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# Taking the Pulse of the Tech Sector: A Coincident Index of High-Tech Activity

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*A new index of the U.S. high-tech sector—drawing upon a range of technology-specific data—has the potential to offer a more timely assessment of economic activity than has been possible to date. The index suggests that while the tech sector has rebounded from its poor performance in the 2000-01 "tech bust," it has not resumed its rapid expansion of the late 1990s.*

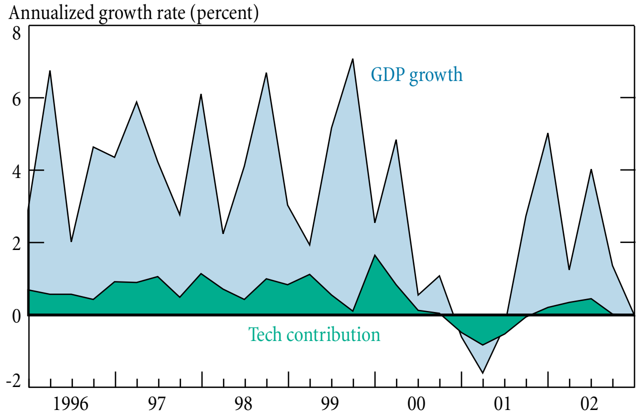
The U.S. high-technology sector is a vital part of the nation's economy.[1] The tech sector played a leading role in the economic boom of the 1990s, fueled by the introduction of the Internet and the many technologies associated with it. Likewise, the subsequent "tech bust" was identified as a key contributor to the national recession in 2001.

The production of high-tech goods represents a significant component of GDP: private high-tech final demand accounted for 3.8 percent of nominal GDP in fourth-quarter 2002, nearly double the 2.0 percent rate in 1977.[2] In terms of real GDP, investment in high-tech assets has contributed 0.89 percentage point to growth per year since 1995 (Chart 1).[3] Moreover, the tech sector has been a central force in the U.S. productivity revival, as reported in such studies as Jorgenson and Stiroh (2000). Still, high-tech investment has shown considerable fluctuation recently in terms of its effects on the economy, adding to the recession of 2001 while helping the recovery of 2002.

The tech sector's importance to the U.S. economy makes it necessary to understand changes in high-tech activity on a timely basis.[4] However, the sector has proved difficult to track in real time. It is a very broad and diffuse entity in which different economic indicators can provide conflicting signals about the magnitude and direction of activity. In recent quarters, for example, investment in information processing equipment and software has picked up despite a continued shrinkage in high-tech employment.

In this edition of *Current Issues*, we attempt to broaden the understanding of the tech sector by constructing a more useful measure of its activity. Our "Tech-Pulse Index" is a coincident index of activity that provides a real-time assessment of the underlying movements in the U.S. high-tech sector. It draws upon a diverse range of technology-specific information, including data on investment, consumption, employment, industrial production, and shipments.

Chart 1
Contribution of High-Tech Investment to Real GDP Growth




Source: U.S. Department of Commerce, Bureau of Economic Analysis.

The index suggests that the tech sector has rebounded from its poor performance in the 2000-01 tech bust. The Tech-Pulse Index increased at an annual rate of 9 percent during seventeen of the eighteen months preceding April 2003. This progress followed eleven months of decline from November 2000 to October 2001, when the index decreased at an annual rate of 21 percent. However, while this turnaround points to an improving trend, gains in the tech sector have occurred much more slowly over the past year than they did in the late 1990s, implying that the sector has not resumed the rapid expansion that characterized it during the boom period.

Our analysis also points to wider economic uses for the Tech-Pulse Index. For example, if the tech sector truly is a driver of aggregate fluctuations, then a more accurate and timely understanding of its movements, which our index attempts to provide, could assist in GDP forecasting efforts.

## Constructing the Tech-Pulse Index

### *Methodology*

Economists have long been interested in developing a single measure that describes the state of the economy. In a broad and diverse economy, however, any one data series is unlikely to describe adequately the true amount of activity, and alternative indicators may even provide mixed signals about economic direction. In the tech sector, for example, rapid productivity has led to declines in employment, even as output has grown. The interest in a single economic measure has led to a large literature that attempts to combine the information from many series into one indicator of overall activity.[5]

In our approach, we use modern coincident indicator methodologies to develop an index of tech-sector activity (a coincident index) from several underlying data series (the coincident indicators). We base this approach on the idea that changes in each indicator reflect movements in the true, but unobserved, state of the tech sector along with random fluctuations that are specific to the indicators—what economists call "noise." We use statistical tools to eliminate this noise and obtain the best estimate of the common component that represents underlying tech-sector activity. This approach has been applied widely to the construction of regional coincident indexes of economic activity, such as in Clayton-Matthews and Stock (1998-99) and Orr, Rich, and Rosen (1999). More specific details can be found in the box.

### *Data Series*

In constructing our index, we consider three important components of tech-sector activity: supply, demand, and employment. To capture these components, we choose five coincident indicators that parallel those used by the Conference Board (2002) in the creation of its coincident index for the overall U.S. economy (see table). These five series are our coincident indicators of the level of tech-sector activity.

To approximate the Conference Board's nonagricultural payroll series, we use total employees in four high-tech sectors: computer and office equipment, communications, communications services, and computer services. To correspond to the Conference Board's industrial production series, we select industrial production in high-tech sectors. To match the manufacturing and trade sales series used by the Conference Board, we rely on shipments of manufactures of computers and communications equipment, private fixed investment in information technology (IT—hardware, software, and telecommunications equipment), and consumption of computers and software. No corresponding series exists for the Conference Board's personal income series. All data are seasonally adjusted.

Our data series generally align with the three components of tech-sector activity in the following way: *supply* is comparable to industrial production in high-tech sectors and information technology shipments, *demand* is comparable to IT investment and computer consumption, and *employment* is comparable to the number of employees in high-tech industries.

A practical issue to address is the fact that large changes in relative prices have led to substantial differences between real and nominal data series. For example, investment in information technology—one of our coincident indicators—has grown much more rapidly in real terms because of the

## Methodological Details

To estimate our Tech-Pulse Index, we follow the methodology developed by Stock and Watson (1988, 1989). This approach filters out the idiosyncratic noise from each coincident indicator to obtain the best estimate of the common comovements of all indicators. This common trend is our estimate of the coincident index of tech-sector activity and serves as our Tech-Pulse Index.

More formally, let $\Delta x_{it}$ be the growth rate of indicator $i$ at time $t$. Here, $i = 1,\ldots,5$ indexes: the employment, industrial production, shipments, consumption, and investment series. Let $\Delta c_t$ be the growth rate of the unobserved coincident index of tech-sector activity that we will estimate. We assume that

$$\Delta x_{it} = \beta_i + \sum_{j=1}^{p} \phi_{ij} \Delta x_{it-j} + \gamma_i \Delta c_t + \varepsilon_{it} \ . \quad (1)$$

Hence, the growth rate of each indicator is assumed to be a weighted sum of its own $p$ past values; an indicator-specific random effect, $\varepsilon_{it}$; and the growth rate of the common factor $\Delta c_t$ that we will estimate. In our application, we choose $p = 3$. It turns out, however, that our results do not depend on the particular model specification and are robust for almost all of the specifications we estimated.

To distill the common factor, we make an assumption about its behavior.

We assume that it follows

$$\Delta c_t = \delta_i + \sum_{j=1}^{2} \theta_j \Delta c_{t-j} + v_t \ , \quad (2)$$

where $v_t$ is again a random shock and is assumed to have a unit variance.

Equations 1 and 2 are also known as a state-space model representation, in which the observed indicators, $x_{it}$, are determined by an unobserved state variable, $c_t$. We assume that the random disturbances, $\varepsilon_{it}$ and $v_t$, are independently normally distributed.

The estimated trend growth rate of $c_t$ in this model is a weighted average of the average growth rates of the indicator variables. The specific weights, also known as the cumulative dynamic multipliers, are a complex function of the estimated parameters of the model. These multipliers can be normalized to calculate the share that the average growth rate of each indicator contributes to the trend in $c_t$. We report these estimated shares in the table. Because the trend growth rate of the index is a weighted average of the growth rates of the indicator variables, it is not advisable to compare it with the growth rates of other variables.

We estimate the model using maximum likelihood and the Kalman filter. Estimation is conducted using the software developed by Clayton-Matthews (2001) and based on Stock and Watson (1989) and Clayton-Matthews and Stock (1998-99). The table presents the means and standard deviations of the five coincident indicators and the coincident index, as well as the growth rate share and the number of estimation lags for each coincident indicator. An important virtue of this method is that it allows us to combine data that are observed at different frequencies. That is, whereas all other variables are reported monthly, data on investment are released only every quarter.

It is worth noting that we do not prefilter the coincident indicators. As shown in the table, certain coincident indicators, such as shipments and personal consumption expenditures, are quite volatile at monthly frequencies, a pattern that leads to a volatile Tech-Pulse Index. However, we do not consider this to be a practical problem (in principle, the Kalman filter should be able to distinguish the idiosyncratic noise from the common trend) but rather an indication of the inherent volatility of tech-sector activity. By choosing $p = 3$ in equation 1, we have already allowed the model to capture sizable fluctuations specific to each indicator.

### Summary Statistics for Estimation of the Tech-Pulse Index

| | Annualized Growth Rate | | | Model | |
|---|---|---|---|---|---|
| | Frequency | Mean (Percent) | Standard Deviation (Percent) | Share (Percent) | Number of Lags ($p$) |
| Coincident indicator | | | | | |
| Employment | Monthly | 3.2 | 8.4 | 17.2 | 3 |
| Industrial production | Monthly | 21.3 | 23.4 | 7.3 | 3 |
| Shipments | Monthly | 19.2 | 40.8 | 58.8 | 3 |
| Investment (real) | Quarterly | 16.0 | 14.3 | 13.9 | 3 |
| Consumption (real) | Monthly | 95.2 | 259.7 | 2.9 | 3 |
| Tech-Pulse Index (real) | Monthly | 17.97 | 19.12 | 100.0 | |

Sources: Authors' calculations; U.S. Department of Commerce, Bureau of Economic Analysis; U.S. Department of Labor, Bureau of Labor Statistics; Board of Governors of the Federal Reserve System.

Note: The model is estimated from October 1970 to March 2003.

### A Comparison of Indicators

| Conference Board Indicator | Tech-Pulse Index Indicator | Sample (Frequency) |
|---|---|---|
| Employees on nonagricultural payroll | Employees in SIC categories 357, 366, 48, 737 | January 1977 to present (monthly) |
| Industrial production | Industrial production in high-tech sectors (NAICS categories 3341, 3342, 334412-9) | January 1967 to present (monthly) |
| Manufacturing and trade sales | Shipments of manufactures of computers and communications equipment | January 1958 to present (monthly) |
| | Private fixed investment in information technology | 1946 to present (quarterly) |
| | Personal consumption expenditures on computers and software | January 1977 to present (monthly) |
| Personal income less transfer payments | N.A. | N.A. |

Memo:

Deflator

Personal consumption expenditures: Deflates personal consumption expenditures on computers and software

Producer price index: Deflates shipments of manufactures of computers and communications equipment

Nonresidential private fixed investment: Deflates private fixed investment in information technology

Note: SIC is the Standard Industrial Classification system; NAICS is the North American Industry Classification System.

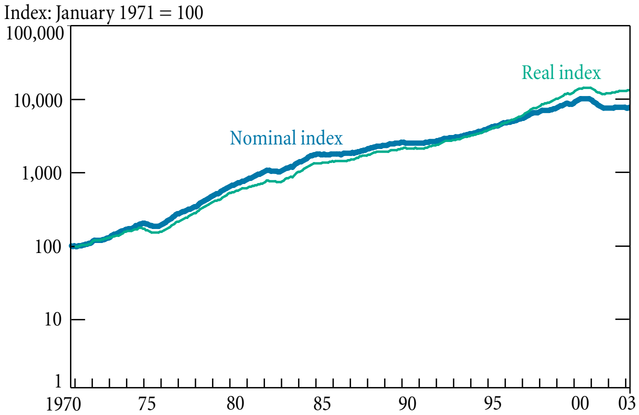
enormous declines in quality-adjusted prices for these assets. While measures of real activity in the high-tech sector are useful to policymakers assessing real economic growth, measures of nominal activity may be more informative for business leaders monitoring profits and sales—both of which are measured in dollars. With the needs of these different audiences in mind, we estimate one Tech-Pulse Index that uses nominal variables and a second index that uses real variables.

## Trends Revealed by the Tech-Pulse Index

Our examination of real and nominal Tech-Pulse Index levels from October 1970 to March 2003 suggests that the indexes accurately capture the state of tech-sector activity.

Chart 2

Level of Real and Nominal Tech-Pulse Indexes




Source: Authors' calculations.

Both indexes demonstrate rapid acceleration during the second half of the 1990s and sharp growth declines in 2000 and 2001 (Chart 2). However, the real index saw a much faster acceleration during the 1990s, fueled by the sharper price declines of technology goods. For example, in the nine years before the tech boom—January 1985 through December 1993—the real Tech-Pulse Index grew at an average annual rate of 10.64 percent, but it rose at an average annual rate of 18.56 percent in the nine years following the acceleration—January 1994 through December 2002.

The acceleration was followed by the tech bust of 2000 and 2001, when the real index fell for eleven consecutive months from November 2000 to October 2001 and experienced a cumulative decline of 18 percent. More recently, however, the index has rebounded, increasing for seventeen of the eighteen months preceding April 2003 and posting a cumulative increase of 14 percent from September 2001 to March 2003. This rebound suggests that the worst may be over for the U.S. tech sector. Still, gains in the sector have not occurred as swiftly over the past year as they did in the late 1990s.

We also examine the twelve-month growth rates for the real and nominal Tech-Pulse Indexes (Chart 3).[6] As we observed in our analysis of levels, the growth rate of the real index increased more sharply in the second half of the 1990s than that of the nominal index, reflecting the acceleration of IT price declines in the late 1990s. More recently, the real Tech-Pulse Index has also rebounded more rapidly, suggesting that the sector's current recovery is much stronger in real terms than in nominal terms. This divergence between the two indexes accounts for some of the recent differences in perceptions surrounding the tech sector. For example, although real GDP growth improved in 2002, business analysts—who are more interested in the nominal measure of dollars than the real measure of quantities—continued to emphasize the sluggish nature of business conditions.[7]

It is also interesting to note that the major declines in the Tech-Pulse Index typically coincide with aggregate recessions. When the U.S. economy was in recession in the early 1980s, the early 1990s, and 2001, the growth of our real Tech-Pulse Index also stagnated.

In fact, the Tech-Pulse Index provides a good account of the tech sector's development over the past twenty years.[8] The index reveals that the sector trailed the overall economy into the 1981-82 recession. This lag can be attributed to IBM's introduction of its first PC, which caused a temporary boom in the sector. The rebound after the 1981-82 recession was especially strong in the tech sector because of the continued investment in PCs and peripherals as well as investment in telecommunications, especially cellular networks. The index also reflects a tech slowdown in the mid-1980s that did not coincide with an aggregate economic downturn but instead appears to have been associated with the "maturing" of the PC market. This market was eventually revived by the invention of faster processing chips, enhanced word processors, and laser printers.

In the second half of the 1990s, the index shows that the onset of the tech boom coincided with the availability of revolutionary new technologies. For example, the World Wide Web was established in 1991 and the first browser appeared in 1993. Digital cellular service was also introduced that year, and the number of cell-phone subscribers grew from 10 million in 1992 to 40 million in 1996. Some individual events are also reflected in the Tech-Pulse Index. For example, on August 24, 1995, Microsoft introduced Windows 95 and, over the next four days, sold more than 1 million copies of the product. This development, which also spurred sales of new PCs, appears as a sizable increase in the index's growth rate in 1995. Particularly noteworthy is the fact that the growth rate did not come down afterward, but maintained its high level.

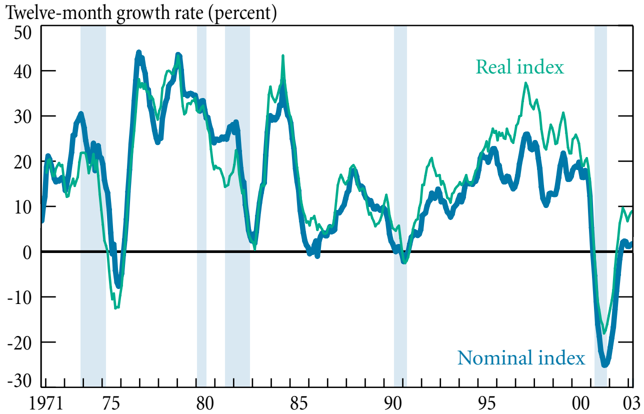
## The Tech Sector and Aggregate Economic Activity

The tech sector's key role in recent booms and busts suggests that the sector could serve as a leading indicator of aggregate economic activity. Accordingly, we examine this relationship more closely by comparing the quarterly growth rates of GDP with the three-month annual growth rate of the real Tech-Pulse Index (Chart 4).

In terms of GDP forecasting, the most notable observation derived from the chart is that the Tech-Pulse Index has led the economy during the last two downturns. (It did not do so during earlier downturns, presumably because the tech sector accounted for a much smaller part of overall economic activity.) The recent close association between the economy and the Tech-Pulse Index is underscored by the difference over time in correlations between GDP growth and the one-quarter lag of the real index: Before 1990, the correlation was just 0.01; afterward, it was 0.41. Moreover, in

Chart 3

Growth Rates of Real and Nominal Tech-Pulse Indexes

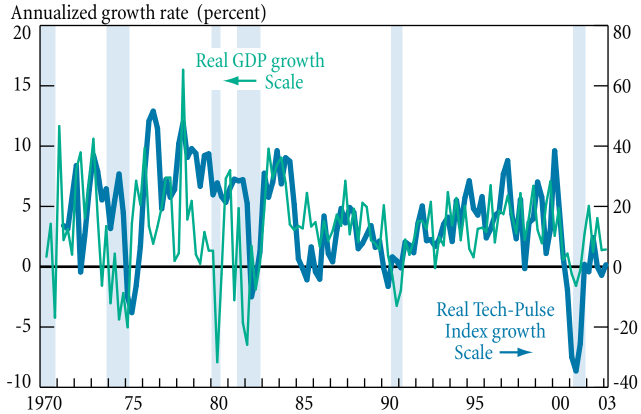



Source: Authors' calculations.

Note: Shaded areas indicate periods designated recessions by the National Bureau of Economic Research.

Chart 4

Growth in Real GDP and in the Real Tech-Pulse Index




Source: Authors' calculations.

Note: Shaded areas indicate periods designated recessions by the National Bureau of Economic Research.

a basic GDP forecasting model, the Tech-Pulse Index shows predictive power beyond that of other indicators—such as lagged GDP and business sentiment indexes—further suggesting that the tech sector could be a predictor of economic activity.

Needless to say, this simplified analysis does not identify the direction of causation—that is, whether the Tech-Pulse Index is leading economic activity, or vice versa. However, it does show that, at a minimum, the index is correlated with aggregate activity. It is therefore reasonable to look to the tech sector as a potential indicator of overall activity—particularly in light of the 2001 recession, which was in large part a "tech recession."

## Conclusion

Researchers have often had difficulty tracking the U.S. tech sector's activity in real time, largely because different economic indicators in the sector can provide mixed signals about the magnitude and direction of activity.

To provide a more reliable gauge of tech activity, we construct a coincident index that distills information from a variety of data into a single measure. Our Tech-Pulse Index thus offers a real-time assessment of underlying movements in the tech sector that can complement the more anecdotal evidence available from such sources as the business press. Currently, the index shows that the tech sector has been growing for more than a year, a sign that the tech bust of 2000 and 2001 has ended.

In addition, the Tech-Pulse Index has the potential to serve as an indicator of aggregate economic activity. Preliminary work on our part shows that the index may lead aggregate activity and may outperform other indicators of business activity in predicting GDP growth. Accordingly, the Tech-Pulse Index could function as a useful early-warning signal of overall economic downturns and recoveries.

## Notes

1. The tech sector broadly describes firms that make high-technology products such as computer hardware, software, semiconductors, and telecommunications equipment, as well as the companies that use these products intensively and the firms that support them.

2. Private high-tech final demand—the component of the tech sector that this article focuses on—includes investment in computer hardware, software, and telecommunications equipment; consumption of computers and software; and net exports of computers.

3. Nominal economic variables measure activity in dollars; real variables measure activity in quantities of goods. We discuss this difference later on.

4. See Jorgenson, Ho, and Stiroh (2002a, 2002b) for details.

5. In 1937, the National Bureau of Economic Research developed a list of leading and coincident indicators for the U.S. economy.

6. One must interpret these growth rates carefully. Intuitively, the rates are weighted averages of the underlying growth trends of the component series, so they cannot be compared directly with the growth of any individual series. Only comparisons of the relative growth rate of the index at different points in time are interpretable.

7. See Cooper and Madigan (2002).

8. For an account of the ups and downs of the tech sector in recent decades, see *Wall Street Journal* (2002).

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