CHAIN-GES IN THE MEASURE OF ECONOMIC GROWTH

PREVIEW OF THE NEW CHAIN-WEIGHTED MEASURES OF REAL OUTPUT IN THE NATIONAL ACCOUNTS

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The Bureau of Economic Analysis (BEA) is keeping up with the spirit of change in Washington. In December, they will release comprehensive revisions to the National Income and Product Accounts. This revision has generated a lot of debate as it involves viewing economic growth through a new lens. The picture still looks a little blurry, but we hope that a short discussion will help bring the new NIPAs into focus.

The largest difference between the old and new measures of growth is due to the treatment of computers. As discussed below, the current system tends to overestimate the share of computers in real output. INFORUM has long recognized this "substitution bias" in the measurement of real output and has mitigated its impact on our forecasts by adjusting our measure of real output to account for the decline in computer prices. We have not allowed that portion of output change that is accounted for by a decline in computer prices to be a driving force in the economy. Consequently, our forecasts will be less affected than others' by the forthcoming changes.

Revisions to the National Income and Product Account Data

The NIPAs are revised annually to incorporate more extensive sources than are used in first estimates. The annual revisions are usually released in July. The BEA also periodically conducts comprehensive revisions to the data that implement definitional changes, update base years and weights, and utilize more comprehensive data, such as the new input-output tables and Economic Censuses. At the time of comprehensive revisions, the entire time-series of the NIPAs are rewritten. The last comprehensive revision was in December, 1991.

The next scheduled comprehensive (and delayed annual) revision of the NIPAs is scheduled for release in December, 1995, and has already generated a lot of discussion because it involves a substantial change in methodology. The featured measures of real output and price growth will be calculated using chain-type annual-weighted indexes, rather than the current fixed-weight indexes.

The current fixed-weight method of calculating real GDP and prices measures how much goods were worth in a benchmark year. For now, the NIPA base year is 1987, and real quantities are calculated by measuring what the nominal quantity was worth in 1987. For example, using a pure fixed-weight system, if I buy a 386 computer for $500 today that would have cost $3,000 in 1987, then my computer contributes $3,000 to real fixed-weight GDP. By computing real output this way, we can abstract away from price changes and examine how the actual quantity of output has changed over time.

Substitution Bias in a Fixed-Weight System

This same example illustrates the pitfalls of the fixed-weight system. Over the past few years, computer prices have fallen precipitously and computer purchases have exploded. The real value of computers is overstated by valuing computers at their 1987 price. The further we are from the base year, the more seriously we overstate current-period growth using fixed price weights. This "substitution bias" reflects the fact that the goods which have the fastest growth of sales are often those which have price decreases, or the smallest price increases. The technology comparable to today's new PCs would have cost the equivalent of a fancy new car in 1987. And now, even though PCs cost a fraction of their 1987 price, each contributes to real GDP as much as an average new car. In contrast, in years before the base year, the contribution to real output growth of goods like computers, which are subject to this substitution bias, will be understated by fixed-weight measures. The fixed-weight measure of the real output of goods, like medical services, which have had rapidly rising prices and steady or decreased output will have a substitution bias that understates their real contribution after the base year and overstates it prior to the base.

To lessen substitution bias, the BEA periodically updates the NIPA base year. When we update the base year to 1992, computers will receive less weight in our GDP calculations, and aggregate GDP growth will appear much slower. Each time the base is moved forward, economic history is rewritten, sometimes with striking implications for growth.

The chain-weighted index essentially moves the base year ahead every year. It minimizes the substitution bias in the fixed-weight system and eliminates the need to rewrite economic history periodically. Table 1 below shows growth rates of real GDP measured by the two different methods. As we move further beyond the base year of 1987, the substitution bias accumulates and the fixed-weight measure results in higher growth rates than the chain-weighted measure. As we move back from 1987, we see that the fixed-weight measures of growth are lower.

Table 1. Average Annual Growth in Real GDP by Different Measures

Period	*Fixed-Weight (percent)*	*Chain-Weight (percent)*	*Difference (percentage points)*
1961-1975	3.38	3.75	-0.37
1975-1986	2.88	3.18	-0.30
1986-1991	2.02	2.02	0
1991-1994	3.16	2.72	0.44

Near the base year the differences between the new and old measures are minor at the aggregate level. Real GDP in 1993 was only 10 billion 1987 dollars different by the two measures. This was less that one tenth of one percent of GDP. However, some components of output are more affected by the methodological changes than the overall figures. The substitution bias in computers has been the largest source of the difference in the two output series. Differing treatment of computers in the chain-weighted index accounts for about three-fifths of the "overstatement" of GDP growth in the fixed-weight system. The graphs below show the fixed-weight and chain-weighted index of real output of GDP and Producers' Durable Equipment (PDE).

The differences in the GDP indexes are minor in the two decades that we show on the graphs. However, the difference is larger for the index of real PDE. Each index equals 100 in 1987. The lower index prior to and after 1987 with the chain-weighted measure implies higher growth with the chain-weighted measure before 1987 and lower growth after the base year.

The new NIPA measures also will change our view of past business cycles. The chain-weighted figures will eliminate the smoothing effect of the fixed-weight system with periodic updating of the base years. Updating the base year in a fixed-weight procedure tends to systematically understate growth as we move further back in time from the base year because consumers tend to substitute away from goods with rising prices. The impact of the new measures on behavioral relationships that rely on business cycle fluctuations in output and other NIPA numbers is discussed below.

The July 1995 *Survey of Current Business* analyzes the past differences in the old and new measures of GDP. The chain-weighted measures will give us a clearer view of the relative contribution to overall growth of the various components of output. With the new measures, business cycles are slightly more pronounced: contractions in the past appear steeper and expansions more robust. The most current expansion is an exception to this. It appears much less robust with the new figures. The BEA estimates that the strength of the current expansion relative to past expansions may be overstated by as much as 1 percentage point of GDP growth. The percent changes for the past 5 quarters at annual rates are shown below for the two different measures.

	1994		*1995*		
	III	*IV*	*I*	*II*	*III*
Real GDP growth					
Fixed 1987 weights	4.0	5.1	2.7	1.3	4.2
Chain-type annual weights	3.6	4.0	1.7	0.7	3.0

Quick Review of the Theory of Indexes

This section will provide a quick review of the theory of index numbers for those people who want to understand the nitty-gritty details of how price and quantity changes are measured.

A true measure of the impact of a change in prices on a consumer would show the difference in the cost of obtaining a reference level of utility with a different vector of prices. The true price index can be summarized as the ratio of the costs of obtaining a reference utility, u^R, at the new prices, p^1, to the costs of obtaining the same level of utility at the old prices, p^0. If the cost function is summarized by the function C(u,p), we can write the true price ratio as:

$$P_T(p^1,p^0;u^R) = \frac{C(u^R,p^1)}{C(u^R,p^0)}$$

From introductory microeconomics, we know that the problem with this sort of measure is that utility is not quantifiable. The quantities of different goods that people buy at different prices are observable, however. We know that as the prices of goods change, the quantities we choose to purchase will change as well. Two well-known indexes provide alternative estimates of price changes by looking at the quantities of goods bought at either the old or new prices.

The Laspeyres index is a base-quantity weighted index,

$$P_L(p^1,p^0;q^0) = \frac{p^1.q^0}{p^0.q^0}$$

while the Paasche index uses current quantities as weights:

$$P_P(p^1,p^0;q^1) = \frac{p^1.q^1}{p^0.q^1}$$

where the p's are as defined before and q^0 and q^1 are the quantities purchased at the old and new prices, respectively. Both the Paasche and Laspeyres indexes are approximations of the true increase in costs.

If prices have increased between period 0 and 1 ($p^1 > p^0$), then we can say

$$P_L(p^1,p^0;q^0) \geq P_T(p^1,p^0;u^0), \text{ and } P_P(p^1,p^0;q^1) \leq P_T(p^1,p^0;u^1).$$

Of course, the true index at reference utility u^1 is usually not the same as at reference utility u^0. So unless indifference curves are homothetic, which implies that consumers do not substitute among goods when prices are constant and income changes, then we can not say anything about the relative size of each index. Irving Fisher proposed an index that was the average of the Paasche and Laspeyres indexes. It is called the Fisher ideal index, although it only equals the true index if preferences are homothetic and the cost function is of a very specific form.

The Fisher ideal index is written:

$$P_F = \sqrt{P_L . P_P}$$

If we want to measure the growth of real quantities, we can use the same measures, except we would switch the p's and q's in the equations above. This means that the Laspeyres quantity index measures quantities using prices in the base year. The Laspeyres index for quantity change can be written:

$$G_L(q^1,q^0;p^0) = \frac{q^1 . p^0}{q^0 . p^0}$$

rearranging, and writing the equations as sums rather than dot products, we get

$$G_L\ (q^1,q^0;p^0) = \sum_i \beta_i^0\ \frac{q_i^1}{q_i^0}$$

where the $ß^0$'s are the shares of good i in nominal GDP in period 0. In other words, the Laspeyres index is a base-share weighted measure of output growth. Similarly, we can write the Paasche quantity index as

$$G_P(q^1,q^0;p^1) = \frac{q^1 . p^1}{q^0 . p^1}$$

or

$$G_P\ (q^1,q^0;p^1) = [\ \sum_i \beta_i^1\ \frac{q_i^0}{q_i^1}]^{-1}$$

where the $ß^1$'s are the shares in nominal GDP in period 1. The Paasche index is then a current-share weighted measure of output growth. As before, we know that the Laspeyres index overstates the true value of quantity changes and the Paasche understates it. The Fisher ideal index is the geometric average of the two and sixty years after it was first proposed, is the yardstick that BEA will use to measure of changes in real activity. The Fisher quantity index for annual GDP gives the growth rate of output between year 0 and year 1.

The example below highlights how the indexes are calculated. Consider the hypothetical economy that produces only apples and bagels. The prices and quantities of apples and bagels for 3 different years are shown in the table below. The Laspeyres index for quantity change from year 1 to year 2 is {(5x7)+(4x7)}/{(5x6)+(4x5)} = 1.26, while the Paasche index is {(7x6)+(7x4)}/{(6x6)+(5x4)} = 1.25. This Fisher index is then the square root of 1.26x1.25 = 1.255. To form an index of real growth, we allow one year to equal 100, and "chain" together the Fisher index percent changes to give a chain-weighted quantity index shown as the second-to-last entry on the table. In the example, year 3 is the base, but the weights for the chain-weighted index are the shares of the two adjacent years. If we want a real value of chain-weighted GDP, we can multiply the chain-weighted index by the nominal value of GDP in the base year. The real (year 3 based) GDP calculated in this manner is the last entry in the table.

Presentation of the New Numbers

The discussion and example above illustrate the basic technique that BEA will employ to construct the new indexes. A few caveats must be added to explain the reality of some of the numbers. The first estimate of the last year of data will not be estimated by growing the previous year's index by the percent change calculated by the Fisher index. Doing so would mean using the preliminary shares of nominal GDP for that year in calculating the Paasche portion of the index. Instead, the last year of the reported annual data (currently 1994) will be calculated with a Laspeyres index only and has been called the "Laspeyres tail". After the annual revision of the NIPAs the following year, the data will be revised to be Fisher ideal.

In order to reduce the volatility in the quarterly data, a slightly modified methodology is employed. The BEA will weight the quarterly changes in shares by using the shares from the two adjacent years rather than just the adjacent quarters. Joel Prakken and Lisa Guirl provide a good summary of this methodology in a publication distributed at the Annual Meeting of the National Association of Business Economists in September. One further adjustment to the quarterly figures is done in order to ensure that the average of the calendar year quarterly value equals the annual value. We are not yet certain how this adjustment is made.

Inventories also create a special problem for the BEA. Changes in business inventories are occasionally negative, and so we could get a negative weight in the chain-type calculations. This implies that the next quarter, an increase in business inventories could decrease output. The BEA is still developing alternative methods for calculating chain-weighted estimates of inventory investment. Likewise, they are examining new measures of the capital stock that are more compatible with the chain-weighted figures.

The chain-weighted index for GDP and its broad components is published monthly in tables 7.1,7.2, and 7.3 of the NIPAs. The percent changes are also published in table 8.1. These data are available as G databanks in INFORUM's NIPAA and NIPAQ banks on EconData. When the comprehensive release is published, the chain-weighted measures will be available at the same level of detail as the constant-1987-dollar series now featured. The new base year will be 1992. Current-dollar NIPA estimates will be unchanged and implicit deflators will still be available. Dollar-denominated values of chain-weighted

Table x. Sample Calculations in a Hypothetical Two-Good Economy

	Year 1	*Year 2*	*Year 3*
Price ($)			
Apples	5	6	8
Bagels	4	4	5
Quantity (#)			
Apples	6	7	7
Bagels	5	7	8
Nominal value ($)			
Apples	30	42	56
Bagels	20	28	40
Total	50	70	96
Fixed-weight Output, Year 3 Prices	73	91	96
Indexes of Quantity Changes			
Laspeyres		1.260	1.057
Paasche		1.250	1.055
Fisher		1.255	1.056
Percent Change in Real Output			
Fixed Weights (Year 3 Base)		24.7	5.5
Chain Weights		25.5	5.6
Indexes of Real Output (Year 3 = 100)			
Fixed Weights	76.0	94.8	100.0
Chain Weights	75.5	94.7	100.0
Chain-Weighted Output, Base Year 3	72.5	90.0	96.0

Table adapted from Alan H. Young, "Alternative Measures of Change in Real Output and Prices," *Survey of Current Business*, April 1992.

GDP will be published for recent periods in the GDP news release, but past data will be released as indexes only. Constant-dollar figures with fixed 1992 weights will continue to be released for some time.

The revised NIPA figures for 1959-92 will be available from BEA on November 21, and the revised estimates for 1993 through the third quarter of 1995 will be released on December 15.[1]

[1] These dates were reported in the October 1995 GDP news release. The timing may be delayed a continued partial furlough of government employees.

Modeling Issues

The Adding Up Problem

Our method of modeling relies heavily on identities in the National Income and Product Accounts. One oft-touted fact about the new measures is that they do not "add up". The most basic identity in macroeconomics is that GDP = C + I + G + X - M. For nominal figures, this identity holds without fail. With fixed-weight constant-dollar measures of output, this identity also holds. However, because chain-weighted GDP uses weights from two different periods, the constant-dollar denominated sum of the components of GDP will generally not equal the reported value of total GDP. The quarterly figures will never "add up". The annual numbers will only add up in the base year and in the Laspeyres tail. In the Laspeyres tail, the weights are only from one year.

The importance of the adding up problem depends upon the size and volatility of the aggregation discrepancy. If we work at a very aggregate level of the basic identity above, the difference between the chain-weighted 1987-based sum C+I+G+X-M and the chain-weighted GDP figure is only $3 billion in 1993. This amounts to 0.06 percent of GDP. Since 1972, the discrepancy has remained below 0.5 percent of GDP and has been fairly stationery. As we move further back from the base year, the discrepancies grow, but we must look prior to 1969 for the sum of C+I+G+X-M to differ by more than one percent of GDP.

The graph below shows the size of the additive error in constant-dollar denominated annual GDP. The sum of C+I+G+X-M is greater than reported GDP before 1976, but after 1976, the size of the additive error is very small and we have no reason to believe that it will be anything other than zero. The current series has a base year of 1987 and a Laspeyres tail for 1994. As we expect, the components of GDP sum exactly to the total in those years.

Behavioral Relationships

Alternate measures of changes in prices and real output should not alter our basic beliefs about how the economy behaves. However, the changes will have definite impacts on many of our equations. Since we will be changing our measure of growth while leaving the history of other variables, such as unemployment and interest rates, unchanged, we expect the coefficients to change in our equations relating output growth or other NIPA figures to unchanged macro variables. If we know that output growth prior to the base is consistently underestimated in the old system, then we know that coefficients that measure the effect of output growth on other economic variables will be overstated. For a more thorough discussion of this point, see "Alternative Measures of Real GDP and Potential Growth," an unpublished INFORUM paper (July 1994) by Ralph M. Monaco and Jennifer L. Beattie.

As an example, we'll use a simple relationship between output growth and the unemployment rate. Okun's law says that an increase in the rate of growth of output above its potential should reduce the rate of unemployment by slightly less than a half of a percentage point. We can capture this relationship by regressing the change in the unemployment rate on the contemporaneous percentage change in output and a constant. Clearly, the dependent variable is unaffected by our choice of output measure. Before we run regressions, we convert the chain-weighted index to a real dollar value by multiplying the chain-type index by the nominal GDP in a base year (currently 1987). We expect the basic behavioral relationship to hold with either measure of output growth, but, as discussed above, we expect to see different coefficients depending upon which measure of growth we use.

The results from annual regressions are shown below. As expected, the coefficient of output growth is lower when we use the chain-weighted measure of growth. The figure shows the actual unemployment rate (the heavy dotted line) versus the unemployment rate predicted using Okun's law and the fixed-weighted measure of GDP growth (the solid line with + symbols) and the chain-weighted measure of GDP growth (the dashed lines with squares). The two points from the figure are that Okun's law does a pretty good job in general, and that it does a good job regardless of which measure of output growth we use.

Monaco and Beattie show that if we use the equations to "backsolve" for potential GDP growth, we find that the potential is much higher using the new chain-weighted measures of growth. This is not surprising, given that average annual growth of chain-weighted GDP was 0.4 percentage points higher between 1969 and 1975 than growth of the fixed-weight measure. The substitution bias in the old methodology understated the economy's potential growth in the past and therefore in recent years has overstated the health of the economy relative to its potential. If policymakers use the deviation of GDP from its potential as a rule of thumb for monetary policy, then policy based on the old measures may have been overly restrictive.

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# chun is the change in the unemployment rate
# pcf is the annual percent change in fixed-weight real GDP
# pcc is the annual percent change in chain-weighted real GDP

:                      Okun’s law with Fixed-Weighted GDP
  SEE   =       0.53 RSQ   = 0.7372 RHO =  -0.07 Obser  =   25 from 1970.000
  SEE+1 =       0.53 RBSQ  = 0.7258 DW  =   2.13 DoFree =   23 to   1994.000
  MAPE  = 4300079.69
    Variable name          Reg-Coef  Mexval t-value  Elas   NorRes     Mean
  0 chun                 - - - - - - - - - - - - - - - - - - - - -      0.04
  1 intercept              1.07500    65.5   6.326  24.43    3.81      1.00
  2 pcf                   -0.40657    95.1  -8.032 -23.43    1.00      2.54

 :                      Okun’s law with Chain-Weighted GDP
  SEE   =       0.57 RSQ   = 0.7054 RHO =   0.06 Obser  =   25 from 1970.000
  SEE+1 =       0.57 RBSQ  = 0.6926 DW  =   1.88 DoFree =   23 to   1994.000
  MAPE  = 4200248.44
    Variable name          Reg-Coef  Mexval t-value  Elas   NorRes     Mean
  0 chun                 - - - - - - - - - - - - - - - - - - - - -      0.04
  1 intercept              1.05004    57.6   5.844  23.86    3.39      1.00
  2 pcc                   -0.37515    84.2  -7.421 -22.86    1.00      2.68
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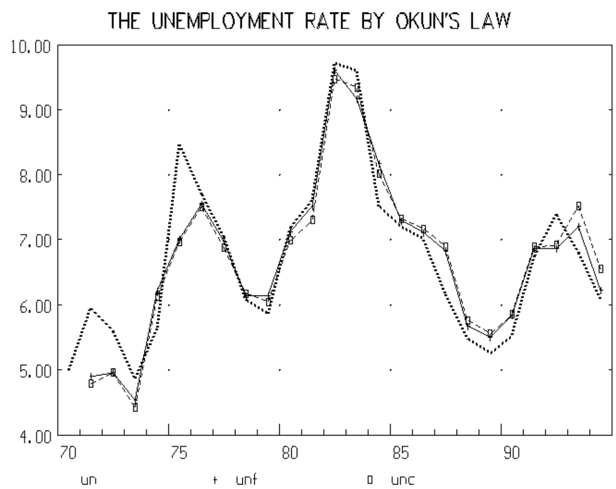

Conclusions

The first step in utilizing the new data in our model is to thoroughly understand how the figures are calculated. This document is a summary of that work. We have also begun to examine how the new measures will affect our behavioral equations, as illustrated by the example above. Certainly when we fully implement the new methodology in our forecast, we will estimate all our behavioral equations with the new chain-weighted data.

From a modeling standpoint, the main benefit of the new figures is to remove the substitution bias in the fixed-weight measures. Modelers who are unaware of the magnitude of the bias caused by how the BEA handles computers will be caught by surprise at the difference between the old and new figures. In the past, we have been careful to separate out the impact of falling computer prices on the overall measures of output. Our primary measure of output change used in our behavioral equations is already adjusted to exclude the artificially inflated value of real computers. In the coming months, we will replace this with the output as measured by the new chain-weighted indexes and thus will remove all the substitution bias, not just the part associated with computers.

We have examined a few alternatives ways to take account of the aggregation errors caused by the fact that the components of constant-dollar-denominated GDP do not add up to the total. Given the small size of the aggregation error near the base year and the very short time horizon of our quarterly forecast, we intend to stick with our old identities to calculate aggregate output. We will add an additional exogenous variable to account for the aggregation error. In historical simulations, it will equal the actual error, and in the forecast it will be assumed to be zero. If necessary, we can add an exogenous variable for the aggregation error in each of the identities in the model.

As mentioned above, since the driving force in our model already adjusts for the substitution bias in fixed-weighted GDP, we do not expect large changes in our forecast of unemployment, interest rates, and other macro variables. In some sense, our methodology already approximates the chain-weighted data. Our growth rates of NIPA-based numbers will change with the new figures, but the basic outlook will remain the same. We welcome the move towards the chain-weighted GDP.