	-15.6	20.0	-7.1
98:4	23.1	-48.7	22.5	-53.5	1,949	-45.2	3.5	-4.8
94-98		-26.5		-27.0		-7.8	18.7	-0.4
94-96		-20.5		-20.4		2.0	22.5	0.0
97-98		-34.2		-35.1		-19.8	14.4	-0.9

Source: Authors calculations based on proprietary data from *Dataquest.*

Table 9. Matched-model Price Indexes for Intel Desktop CPUs (includes Celeron)

	Fisher formula		Geomean formula		Memos: Average Price per unit		Memos: Quality Change	Memos: Geomean Subs.
	Index 93Q1=100	Percent change (annual rate)	Index, 93Q1=100	Percent change (annual rate)	Dollars	Percent change (annual rate)	(6)-(2) Percentage points, annual rate	Bias, (4)-(2) Percentage points, annual rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
93:1	100.0	--	100.0	--	251	--	--	--
93:2	96.2	-14.2	95.6	-16.4	248	-3.6	10.6	-2.2
93:3	90.8	-20.8	90.0	-21.6	222	-35.7	-15.0	-0.9
93:4	81.0	-36.7	78.0	-43.5	217	-9.6	27.1	-6.8
94:1	76.7	-19.8	74.8	-15.5	218	1.9	21.6	4.3
94:2	69.0	-34.4	67.2	-34.7	228	18.8	53.2	-0.4
94:3	58.1	-49.6	58.1	-44.1	233	9.2	58.8	5.5
94:4	48.6	-51.1	47.5	-55.4	219	-21.3	29.8	-4.3
95:1	37.9	-63.1	32.8	-77.2	211	-14.2	48.9	-14.1
95:2	29.4	-63.8	25.5	-63.3	228	36.9	100.7	0.5
95:3	22.4	-66.3	20.6	-57.7	229	1.9	68.2	8.7
95:4	17.4	-63.5	17.0	-53.4	227	-3.4	60.1	10.1
96:1	12.9	-69.9	13.0	-66.2	238	19.6	89.4	3.7
96:2	9.93	-64.8	9.87	-66.6	230	-11.7	53.1	-1.8
96:3	8.14	-54.8	8.10	-54.5	220	-16.4	38.4	0.3
96:4	7.79	-16.1	7.63	-21.2	236	32.7	48.8	-5.2
97:1	6.68	-46.0	6.48	-48.1	231	-8.2	37.8	-2.2
97:2	5.11	-65.6	4.92	-66.8	235	5.9	71.5	-1.2
97:3	3.78	-70.0	3.42	-76.6	224	-17.3	52.8	-6.6
97:4	2.89	-66.1	2.69	-61.4	225	2.6	68.6	4.7
98:1	2.00	-77.1	1.87	-76.7	231	10.5	87.6	0.4
98:2	1.44	-72.9	1.38	-70.3	229	-2.9	70.0	2.6
98:3	1.10	-66.4	1.07	-63.8	223	-10.9	55.5	2.6
98:4	0.89	-56.3	0.95	-37.1	216	-10.7	45.6	19.3
99:1	0.67	-67.4	0.68	-74.9	202	-24.9	42.6	-7.5
99:2	0.46	-77.3	0.51	-68.1	191	-19.4	57.9	9.2
99:3	0.32	-78.3	0.37	-70.5	186	-10.3	68.0	7.8
99:4	0.21	-80.4	0.29	-61.4	190	10.2	90.5	18.9
93-99		-59.9		-57.8		-4.0	55.8	2.0
95-99		-66.3		-63.8		-2.8	63.5	2.5

Source: Authors calculations based on proprietary data from *MicroDesign Resources* .

Table 10. Matched-model Price Indexes for Intel Mobile CPUs (includes Celeron)

	Fisher formula		Geomean formula		Memos: Average Price per unit		Memos: Quality Change	Memos: Geomean Subs.
	Index 93Q1=100	Percent change (annual rate)	Index, 93Q1=100	Percent change (annual rate)	Dollars	Percent change (annual rate)	(6)-(2) Percentage points, annual rate	Bias, (4)-(2) Percentage points, annual rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
95:1	100.0	--	100.0	--	226	--	--	--
95:2	97.7	-9.1	97.7	-9.1	247	43.6	52.6	0.0
95:3	79.7	-55.7	79.7	-55.7	209	-49.2	6.5	0.0
95:4	64.2	-57.8	64.4	-57.3	189	-32.0	25.8	0.5
96:1	43.7	-78.6	43.5	-79.2	175	-27.5	51.1	-0.6
96:2	28.9	-80.9	30.29	-76.5	158	-33.8	47.1	4.4
96:3	22.3	-64.6	24.34	-58.3	151	-15.4	49.1	6.3
96:4	19.5	-41.3	21.12	-43.3	178	92.1	133.3	-2.0
97:1	16.7	-46.7	18.58	-40.1	216	117.9	164.6	6.6
97:2	13.7	-54.2	15.79	-47.9	219	5.0	59.2	6.3
97:3	10.8	-60.9	11.76	-69.2	215	-6.6	54.3	-8.2
97:4	8.82	-56.2	8.96	-66.4	206	-15.6	40.6	-10.2
98:1	5.88	-80.2	6.46	-73.0	192	-25.1	55.1	7.2
98:2	4.08	-76.8	4.74	-71.0	196	7.6	84.4	5.8
98:3	2.49	-86.2	2.81	-87.6	216	49.2	135.4	-1.4
98:4	1.98	-60.3	2.16	-65.2	212	-7.7	52.6	-4.9
99:1	1.56	-61.5	1.84	-47.8	223	23.9	85.4	13.6
99:2	1.00	-83.1	1.34	-71.9	219	-8.2	75.0	11.2
99:3	0.69	-77.8	1.02	-66.3	208	-17.7	60.1	11.5
99:4	0.49	-73.8	0.76	-69.1	214	11.9	85.7	4.7
95-99		-67.4		-64.2		-1.1	66.3	3.2

Source: Authors calculations based on proprietary data from *MicroDesign Resources* .

Table 11. Matched-model Price Indexes for Intel Workstation and Server (Xeon) CPUs.

	Fisher formula		Geomean formula		Memos: Average Price per unit		Memos: Quality Change	Memos: Geomean Subs.
	Index 96Q1=100	Percent change (annual rate)	Index, 96Q1=100	Percent change (annual rate)	Dollars	Percent change (annual rate)	(6)-(2) Percentage points, annual rate	Bias, (4)-(2) Percentage points, annual rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
96:1	100.0	--	100.0	--	1,115	--	--	--
96:2	79.03	-61.0	66.41	-80.6	930	-51.4	9.5	-19.6
96:3	66.82	-48.9	55.25	-52.1	777	-51.5	-2.6	-3.2
96:4	61.39	-28.7	49.46	-35.8	723	-24.7	4.0	-7.0
97:1	61.02	-2.4	50.41	7.9	715	-4.5	-2.1	10.3
97:2	60.42	-3.9	43.69	-43.6	857	106.7	110.6	-39.7
97:3	58.80	-10.3	42.40	-11.3	899	21.0	31.3	-1.1
97:4	59.66	6.0	43.11	6.9	899	0.0	-6.0	0.9
98:1	60.41	5.1	43.74	5.9	899	0.0	-5.1	0.8
98:2	60.02	-2.6	43.37	-3.3	899	0.0	2.6	-0.8
98:3	58.93	-7.1	42.39	-8.8	1,161	177.6	184.7	-1.7
98:4	58.29	-4.3	40.69	-15.0	1,050	-33.1	-28.8	-10.8
99:1	55.28	-19.1	29.19	-73.5	846	-57.9	-38.8	-54.4
99:2	54.53	-5.3	28.31	-11.5	868	10.8	16.1	-6.2
99:3	54.44	-0.7	28.29	-0.3	884	7.5	8.2	0.3
99:4	54.03	-2.9	28.09	-2.8	855	-12.4	-9.4	0.1
96-99		-15.1		-28.7		-6.8	8.3	-13.6

Source: Authors calculations based on proprietary data from *MicroDesign Resources* .

Table 12. Matched-model Price Indexes for All Intel Computational Microprocessors

	Fisher formula		Geomean formula		Memos: Average Price per unit		Quality Change	Geomean Subs.
	Index 93Q1=100	Percent change (annual rate)	Index, 93Q1=100	Percent change (annual rate)	Dollars	Percent change (annual rate)	(6)-(2) Percentage points, annual rate	Bias, (4)-(2) Percentage points, annual rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
93:1	100.0	--	100.0	--	251	--	--	--
93:2	96.2	-14.2	95.6	-16.4	248	-3.6	10.6	-2.2
93:3	90.8	-20.8	90.0	-21.6	222	-35.7	-15.0	-0.9
93:4	81.0	-36.7	78.0	-43.5	217	-9.6	27.1	-6.8
94:1	76.7	-19.8	74.8	-15.5	218	1.9	21.6	4.3
94:2	69.0	-34.4	67.2	-34.7	228	18.8	53.2	-0.4
94:3	58.1	-49.6	58.1	-44.1	233	9.2	58.8	5.5
94:4	48.6	-51.1	47.5	-55.4	219	-21.3	29.8	-4.3
95:1	37.9	-63.1	32.8	-77.2	211	-14.0	49.1	-14.1
95:2	29.4	-63.5	26.0	-60.4	228	37.7	101.1	3.1
95:3	22.5	-66.1	21.0	-57.4	228	-0.2	65.9	8.8
95:4	17.5	-63.3	17.3	-54.1	224	-6.9	56.4	9.2
96:1	12.9	-70.4	12.9	-69.5	231	13.2	83.6	0.9
96:2	9.86	-65.8	9.45	-70.8	221	-17.5	48.3	-5.0
96:3	8.06	-55.4	7.74	-55.2	210	-17.3	38.1	0.2
96:4	7.65	-19.0	7.08	-29.8	228	38.1	57.0	-10.8
97:1	6.57	-45.3	6.21	-41.0	230	3.8	49.2	4.4
97:2	5.12	-63.1	4.96	-59.2	234	6.9	70.0	4.0
97:3	3.87	-67.5	3.65	-70.7	225	-15.0	52.5	-3.3
97:4	3.02	-62.7	2.92	-59.0	225	0.0	62.7	3.7
98:1	2.13	-75.5	2.16	-70.3	227	4.0	79.5	5.2
98:2	1.56	-71.3	1.64	-66.7	226	-1.5	69.8	4.6
98:3	1.17	-68.1	1.21	-70.2	227	1.9	70.0	-2.1
98:4	0.98	-50.5	1.03	-47.6	226	-2.6	47.8	2.9
99:1	0.79	-57.4	0.79	-65.9	225	-1.7	55.8	-8.5
99:2	0.61	-65.2	0.62	-61.7	224	-0.7	64.5	3.5
99:3	0.47	-63.3	0.48	-64.9	218	-11.2	52.1	-1.6
99:4	0.38	-60.1	0.38	-61.3	221	6.6	66.7	-1.2
93-99		-56.3		-56.3		-1.8	54.4	0.0
95-99		-62.2		-62.0		0.2	62.4	0.2

Source: Authors calculations based on proprietary data from *MicroDesign Resources* .

Table 13. Matched-model Price Indexes for DRAM

	Fisher formula		Geomean formula		Memos: Average Price per unit		Memos: Quality Change	Memos: Geomean Subs.
	Index 96Q1=100	Percent change (annual rate)	Index, 96Q1=100	Percent change (annual rate)	Dollars	Percent change (annual rate)	(6)-(2) Percentage points, annual rate	Bias, (4)-(2) Percentage points, annual rate
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
91:2	100.0	--	100.0	--	$65.68	--	--	--
91:3	79.2	-60.7	89.0	-37.3	$52.84	-58.1	2.6	23.4
91:4	71.4	-33.9	81.5	-29.6	$43.71	-53.2	-19.2	4.3
92:1	64.4	-33.7	72.1	-38.9	$33.14	-67.0	-33.3	-5.2
92:2	57.7	-35.6	64.1	-37.5	$26.39	-59.8	-24.2	-1.9
92:3	54.4	-21.0	58.2	-31.8	$22.46	-47.5	-26.5	-10.9
92:4	53.7	-4.7	56.1	-13.7	$19.22	-46.4	-41.6	-8.9
93:1	56.6	23.4	56.0	-1.1	$18.82	-8.2	-31.6	-24.5
93:2	57.9	9.5	55.5	-3.3	$17.75	-20.8	-30.3	-12.8
93:3	58.5	3.8	56.0	3.9	$17.16	-12.6	-16.4	0.1
93:4	60.9	17.8	55.8	-1.3	$15.91	-26.1	-43.9	-19.1
94:1	62.1	7.9	56.2	2.8	$15.60	-7.6	-15.5	-5.1
94:2	60.0	-12.9	53.9	-15.4	$14.31	-29.1	-16.2	-2.5
94:3	58.7	-8.4	52.7	-8.8	$13.66	-17.1	-8.8	-0.4
94:4	58.1	-3.7	52.0	-5.4	$13.33	-9.3	-5.6	-1.7
95:1	58.7	3.9	52.0	-0.2	$13.31	-0.4	-4.4	-4.1
95:2	59.6	6.5	52.4	3.6	$13.57	8.1	1.6	-3.0
95:3	60.4	4.9	52.7	2.3	$13.78	6.4	1.5	-2.6
95:4	56.6	-22.6	50.9	-13.1	$13.07	-19.1	3.5	9.4
96:1	44.0	-63.5	40.3	-60.8	$12.29	-21.9	41.6	2.7
96:2	24.1	-91.0	30.8	-65.9	$8.67	-75.2	15.7	25.1
96:3	17.3	-73.5	25.5	-52.9	$7.36	-48.1	25.4	20.6
96:4	15.3	-38.4	23.1	-32.3	$6.94	-21.0	17.4	6.1
97:1	11.9	-63.2	13.0	-90.1	$3.47	-93.7	-30.5	-26.8
97:2	10.3	-43.9	12.8	-5.5	$3.70	29.1	73.0	38.4
97:3	7.72	-68.9	11.05	-44.5	$3.07	-52.6	16.3	24.4
97:4	6.27	-56.4	9.59	-43.2	$2.74	-36.7	19.8	13.2
98:1	4.40	-75.8	8.32	-43.4	$3.04	51.1	126.9	32.4
98:2	3.17	-72.9	7.11	-46.6	$2.76	-32.5	40.4	26.3
98:3	2.44	-65.1	6.23	-41.2	$2.49	-33.6	31.6	24.0
98:4	2.63	36.3	6.52	20.0	$2.56	12.4	-23.9	-16.3
91-98		-38.4		-30.5		-35.1	3.3	7.9
91-95		-10.8		-12.6		-27.6	-16.8	-1.9
96-98		-64.0		-49.6		-41.9	22.1	14.4

Source: Authors calculations based on proprietary data from *Dataquest.*

Table 14. Hedonic Price Indexes for Intel Computational Microprocessors

	All Computational Microprocessors				Desktop CPUs (including Celeron)			
	DV Hedonic Price Index		Difference from:		DV Hedonic Price Index		Difference from:	
	Index, 93Q1=100	Percent change, (annual rate)	Geomean	Fisher	Index, 93Q1=100	Percent change, (annual rate)	Geomean	Fisher
			Percentage points, annual rate				Percentage points, annual rate	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
93:1	100.0	--	--	--	100.0	--	--	--
93:2	92.5	-26.8	-10.3	-12.6	92.4	-27.1	-10.7	-12.9
93:3	87.0	-21.6	0.0	-0.9	86.9	-21.6	0.0	-0.9
93:4	75.5	-43.5	0.0	-6.8	75.4	-43.5	0.0	-6.8
94:1	69.0	-30.1	-14.6	-10.4	68.9	-30.1	-14.6	-10.3
94:2	62.0	-34.7	0.0	-0.4	61.9	-34.7	0.0	-0.4
94:3	53.6	-44.1	0.0	5.5	53.6	-44.1	0.0	5.5
94:4	43.7	-56.0	-0.6	-4.9	43.6	-56.0	-0.5	-4.9
95:1	29.5	-79.2	-2.0	-16.0	29.9	-78.0	-0.8	-14.9
95:2	23.1	-62.6	-2.2	0.9	23.0	-64.9	-1.6	-1.1
95:3	18.5	-58.6	-1.2	7.5	18.4	-59.1	-1.5	7.2
95:4	15.1	-55.1	-1.0	8.3	14.5	-61.3	-7.8	2.3
96:1	10.7	-75.5	-5.9	-5.1	10.7	-70.8	-4.6	-0.9
96:2	7.95	-69.0	1.8	-3.2	8.24	-64.5	2.1	0.3
96:3	6.63	-51.8	3.4	3.6	6.84	-52.3	2.2	2.5
96:4	5.95	-35.1	-5.3	-16.1	6.07	-38.2	-17.0	-22.2
97:1	5.25	-39.1	1.9	6.3	5.23	-44.8	3.3	1.1
97:2	4.18	-60.0	-0.8	3.2	3.88	-69.7	-2.9	-4.1
97:3	3.23	-64.2	6.5	3.3	2.69	-76.9	-0.3	-6.9
97:4	2.70	-51.4	7.6	11.3	2.09	-63.4	-2.0	2.6
98:1	2.05	-67.0	3.2	8.4	1.38	-80.9	-4.1	-3.7
98:2	1.56	-66.5	0.2	4.8	1.03	-69.5	0.8	3.4
98:3	1.16	-69.1	1.1	-1.0	0.79	-65.1	-1.3	1.3
98:4	0.99	-47.8	-0.2	2.7	0.69	-43.2	-6.1	13.1
99:1	0.74	-68.0	-2.1	-10.6	0.49	-73.0	2.0	-5.5
99:2	0.58	-62.4	-0.7	2.8	0.37	-70.2	-2.1	7.2
99:3	0.43	-68.8	-4.0	-5.5	0.27	-70.9	-0.4	7.4
99:4	0.34	-64.1	-2.8	-4.0	0.21	-64.4	-2.9	16.0
93-99		-57.0	-0.7	-0.7		-60.0	-2.1	-0.1

Note -- the columns showing differences are the percent change in the DV hedonic index less the percent change in the matched-model index shown in the column heading.

Table 15. Hedonic Price Indexes for Intel Computational Microprocessors

	Mobile Performance and Mobile Celeron CPUs				Workstation and Server (Xeon) CPUs			
	DV Hedonic Price Index		Difference from:		DV Hedonic Price Index		Difference from:	
	Index, 93Q1=100	Percent change, (annual rate)	Geomean	Fisher	Index, 93Q1=100	Percent change, (annual rate)	Geomean	Fisher
			Percentage points, annual rate				Percentage points, annual rate	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
95:1	100.0	--	--	--	--	--	--	--
95:2	92.5	-26.7	29.1	29.0	--	--	--	--
95:3	75.5	-55.7	1.6	2.1	--	--	--	--
95:4	69.5	-28.2	51.0	50.4	--	--	--	--
96:1	46.9	-79.2	-2.7	1.7	100.0	--	--	--
96:2	32.0	-78.3	-20.0	-13.7	66.4	-80.6	-28.5	-31.6
96:3	25.5	-59.7	-16.5	-18.5	55.2	-52.1	-16.3	-23.4
96:4	20.5	-58.5	-18.4	-11.9	49.5	-35.8	-43.7	-33.4
97:1	18.0	-40.1	7.8	14.1	50.4	7.9	51.5	11.8
97:2	14.8	-54.7	14.4	6.2	45.9	-31.3	-20.0	-21.1
97:3	11.2	-67.0	-0.6	-10.8	49.4	34.5	27.6	28.5
97:4	8.43	-68.0	5.0	12.2	50.3	6.9	1.0	1.8
98:1	5.64	-79.9	-8.9	-3.1	51.0	5.9	9.3	8.5
98:2	4.05	-73.4	14.1	12.7	50.6	-3.3	5.4	3.7
98:3	2.36	-88.5	-23.3	-28.2	48.8	-13.1	2.0	-8.8
98:4	1.84	-62.9	-15.1	-1.4	47.4	-11.3	62.3	7.8
99:1	1.69	-29.1	42.8	54.0	34.7	-71.3	-59.7	-65.9
99:2	1.25	-69.7	-3.4	8.1	33.6	-11.5	-11.2	-10.9
99:3	0.91	-71.8	-2.7	2.0	34.4	8.9	11.7	11.8
99:4	0.66	-73.5	-73.5	-73.5	34.1	-2.8	-2.8	-2.8
95-99		-65.3	-1.0	1.7		-20.3	-0.8	-8.3

Note -- the columns showing differences are the percent change in the DV hedonic index less the percent change in the matched-model index shown in the column heading.

Table 16. Hedonic Price Indexes for Personal Computers and Notebooks

	Personal Computers				Notebook Computers			
	DV Hedonic Price Index		Difference from:		DV Hedonic Price Index		Difference from:	
	Index, 93Q1=100	Percent change, (annual rate)	Geomean	Fisher	Index, 93Q1=100	Percent change, (annual rate)	Geomean	Fisher
			Percentage points, annual rate				Percentage points, annual rate	
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Date								
93:1	100.0	--	--	--	100.0	--	--	--
93:2	97.2	-10.6	8.3	6.8	98.2	-7.0	4.7	0.2
93:3	89.3	-28.8	3.0	-2.1	94.6	-13.9	7.2	-1.6
93:4	85.9	-14.3	3.7	7.5	92.2	-9.8	5.3	3.6
94:1	81.4	-19.5	18.0	6.0	85.4	-26.3	14.0	5.5
94:2	76.0	-24.1	4.0	10.8	82.2	-14.0	10.8	9.2
94:3	72.7	-16.0	3.4	4.0	82.9	3.3	21.6	18.3
94:4	65.8	-32.9	-0.6	-7.4	76.3	-28.3	-1.6	0.6
95:1	62.2	-20.3	2.1	-0.5	74.2	-10.6	8.2	6.9
95:2	56.6	-31.7	1.2	-1.4	69.7	-21.9	-1.0	0.8
95:3	53.7	-18.8	-0.6	0.2	64.9	-25.0	-6.8	-2.3
95:4	51.1	-18.2	0.4	-2.6	59.8	-27.9	-6.3	-6.5
96:1	46.4	-31.7	3.8	0.2	54.3	-31.8	3.0	-1.5
96:2	43.7	-21.3	2.1	0.0	51.4	-19.7	2.9	8.0
96:3	41.9	-15.7	-1.1	-2.0	51.2	-1.8	8.0	1.7
96:4	39.9	-18.1	-1.4	-2.0	48.9	-16.5	0.8	-2.9
97:1	38.5	-13.3	-5.7	2.1	48.9	0.1	4.9	4.7
97:2	33.1	-44.9	2.5	6.4	42.1	-45.1	-6.4	-3.1
97:3	30.4	-28.7	-3.5	-2.9	40.3	-16.0	-4.6	-0.7
97:4	27.2	-36.4	-2.1	-2.4	36.9	-29.8	-2.1	-4.8
98:1	23.7	-41.8	1.2	6.7	32.1	-43.0	-7.0	-10.3
98:2	20.7	-42.2	-0.4	-7.0	30.8	-14.8	0.4	-2.3
98:3	18.1	-42.0	3.4	-2.1	27.9	-33.3	-1.1	-4.1
98:4	14.9	-53.2	3.9	-1.1	22.5	-57.1	2.4	-2.1
93-98		-28.2	2.1	0.7		-22.8	2.1	0.3

Note -- the columns showing differences are the percent change in the DV hedonic index less the percent change in the matched-model index shown in the column heading.