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The strong performance of the U.S. economy during the late 1990’s spawned both popular visions of a transcendent future for the “New Economy” and careful empirical studies of key aspects of that experience. In particular, the marked acceleration of productivity growth during the period has been extensively analyzed in a set of papers using disaggregated growth accounting techniques to make a convincing case that the spurt in aggregate productivity growth is largely traceable to the information technology (IT) sector, which includes computer hardware, software, and communications equipment. The IT contribution to the growth of total labor productivity is traced both to the production of information technology capital at rapidly falling prices, which encouraged aggregate capital deepening, and to the direct contribution of technical progress in the production of information capital to aggregate multifactor productivity (MFP). Jorgenson and Stiroh (2000) and Oliner and Sichel (2000) find some acceleration of MFP outside the IT sector, whereas Gordon (2000) does not, owing to the fact that he attributes part of the acceleration of actual labor productivity to cyclical gains.

These findings naturally lead to the following questions: what does the recent surge of productivity growth imply about the future performance of the economy? Does the experience suggest that the sustainable growth path of the economy – the path consistent with full-employment (F.E.) and low and stable inflation – will embody a corresponding acceleration of productivity growth in the coming years, or was the recent surge due mainly to transitory or cyclical factors? What might the future path look like in quantitative terms?

We answer these questions using an updated version of the supply side of the Hickman-Coen (HC) Annual Growth Model.¹ The model provides an internally consistent framework for estimating and projecting the natural rate of unemployment, the F.E. labor force and hours of work, the F.E. productivity growth rate, and the growth path of potential or F.E. output. Our data is from official government sources in the United States, including the national income accounts (NIA) from the Bureau of Economic Analysis (BEA) and labor force and productivity data from the Bureau of Labor Statistics (BLS). The BLS series on labor productivity, output, hours, and related data in the nonfarm business (NFB) sector are the most widely cited productivity measures and are featured in our analysis. The sample period is 1960-2000 and the projections are for 2001-2020.

**THE NATURAL RATE OF UNEMPLOYMENT**

We allow for demographic factors in modeling the natural rate. The aggregate natural rate is

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¹ See Coen and Hickman (1994, 1995) for the previous version.
calculated as a weighted average of the rates for 16 age-sex groups, with weights proportional to the full-
employment labor force in each group. This specification captures the influence of two demographic
factors. First, demographic changes can raise the aggregate rate insofar as they shift the composition of the
labor force toward groups whose unemployment rates are relatively high, especially those aged 16-24.
Second, the growth in the supply of younger workers may raise their normally high unemployment rates
further as it leads to mismatches between the skills and work experiences employers seek and those offered
by younger job applicants, leading to a high rate of job turnover and unemployment spells for these groups.
The labor-force share of workers aged 16-24 rose markedly during the 1960’s and 1970’s as baby-boomer
cohorts entered the labor force, and then declined just as markedly as they matured in the 1980’s and
1990’s, as may be seen from Figure 1 (the shaded areas in this and subsequent charts mark the cyclical
expansions of the period as dated by the National Bureau of Economic Research).

The natural unemployment rate is estimated in two steps. First, following Staiger, Stock and
Watson (2001), we smooth the aggregate unemployment rate with the Hodrick-Prescott (HP) filter to
remove its high-frequency components, as pictured in Figure 2A. It can be shown that computing the
separate HP trends for all 16 age-sex groups in our model and aggregating them with the corresponding
labor force weights, yields virtually the same aggregate HP trend as directly computed from the aggregate
unemployment rate. The aggregate HP trend thus computed (not shown) is our provisional measure of the
natural rate. Is it also a TV-NAIRU, with the property that it represents a time-varying unemployment rate
consistent with steady inflation? The answer is yes, according to Staiger, Stock and Watson, who compare
their TV-NAIRU estimated from an accelerationist specification of the Phillips Curve with the same HP
trend as pictured in our Figure 2A, stressing that for all practical purposes the estimated NAIRU is the same
as the univariate HP trend.

Second, we extend the scope of the demographic analysis by allowing for the influence of
population shifts on the sectoral unemployment rates themselves through the following regressions:

\[(1) \quad \ln\left(\frac{U_{kt}}{1 - U_{kt}}\right) = c_0 + c_1 (U_{kt}) + c_2 \left(\frac{N_i}{N} \right) + v_i,\]

where \(U_k\) is the actual unemployment rate of prime-age male workers aged forty-five to fifty-four, \(U_i\) is the
actual unemployment rate of age-sex group \(i\), \(\frac{N_i}{N}\) is the (noninstitutional) population ratio for group \(i\),
and \(v\) is a stochastic disturbance. The population ratios are included to allow for the influence of labor
market mismatches on the age-and-sex-specific rates, following Wachter (1976). The rationale for
including the unemployment rate of prime-age males as a regressor is that this group’s unemployment
experience is largely independent of demographic shifts and provides a good measure of the underlying
changes in labor market tightness. Next, we substitute the HP trend of the prime-age male unemployment
rate for its actual rate in equations (1) and set the disturbance terms to zero in order to calculate natural

\[\text{2 Perry (1970), Wachter (1976), and Gordon (1982) studied the early impact of this demographic wave on}
\text{the natural rate of unemployment in seminal studies, and Shimer (1998) and Katz and Krueger (1999) have}
\text{examined its influence in recent decades.}\]
rates for the other age-sex groups by purging them of cyclical and random factors. Finally, the aggregate
natural rate, $UN$, combines the age-sex specific rates with weights equal to each group’s share of the natural
or full-employment (F.E.) civilian labor force.

Figure 2B depicts the estimated natural rate including the direct and indirect effects of
demographic shifts. It will be seen that the estimated rate closely resembles the direct HP filter of actual
unemployment in the top panel, although it peaks at a slightly lower level and a year later than the latter.

To assess the importance of demographic factors in the behavior of the natural rate during the
eighties and nineties, we perform a counterfactual experiment to isolate the changes in the natural rate due
to population shifts. The prime-age natural unemployment rate is fixed at its 1982 level and the system of
age-sex equations is re-solved for the period 1982-2000. The results indicate that had not the natural rate of
this key group declined after 1982, the aggregate natural rate would nonetheless have fallen from 7.38 in
1982 to 6.04 in 2000, or by 44 percent of the total decline in the estimated natural rate. However, most of
the demographic impact occurred before the expansion of the nineties. Between the business cycle troughs
of 1982 and 1992, the counterfactual simulation accounts for 91 percent of the decline in the estimated
natural rate, whereas the corresponding figure for 1992-2000 is only 16 percent. The small contribution of
demographic change to the reduction of the natural rate during the expansion of the 1990’s reflects the fact
that the youth-age component of population was nearly constant during those years, as shown in Figure 1.

THE PRODUCTION FUNCTION AND FACTOR DEMAND SYSTEM

We assume a long run or planning production function of Cobb-Douglas form and constant returns
to scale:

\[
X_t^e = A_t(K_t^*)^\alpha (I_tH_t^*)^{1-\alpha}.
\]

The $e$ superscript signifies the expected value of output, and the * superscript denotes desired levels of the
inputs. The exponential rate of technical change in period $t$ is $\ln (A_t / A_{t-1})$. Let $H$ be hours employed and $I$
an exogenous index of the effects of changes in the composition of labor-hours on the efficiency of current
employees.\(^3\) The desired inputs are assumed to be chosen so as to minimize the cost of producing the
expected output in long-run equilibrium, which requires that the ratio of the marginal products of labor and
capital be equated to the ratio of their expected prices, so that:

\[
K / H = (\alpha / (1 - \alpha)) (W / Q),
\]

where $Q$ is the rental price of capital and $W$ the nominal wage rate. Substituting this condition into the
production function successively for capital and worker inputs and omitting inessential constants, we derive
the following long-run input expressions:

\[^3\] We use as our measure of $I$ the labor composition index published by BLS in its estimates of multifactor
productivity. This index accounts for changes in education, work experience, and gender. The index base
is 1996=1.0.
Firms do not adjust inputs immediately to the desired levels, however, owing to adjustment costs of changing input levels. These costs are represented in the model by an adjustment hypothesis in which the observed inputs are adjusted partially each period at constant geometric rates:

\[ H_t / H_{t-1} = (H_t^* / H_{t-1})^\lambda. \]

\[ K_t / K_{t-1} = (K_t^* / K_{t-1})^\kappa. \]

Our short-run input demand functions are obtained by combining equations (4) and (6) and (5) and (7) to yield:

\[ H_t = \left[ (W_t^e / Q_t^e)^{-\alpha} X_t^e A_t^{-1} I_t^{(1-\alpha)} \right]^\lambda (H_{t-1})^{1-\lambda}. \]

\[ K_t = \left[ (W_t^e / Q_t^e)^{(1-\alpha)} X_t^e A_t^{-1} I_t^{(1-\alpha)} \right]^\kappa (K_{t-1})^{1-\kappa}. \]

The expected rental price of capital is:

\[ Q_t^e = PI_t^e (r + \delta) TX_t, \]

where \( PI \) is the investment deflator, \( r \) the discount rate, \( \delta \) the depreciation rate, and \( TX \) captures the influence of business taxation and investment subsidies. Expectations of wages and prices are determined by second-order autoregressions on current values. Expected output is set equal to actual output to enable our estimate of the Okun’s Law gap between actual and potential output (equations 14 and 15).

Our next task is to estimate the parameters of equations (8) and (9) for the nonfarm business sector, combining the BLS productivity dataset with BEA data on capital stock and depreciation. The first

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4 Examples of these costs for labor are searching, hiring, training and layoff costs. In the case of capital, adjustment costs may stem from purchase costs that are external to the firm or from internal installation costs.

5 The discount rate is set at 6%, which is a rough estimate of the average ex post real after-tax return on capital and can be thought of as the target return firms seek on new investment. This specification gives superior fits for the factor demand functions to formulations using nominal or real long-term market interest rates before or after taxes.

6 As a check, a model simulation substituting an autoregressive specification for expected output differed only marginally from our present findings.

7 The capital stock data is the official BEA series measured in billions of chained 1996 dollars. Chain aggregates are not additive, however, so the corresponding depreciation series cannot be properly measured using the standard identity for the perpetual inventory method to derive an implicit aggregate depreciation rate. As Whelan (2000) shows, such a derived series is biased toward a faster-than-actual pace of depreciation. Rather, the appropriate measure is a weighted average of depreciation rates of the underlying
problem is to specify the treatment of technical progress or total factor productivity (TFP) growth. We begin by calculating the Solow residual $S_t$ from the production function as an approximate measure of the annual rate of technical change for a given value of $\alpha$: \[ S_t = \ln(X_t / X_{t-1}) - \alpha \ln(K_{t-1} / K_{t-2}) - (1 - \alpha) \ln(L_t / L_{t-1}), \] where labor input $L = IH$. $S_t$ is an approximation to $\ln(A_t / A_{t-1})$, since it is affected by varying utilization rates of measured inputs and by stochastic disturbances to aggregate demand and supply. To purge the estimated technical progress trend of these transitory elements, the residual was first cumulated and then smoothed with an HP filter, providing a flexible, low-frequency estimate of $\ln A_t$, which resulted in trend values that accord well with generally accepted views and our own previous estimates based on piecewise trend breaks. Next, the same $\alpha$ value was imposed in the factor demand functions, which were then estimated simultaneously by the method of seemingly unrelated regressions to determine their constant terms and adjustment speeds. This procedure ensures that the imposed technical progress trend is consistent with the value of $\alpha$ in the estimated factor demand system.

Three values of $\alpha$ were tried: 0.36, 0.30, and 0.25. The best fit was attained for 0.25. The fitted factor demands for 1959-1999 are (t-values are shown in parentheses beneath estimated parameters):

\[
\begin{align*}
\left(8A\right) \ln(H_t / H_{t-1}) &= -1.194 + 0.697\left[ -0.25\ln(W_t / Q_t) + \ln(X_t / H_{t-1}) - \ln A_t - 0.75\ln I_t \right] + 0.798HRES_{t-1} \\
&(-14.70) (14.85) (8.79) \\
\text{RSQBAR} = 0.757 & \quad \text{Durbin-Watson} = 2.313 \\
\left(9A\right) \ln(K_t / K_{t-1}) &= -0.222 + 0.095\left[ 0.75\ln(W_t / Q_t) + \ln(X_t / K_{t-1}) - \ln A_t - 0.75\ln I_t \right] + 0.947KRES_{t-1} \\
&(-4.93) (6.67) (17.25) \\
\text{RSQBAR} = 0.816 & \quad \text{Durbin-Watson} = 1.668
\end{align*}
\]

In these expressions, $HRES$ and $KRES$ are the unconditional residuals in AR(1) processes. The estimated adjustment speed of labor is 0.697, indicating that 70 percent of the gap between desired and actual labor categories of equipment and structures. We use the depreciation series Whelan calculated in this manner in our rental price of capital variable.

8 TFP is more commonly used in theoretical expositions and the macroeconomic literature than its synonym MFP.

9 Since the capital stock is dated at the end of the year, the current capital input is based on lagged capital stock in the expression for the Solow residual.

10 We applied a smoothing parameter of 400. We note, however, that imposing less smoothing would yield a greater acceleration of technical progress in the second half of the 1990’s. A smoothing parameter of 100, for example, yields trend estimates for the Solow residual averaging 1.02 in 1991-1995 and 1.29 in 1996-1999, as compared with our preferred measures of 0.97 and 1.10.
input is closed each year. As expected, the adjustment speed for capital stock is a much slower 10 percent per year.

The first trial value for $\alpha$ of 0.36 was calculated as one minus the mean labor share during the sample period. This procedure is frequently used in studies of the production function, since under competitive market conditions and constant returns to scale the factor shares measure their marginal productivities. However, under realistic, imperfectly competitive market conditions, the capital share will include monopoly rents, thereby overstating the marginal productivity of capital services, so that there is no theoretical contradiction in favoring the better fitting value of 0.25 in our estimated production function.

The indexes of technical progress and its HP trend during 1952-1999 are graphed in Figure 3A. The lower panel, Figure 3B, shows the corresponding growth rates of the actual and trended Solow residuals. As an aid to judging the relevance of our estimates of the annual growth rates of technical progress, we compare our measure to the multifactor productivity index of the BLS in Figure 4. The overall similarity between the two series is remarkable – the correlation coefficient is 0.989. A substantial gap did open between them during 1994-1999, however, when the Solow residual averaged an annual gain of 1.76 percent as compared with 1.06 percent for the MFP measure. The gap is attributable to the fact that the input of capital services is assumed to be proportional to the aggregate capital stock in our model, whereas individual capital stocks are weighted by rental prices in the aggregation procedure underlying the aggregate capital-input measure used in the BLS multifactor productivity estimates. The latter approach (originated by Jorgenson and Griliches, 1967) is based on the identification of rental prices with marginal products of different types of capital, so that capital “quality” is improved when assets with higher marginal products are substituted for those with lower ones. The pace of such substitution was accelerated in the late nineties by the rapid decline in prices of IT capital, so that the quality-adjusted capital input measure accounted for relatively more of the growth of output in the BLS measures, reducing their residual estimate of MFP relative to our calculated Solow residual.

**F.E. LABOR SUPPLY**

Labor supply, measured in hours, is the product of annual hours per worker $AH$ and the number of employed persons $E$, the latter depending on the unemployment rate $U$ and the size of the civilian labor force $LC$. The principal determinants of the labor-force participation rate $LP$ are the employment-population ratio $E/N$ and the real after-tax consumption wage $WRC$. The $E/N$ ratio, an indicator of the probability of finding work, captures so-called discouraged-worker effects, while $WRC$ measures the opportunity cost of leisure. The estimated participation equations are disaggregated into 16 age-sex groups.

Denoting F.E. levels of variables by the suffix “$F$”, the F.E. participation rate for the $i$-th group in year $t$ is given implicitly by:

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11 Note that the series denoted TREND in Figure 3B is the first difference of the HP trend through the cumulated Solow residual index in Figure 3A, rather than one directly calculated by filtering the actual Solow residual series plotted in Figure 3B.
\[ \ln \left( \frac{LPF_{i,j}}{(1 - LPF_{i,j})} \right) = c_{1,i} + c_{2,i} \left( \frac{EF_{i,j}}{N_{i,j}} \right) + c_{3,i} WRCF_{i,j} + c_{4,i} \left( \frac{LA_{i,j}}{N_{i,j}} \right) + c_{5,i} \text{TREND} + c_{6,i} \ln \left( \frac{LP_{i,j-1}}{(1 - LP_{i,j-1})} \right), \]

where \( LPF_i = (LCF_i / N_i) \), \text{TREND} is a log-linear trend variable, and \( LA \) stands for the armed forces, appearing only in the equations for males under age 45. The sub-system of labor supply equations (1) and (12) and can be solved for the F.E. values of the natural rate of unemployment \( UN \), civilian labor force \( LCF \), and civilian employment \( EF \), conditional on the real wage and exogenous variables. The volume of F.E. employment in the nonfarm business sector, \( ENFBF \), is then obtained from an identity relating it to the difference between \( EF \) and an exogenous estimate of employment outside the NFB sector, \( EFDIF \).

The average-hours equation is a hybrid relation combining both supply and demand factors. An equation explaining actual hours per worker \( AH \) in the NFB sector depends primarily on the real after-tax consumption wage \( WRC \), which affects workers’ labor supply decisions, and on cyclical variations in labor demand as measured by the unemployment rate \( U \). Then F.E. average hours are given by the F.E. counterpart of the \( AH \) equation:

\[ AH_{F,i} = c_1 + c_2 WRCF_{i} + c_3 UF_{i} + c_4 LCWF_{i}, \]

where \( LCWF \) is the F.E. proportion of women in the labor force, reflecting the fact that women tend to work fewer hours than men do. Given \( AHF \) and \( ENFBF \), the level of F.E. hours \( HF \) in the NFB sector is obtained as their product. Assuming that average hours outside the NFB sector behave the same as those within it, we calculate total hours in the non-NFB sector as \( AHF \times EFDIF \). Finally, F.E. hours in the total economy are obtained by summing those in the NFB and non-NFB sectors.

Determination of F.E. Output

Estimates of F.E. output, the F.E. real wage, and the natural rate of unemployment are obtained by solving a simultaneous system of labor demand and supply equations that also determines the F.E. levels of the labor force and labor hours. The primary calculation is for the NFB sector, but estimates are also presented for the total economy.

We begin by solving the theoretical labor demand function, equation (8), for actual output:

\[ X_t = \left( \frac{W_t^e}{P_I^e} \right) (r + \delta_t) TX_t \right)^\alpha A_I^{-\alpha} H_t^{1/\lambda} H_t^{-\alpha/(3-\lambda)/\lambda}. \]

Now let \( XF \) be F.E. output, \( HF \) be F.E. labor input, and \( WRIF \) be the F.E. real investment wage. Substituting for their counterparts in equation (14) yields the expression for F.E. output:

\[ XF_t = \left( \frac{WRIF_t}{(r + \delta_t) TX_t} \right) \right)^\alpha A_I^{-\alpha} H_F^{1/\lambda} H_t^{-\alpha/(3-\lambda)/\lambda}. \]

Thus we define potential or F.E. output as the output that would have to be demanded to induce firms to hire the F.E. labor supply at the natural rate of unemployment and with the real wage at its (labor-market clearing) F.E. level. Comparing equations (14) and (15), we see that the calculated difference between \( X_t \) and \( XF_t \) is a structural descendent of Okun’s (1962) seminal concept of potential output as providing a
measure of the output gap, or the output increase that would be necessary to reach full employment of labor from the existing levels of employment and output. Thus it is a policy-oriented concept depending on structural factors rather than simply a trend through past business cycles.

The parameters in equation (15) come, of course, from the estimated labor demand equation (8A). Note that $X_F$ is a function of both the real investment wage and the real consumption wage, the latter being a determinant of $L_C$. To close the system, additional equations are needed to determine these F.E. real wage rates. The HC model assumes markup pricing on unit labor cost, which implies that the real product wage equals the reciprocal of the markup times labor productivity. The F.E. version of the equation is:

\begin{equation}
W_X F_i = (1/MUHP)(X_F / H_F_i),
\end{equation}

in which $MUHP$ refers to the smoothed HP-filtered markup.

Changes in the real consumption and investment wages may differ from those in the real product wage for several reasons. First, there may be differential rates of technical progress in the two sectors. Second, consumption and investment goods prices may respond differently to external shocks, such as changes in energy prices. Finally, consumption and investment prices may display different patterns of cyclical behavior. Changes in actual relative prices will, of course, be reflected in observed factor demands and supplies. To allow for their influence on the F.E. path, we express the F.E. real consumption wage as the F.E. real product wage multiplied by the actual ratio of the output deflator to the consumption deflator, and similarly for the F.E. real-investment wage.

The F.E. path for the NFB sector is generated by solving the simultaneous system composed of equations (1), determining the natural unemployment rate, (12) and (13), determining the F.E. labor supply, and (15) and (16), which together with required identities, determine potential output. It is not the smooth path of simple trend estimates of F.E. output, since our concept responds endogenously to changes in the rate of technical progress, demographic changes affecting the natural unemployment rate and the labor supply, changes in taxation affecting the wage-rental ratio and the labor supply, and variations in the rate of change of labor hours (labor adjustment factor). Technical progress and the natural rate of unemployment of prime-age males have been smoothed in estimating the F.E. path, but the remaining elements are subject to considerable variation.

To provide a corresponding series of F.E. GDP, we add as an exogenous component the difference between actual GDP and actual NFB output to the model-determined estimate of potential NFB output.\textsuperscript{12} This procedure is subject to some (probably small) error because the chained real GDP estimates are non-additive in their components. In any event, the output gaps for NFB and GDP coincide closely (the correlation coefficient is 0.999) except for a slightly greater amplitude for the nonfarm business sector.

**OUTPUT AND UNEMPLOYMENT GAPS**

Our estimates of potential output and the output gap for both the NFB sector and real GDP are

\textsuperscript{12} The exogenous component (about 25 percent of GDP) includes the farm, household, housing, and government sectors.
displayed in Figure 5. The profiles for the NFB sector exhibit faster output growth and larger output gaps than those for GDP, but the patterns of the output gaps are much the same.

Of the three long expansions during 1961-2000, that of 1961-1969 was the strongest, with a potential GDP growth rate of 4.70 percent, actual growth at 4.52 percent, and an output gap averaging 75 basis points. During 1982-1990, actual GDP growth of 3.22 percent exceeded potential growth of 2.83 percent and the output gap averaged 59 basis points. The corresponding figures for the expansion of 1991-2000 are respectively 3.32, 3.19 percent and –1.11 percentage points.

In remarkable contrast to its predecessors, the long expansion of 1991-2000 was a late bloomer, nearing potential only in 1998 and exceeding it only at its 2000 peak. Most of the expansion, then, was spent catching up to potential, and despite the stock market bubble, it did not seriously overshoot on either output or inflation.

Our estimates of the output and unemployment gaps for real GDP are compared in Figure 6. The two gaps are inversely correlated as expected, with a correlation coefficient of -0.835. The slope of a regression of the GDP gap on the unemployment gap is –1.9, close to the textbook value of –2.0 usually cited for Okun’s Law. We conclude that our estimates of the natural rate of unemployment and the level of potential output are consistent with one another and satisfy the relationship predicted by accepted macroeconomic theory.

**ACTUAL AND F.E. OUTPUT GROWTH, 1961-2000**

The growth rate of actual output is decomposed into the growth rates of labor hours and labor productivity for both the NFB sector and the total economy in Table 1A. In order to provide an historical perspective on the performance of the “New Economy”, the average annual growth rates of these variables are shown for the three long expansions of 1961-1969, 1982-1990, and 1991-2000 and for the tumultuous period 1970-1981, dominated by the oil shocks and their aftermaths. We discuss the estimates for the NFB sector first, since these are the basic productivity measures available for the macro economy. For that sector, the average growth rates of output, productivity and hours over the entire period 1961-2000 were respectively 3.69, 2.02, and 1.67 percent.

The prize for best real-sector performance in every category is decisively won by the 1961-1969 expansion, with productivity growth exceeding that of 1991-2000 by 96 basis points, hours growth by 21 basis points, and output growth by 1.17 percentage points. The 1991-2000 expansion compares favorably with that of 1982-1990, however, with an edge in productivity growth of 49 and in output growth of 17 basis points.

A breakdown of the 1991-2000 expansion between its first and second halves is included in the last two rows of the table. This division highlights the surge in productivity growth in the late 1990’s, when it increased from 1.51 percent in 1991-1995 to 2.53 in 1996-2000, or by 1.02 percentage points. At the same time, labor input increased 92 basis points, so that total output grew at a rate of 4.61 percent in

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13 After narrowing slightly in 1992, the output gap plunged temporarily in 1993 as potential outpaced actual growth. The growth rate of F.E. output more than doubled between 1992 and 1993, largely because of a marked acceleration in the growth rate of the F.E. labor supply.
1996-2000, as compared with only 2.68 in 1991-1995.

The corresponding decomposition for F.E. output growth in the NFB sector is presented in Table 1B. Over the entire period 1961-2000, the average growth rates of estimated F.E. output, productivity and labor supply were slightly higher than their actual counterparts in Table 1A at respectively 3.74, 2.06, and 1.69 percent. The margin of superiority for the 1961-1969 expansion is somewhat higher for the F.E. estimates than for the actual measures, with F.E. productivity growth exceeding that of 1991-2000 by 1.32 percentage points and F.E. output growth by 1.23 points. During 1991-2000 actual and potential productivity grew respectively by 2.02 and 2.07 percent, or about the same as their rates for the entire sample period. Finally, it is noteworthy that actual productivity growth increased 1.02 percentage points between 1991-1995 and 1996-2000, whereas the corresponding gain for F.E. productivity was only 9 basis points. Thus our structural methodology for separating trend and cycle leads to the conclusion that the great bulk of the recent productivity spurt reflected cyclical gains as the NFB economy caught up to its potential path. This is in sharp contrast to the previous long expansions of 1961-1969 and 1982-1990 (Figure 5).

The story is much the same when the productivity estimates for the total economy are examined in Tables 1A and 1B, although the acceleration of productivity growth is more pronounced for F.E. GDP (51 basis points) than for its NFB counterpart (9 basis points). Also, the growth rates of output, hours and productivity for the total economy are generally slower than in the NFB sector.

**Decomposition of the F.E. Labor Supply**

The growth rate of F.E. hours in the NFB sector may be decomposed into several determinants as follows. First, express F.E. hours as the product of average hours $AHF$ and employment $ENBF$:

$$HF_t = AHF_t \cdot ENBF_t.$$

Now rewrite (17) as:

$$HF_t = AHF_t \cdot EFRAT_t \cdot EF_t.$$

where $EFRAT = ENBF/EF$, the ratio of NFB employment to total employment. $EF$ in turn may be decomposed as the product of the natural employment rate and the civilian labor force:

$$EF_t = (1 - UN_t) \cdot LCF_t.$$

Finally, the civilian labor force can be expressed as the product of the labor force participation rate and the civilian noninstitutional population:

$$LCF_t = LPF_t \cdot POP_t.$$

Combining all of these expressions, we obtain the final decomposition of the level of $HF$:

$$HF_t = AHF_t \cdot EFRAT_t \cdot (1 - UN_t) \cdot LPF_t \cdot POP_t.$$
The decomposition in Table 1C is based on the sub-period average growth rates of the variables in this expression. Hours in the NFB sector increased at virtually the same rate in the first three subperiods, owing to offsetting changes in the various components. During 1961-1969, hours increased at a yearly rate of 1.67 percent despite a decline in average hours at a rate of 39 basis points. Population growth explains most of the increase in labor input, but contributions also came from increases in labor force participation, the NFB employment share, and the natural employment rate. The average rate of population growth increased from 1.51 percent in 1961-1969 to 1.97 percent in 1970-1981, and growth of the participation rate also increased from 10 to 56 basis points. Yet the growth rate of NFB hours decreased slightly between the two periods, as the rate of decline of average hours accelerated, NFB employment grew less rapidly relative to total employment, and the natural employment rate fell. Population growth fell sharply in 1982-1990, to 1.18 percent per year, but hours continued to grow at about the same pace as in the previous sub-periods, because average hours stabilized, the natural employment rate rose, and the participation rate continued its rise. The period with the smallest population growth rate and lowest rate of growth of labor force participation was 1991-1995, and this was also the period of smallest growth of hours (1.52 percent). The growth rate of F.E. hours rebounded to a peak of 2.02 percent in 1996-2000, largely due to a sharp increase in the growth of NFB employment relative to total employment and to further increases in the natural employment rate. Finally, the F.E. growth rates of NFB and total employment are displayed as an addendum in the last two columns, as an aid to understanding the relative movements underlying the evolution of the $EFRAT$ variable.

Components of F.E. Productivity Growth

A decomposition of F.E. labor productivity into its principal systematic components is obtained by dividing equation (15) by $HF$ to obtain:

$$\frac{XF_t}{HF_t} = \left[\frac{WRIF_t}{r + \delta_t}TX_t\right]^\alpha A_t f^{(1-\alpha)} \left(\frac{HF_t^{-\lambda}}{(1-\lambda)}\right) X_{t-1}^{-\lambda}.$$  

(22)

The first term measures the contribution to F.E. productivity of capital deepening, since the wage-rental ratio determines the capital-labor ratio. The next two terms account for the levels of technology and of labor “quality” as measured by the labor composition index, whereas the final term allows for the effects of the lag in the adjustment of labor input to its long-term equilibrium. Taking logs and first-differencing the equation yields an expression for the decomposition of the growth rate of F.E. labor productivity as a function of the rates of capital deepening, technical progress, increase in labor quality, and labor adjustment. However, our estimated labor demand function (equation 8A) also includes an autoregressive error term in addition to the four structural components. The decomposition presented in Table 1D includes a column labeled Labor Resid to account for the autoregressive term.

The decomposition reveals that the superior performance of F.E. productivity growth in the sixties was due to substantially higher rates of both technical progress and capital deepening than were subsequently achieved. Productivity growth averaged 1.32 percentage points higher in the sixties than in the nineties, with technical progress contributing 1.02 percentage points and capital deepening another 38
basis points. The expansion of 1982-1990 was a distant third in all respects except for an acceleration of the labor composition component relative to 1961-1969. Finally, the modest acceleration of F.E. productivity growth in the second half of the expansion of 1991-2000 – 9 basis points – reflects increases of 18 basis points in capital deepening and 13 basis points in technical progress, mostly offset by a reduction of 16 basis points in labor composition.

**Decomposition of Factors Affecting Capital Deepening**

Further insight concerning the sources of variations in capital deepening may be gained by decomposing its determinants as follows. The contribution of capital deepening to F.E. productivity is determined by the following expression from equation (22):

\[(23) \quad \frac{WRI_F}{(r + \delta_X)T_X} \]

The F.E. real investment wage, \( WRI_F \), may be factored as \( WRXF*PXPI \), or the real product wage times the ratio of the output and investment deflators. Making this substitution in (23), taking logs, and first differencing yields the decomposition of the growth rate of capital deepening:

\[(24) \quad D\alpha = \alpha^*[DWRXF + DXPXPI - D(r + \delta_X) - DTX] \]

where the prefix \( D \) represents the logarithmic first-difference operator. An independent increase in the real product wage decreases \( PX/W \), and hence \( PI/W \), inducing deepening. Similarly, an independent increase in \( PXPI \) reduces \( PI/PX \), and hence \( PI/W \), with the same result. The discount rate is a constant in our model, but changes in the depreciation rate and in taxes affecting investment decisions have inverse effects on the deepening rate.

Table 1E contains the breakdown of the components of the growth rates of F.E. capital deepening during the sample period. Deepening occurred at 1.17 percent per annum in 1961-1969, declined to an average of 50 basis points in 1970-1981, and rebounded to 70 basis points in 1991-1995 and 88 basis points in 1996-2000. Real wage growth was a substantial stimulus to capital deepening throughout the sample period and was especially important during the 1961-1969 expansion. Large decreases in the relative price of investment goods dominated the real wage effect beginning in the early eighties, however, owing principally to the rapid fall of semi-conductor and computer prices during those years. Increasing depreciation rates depressed deepening moderately between 1961 and 1995, but rather substantially in 1996-2000. Significant increases in deepening accompanied the liberalization of tax policy affecting investment decisions from the early sixties to the mid eighties, but subsequent tightening of depreciation rules and elimination of the tax credit for equipment investment led to small negative impacts through the mid-nineties.

**PROJECTIONS OF F.E. GROWTH IN 2001-2020**

We now utilize our model to project the F.E. growth path of the economy over the next two decades, conditional on alternative trajectories of the principal exogenous variables. For our baseline projection, we adopt the Census Bureau’s intermediate population series and assume that ratios of non-
institutional to total population remain constant at their 2000 values for each age-sex group. The rate of technical progress is assumed to continue at its 1997-99 average of 1.1 percent per year, and the following exogenous elements are incorporated:

- Steady growth of the labor quality index at 0.39 percent per year, the rate observed in 2000.
- A constant natural unemployment rate of 45-54 year old males, the key labor force group, at 2.55 percent, its level in 2000.
- A constant markup of price over unit labor cost at its 2000 value. After rising from 1.57 to 1.61 in the 1990's, the markup appeared to be leveling off in the last years of the decade.
- Reductions in federal income tax rates for 2001-2006 and other currently legislated changes in federal taxation that affect our measure of the tax rate on labor income. The rates in effect in 2006 are assumed to remain unchanged through 2020. There are no scheduled changes in corporate taxation that alter our estimates of the implicit rental cost of capital.
- Continual reductions in the relative price of investment goods at rates determined by a second-order autoregression fitted to actual data for 1986-2000.
- A gradual rise in the rate of depreciation of capital at the pace observed during 1985-2000.
- A constant ratio of armed forces to non-institutional population at the 2000 level.
- A constant level of employment outside of the NFB sector at that observed in 2000, which implies a continuing decline in the ratio of non-NFB to NFB employment.
- Growth in productivity (output per hour) outside of the NFB sector at a rate of 1.50 percent per year, which was the average rate of increase in 1981-2000. Hours per worker outside of the NFB sector are set equal to the solution value for F.E. average hours in the sector.

The F.E. path is obtained by solving the model dynamically over the period 2000-2020, using actual values of lagged endogenous variables for 1999 and earlier. The dynamic solution yields a path along which full employment is continuously maintained, in contrast to the static solution over the sample period, for which each year’s F.E. values are conditional on the actual path of the economy up to that time. For the two estimated equations that were adjusted for serially correlated residuals – the average hours equation and the labor demand equation – the solution incorporates lagged residuals from the final year of the sample, so that these residuals affect only the levels of the solution values of the variables, not their changes over time.

As noted above, the estimated labor force participation equations include trends to account for factors influencing participation that are not captured by other variables in the equations. When run out mechanically over twenty years, the trends sometimes result in implausible levels of participation. In these cases, we adjusted the trend terms to keep the participation rates within reasonable bounds.

Table 2 summarizes the baseline projection, showing average annual growth rates for each decade, 2001-2010 and 2011-2020, together with a recap of our estimates of F.E. growth rates for 1996-2000. In panel A of the table, we see that F.E. output in the NFB sector is projected to rise at 3.41 percent per year in the first decade, slowing to 2.74 percent in the second decade. The corresponding figures for F.E. GDP are
2.99 and 2.50. These growth rates represent significant reductions from those of the last half of the 1990’s and are largely traceable to significantly lower rates of labor supply growth. F.E. productivity growth rises slightly in the NFB sector and remains roughly constant for the total economy, relative to the late 1990’s.

We see from panel B that very little of the decline of F.E. labor supply growth in the first decade of the projection is due to a retardation in population growth; rather, changes in all of the other factors impact labor supply growth negatively. We project that average hours will resume a downward trend, following a modest rise in the 1990’s. The share of NFB employment in total employment is projected to continue its upward trend, but at a slower pace than observed in 1996-2000. The natural rate of employment, whose increase in 1996-2000 contributed about one-quarter of a percentage point to F.E. labor supply growth, declines very slightly in the first decade of the projection (the natural unemployment rate rises from 4.29 percent in 2000 to 4.36 in 2010). And finally, we foresee only a slight increase in the aggregate rate of labor force participation in 2001-2010 and a decline in 2011-2020, in contrast to a modestly rising trend in the 1990’s.14

Panel C shows the decomposition of F.E. NFB productivity growth. The small acceleration in the projection, relative to 1996-2000, stems largely from smaller drag arising from labor adjustment. By assumption, the contribution of technical progress remains at 1.10 percent, and the contribution of labor quality declines slightly to 0.29 (one minus the capital elasticity times 0.39), while the endogenous rate of capital deepening is unchanged. From panel D we see that capital deepening is stimulated by higher growth of the real product wage and by a somewhat smaller rate of increase in the depreciation rate (the discount rate is held constant at 6 percent, as in the sample period). However, these positive influences are offset by a diminished rate of decline of the relative price of capital goods.

Viewed in the longer perspective provided by panel B of Table 1, F.E. NFB output growth in the first decade of the baseline trails the 1960’s by 1.65 percentage points and the 1990’s by 0.42, but exceeds that in the 1980’s by 0.46. The strongest resemblance is to the decade of the 1970’s; but in comparison to the 1970’s, productivity growth accounts for a larger portion, and labor supply growth for a smaller portion, of potential growth. The second half of the projection registers the slowest decade of F.E. growth since 1960, due principally to a low rate of growth of F.E. labor supply.

Our projection may be compared with that recently published by of the Congressional Budget Office for 2003-2012, which serves as the basis for CBO’s assessment of the federal budget outlook (CBO, 2002, Table E-1). CBO seeks to project actual rather than F.E. output, but only the first two or three years of their forecast is meant to incorporate business cycle considerations; thereafter, they essentially envisage a stable, high-employment growth path. For the period 2002-2012, they forecast average growth of real GDP at 3.05 percent, which is virtually the same as our F.E. estimate of 2.93 percent for the same period.

14 The participation rate rises from 67.1 in 2000 to 67.4 in 2010, then declines to 65.4 in 2020. If participation rates by age and sex are held constant at their 2001 F.E. levels, the aggregate participation rate declines even more sharply – to 66.0 in 2010 and 63.1 in 2020. Rising rates of female participation continue to counterbalance declines in male participation and to partially or wholly offset the negative impact of demographic changes on aggregate participation.
Their unemployment rate forecast rises to 6.1 percent in 2002, then declines to 5.2 percent in 2005 and remains at that level, which may be viewed as CBO’s estimate of the natural rate of unemployment. This considerably exceeds our projected natural rate of 4.3 percent.

CBO’s published forecast does not include explicit estimates of productivity and hours growth. However, the former might be inferred from their projected growth of real wages, which ought to approximate the rate of productivity growth on a steady growth path (on the assumption of constant price markups). The difference between their projected growth of employment costs and that of consumer prices is about 1.5 percentage points on average. This is quite a bit below our estimate of F.E. productivity growth for either the total economy (2.1 percent) or the NFB sector (2.3 percent). Since CBO arrives at about the same medium-term GDP growth rate as we do, the implication is that they foresee more rapid growth of hours.

**Alternative Population Paths**

The Census Bureau prepares high and low estimates of future population, in addition to the middle series utilized in our baseline projection. Table 3 compares solutions of our model for the three variants. Since the growth decompositions of productivity and capital deepening for the three variants are similar to those shown for the baseline, the table reports growth rates only for F.E. output, productivity and hours and the decomposition of hours growth.

For the low population variant, non-institutional population grows 0.21 percentage points more slowly in the first decade and 0.27 more slowly in the second decade, compared to the baseline (middle variant). This translates into somewhat larger differences in F.E. hours (0.28 and 0.35 for the first and second decades, respectively) largely because of slower growth of NFB relative to total employment. F.E. productivity growth is about the same as in the baseline, and so the lower growth rates of F.E. output are almost wholly due to lower growth of labor supply. For the high population variant, non-institutional population growth is 0.29 percentage points higher in the first decade and 0.38 higher in the second. The increases in F.E. hours are larger (0.37 and 0.52, respectively), because of more rapid growth in the ratio of NFB to total employment and smaller reductions in labor force participation. F.E. productivity growth is only very slightly higher than in the baseline, and so the difference in hours growth is the reason for higher growth of F.E. output. Even for the high population estimates, the growth rate of F.E. hours in 2001-2010 is 0.15-0.25 percentage points below that in past decades; in 2011-2020, it falls even further short of prior decades by 0.66-0.76 percentage points.

**Higher Technical Progress**

The baseline projection maintains technical progress at the rate of 1.10 percent observed in 1997-99. This rate is not extraordinarily high compared to prior decades and, in fact, falls well short of the rate of 2.05 percent recorded in 1961-69. How would potential growth differ if we added, say, 0.5 percentage point to rate of technical progress beginning in 2001? The answer is that F.E. productivity growth will be higher by about 0.67 percentage points. This result can be obtained analytically, as well as by model simulation, and is consistent with the standard neoclassical growth model with a constant-returns, Cobb-
Douglas production function.

The relationship between productivity growth and technical progress in the standard model and in our own can be derived as follows. Both models begin with the same production function, equation (2) above. Neglecting distinctions between desired or expected and actual variables, denoting logarithmic time derivatives of variables with corresponding lower-case letters, and dropping time subscripts, the production function implies:

\[ x = a + \alpha k + (1 - \alpha)(i + h), \]  

The standard model assumes a constant saving rate and therefore requires a constant capital-output ratio for steady growth, i.e., \( k = x \). Assuming that \( a, i \) and \( h \) are constants, the steady state growth of productivity is:

\[ x - h = \frac{a}{1 - \alpha} + i, \]  

Our model does not specify a constant saving rate but instead imposes the expansion-path condition on the capital-labor ratio, as in equation (3), which allows us to identify explicitly the relative-price determinants of capital deepening. Using the definition of \( Q \) in equation (10) and the markup pricing assumption in equation (16), with \( M \) denoting the markup, equation (3) can be written as:

\[ K \frac{H}{H} = \frac{\alpha}{1 - \alpha} \frac{1}{M} \frac{X}{H} \frac{PX}{PI(r + \delta)TX}, \]  

which implies, assuming constant \( M \):

\[ k = x - p - d - tx, \]  

where \( p \) is the growth rate of \( PI/PX \), \( d \) is the growth rate of \( r+\delta \) and \( tx \) is the growth rate of \( TX \).

Substituting from (28) into (25), and assuming \( a, p, d, tx, i \) and \( h \) are constant, our model generates steady growth of productivity at:

\[ x - h = \frac{a}{1 - \alpha} + \frac{\alpha}{1 - \alpha}(-p - d - tx) + i. \]  

If \( p \) and \( d \) are negative and \( tx \) is zero, as in our baseline projection, the productivity growth rate exceeds the value expected in the standard model (26) for given \( a \) and \( i \); thus, Hicks-neutral technical progress at a rate of 1.10 translates into steady state productivity growth at a rate of 2.29 in our baseline (2.25 after allowing for Labor Adj, as shown in Table 2). However, if we assume a higher value of technical progress than in the baseline, but maintain all other baseline assumptions, we see from (29) that the increase in productivity growth, relative to the baseline, is simply \( \Delta a/(1-\alpha) \), as in the standard model.15

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15 In the Cobb-Douglas case, Hicks-neutral progress at rate \( a \) is equivalent to Harrod-neutral progress at rate \( a/(1-\alpha) \), so that the simulation result could equally well be described as a shock to Harrod-neutral progress of 0.67 percentage points inducing an equal increase in productivity growth, as in the standard non-parametric growth model. Our use of Hicks-neutral progress allows for the incorporation of the Solow residual as an empirical measure of technical progress and for direct comparison with the growth-
In the neo-classical growth model, both F.E. productivity and F.E. output would rise by $\Delta a/(1-\alpha)$, since labor supply growth is exogenous and constant. However, in our model with endogenous labor supply, faster growth of F.E. productivity is partially offset by slower growth of F.E. labor supply, owing to declining labor force participation caused by faster growth of real wages.

Finally, we call attention to the fact that the determinants of labor productivity growth (equation 29) are held constant or nearly constant (see p. 13) in the baseline projection in Table 2, so that it is reasonable to interpret the results for F.E. productivity growth in the NFB sector (a growth rate of about 2.25 percent) as a steady-state value for the entire period.

**SUMMARY AND CONCLUSIONS**

Our historical analysis indicates that the productivity surge observed in the NFB sector during the second half of the 1990’s was largely a cyclical phenomenon as the economy caught up to its potential path, with actual productivity growth increasing 1.02 percentage points and F.E. productivity growth only 9 basis points from the first half of the expansion.

Even though potential productivity growth did not accelerate much in the second half of the 1990’s, growth of potential output did, owing to a 0.5 percentage point rise in labor supply growth. Because the recovery in the early nineties started from a low level of output utilization, and because potential growth accelerated moderately in 1996-2000, the expansion ended with output only slightly above potential, for both real GDP and NFB output. The experience differed markedly during the long expansions of the 1960’s and 1980’s, when output rose to levels 3 to 4 percent above potential. The close balance between actual and potential output in the mature stage of the expansion of 1991-2000 is consistent, of course, with the modest level of inflation of the period.

Our baseline projection for 2001-2010 embodies an average annual growth rate of F.E. productivity of 2.27 percent in the NFB sector, with little change in the subsequent decade. By way of comparison, actual average productivity growth for the sector was 1.51 percent in 1991-1995 and 2.53 in 1996-2000. Thus the F.E. projection is 26 basis points lower than the growth rate of measured productivity during the late nineties, but 16 basis points higher than our estimate of 2.11 percent for F.E. productivity growth for the same period. It is also 25 basis points above the average rate of productivity growth of 2.02 percent during 1961-2000, and 21 basis points above the corresponding average of 2.06 for F.E. productivity growth. Overall we regard it as a rather optimistic forecast.

While our outlook for F.E. productivity growth over the next two decades is reasonably bright, we foresee reductions in the growth rates of F.E. output for both the NFB sector and total GDP, due to reduced rates of labor supply growth that are below those experienced in any decade since 1960. Growth of F.E. GDP along our baseline averages 2.99 in 2001-2010 and 2.50 percent in 2011-2020, compared to 3.65 percent in 1996-2000 and 3.42 percent for the entire period, 1961-2000. Our GDP projection is similar to CBO’s latest forecast of about 3 percent growth for the years out to 2012, but our estimate appears to rest on higher productivity growth and lower growth of hours than theirs.

accounting approach to the measurement of total- or multi-factor productivity.
Our projection is, of course, conditional on assumptions about the projected exogenous variables. These assumptions, however, are explicit and quantitative, and their underpinnings are provided in the model specification and the sample-period analysis. It is worth reviewing some of the key points underlying the model solution.

First, because the goal is to project a sustainable F.E. growth path, it is necessary to specify a F.E. unemployment rate compatible with continuing low inflation. We have adopted the TV-NAIRU approach of Staiger, Stock and Watson (2001) that is based on a HP trend through actual unemployment rates and verified by those authors as possessing NAIRU properties. Apart from demographic shifts, which we have incorporated in our modified version, the movements of our estimated NAIRU depend on the change in the prime-age unemployment rate. We have held the latter constant at its level in 2000, for want of any basis for assuming an upward or downward trend thereafter.

Second, we have held the trend rate of technical progress in the baseline at its average during 1997-1999 of 1.10 percent. This is well below the average Solow residual during the same years (1.69 percent), but a trend estimate is the right concept for estimating the long-run tendency of TFP.

Third, capital deepening made a contribution to F.E. productivity growth during 1991-2000 second only to that of 1961-1969, and it increased from an average contribution of 70 basis points in 1991-1995 to 88 in 1996-2000. A decline in the relative price of investment goods (PI/PX) contributed 19 basis points to the acceleration in deepening, more than accounting for the overall increase of 18 points. The decline in PI/PX began in the early eighties and is due in large part to the introduction of hedonic price indexes for semiconductors and computers in the national product accounts. Rapid increases in the speed and efficiency of computers – mostly attributable to faster semiconductors – are reflected in quality adjustments that reduce the PI index. Moore’s Law - that the number of transistors that can be placed on a computer chip doubles every 18 months – has recently been amended to shorten the interval to 12 months. Hence semiconductor technology is expected to continue to evolve at a rapid pace. While it is uncertain that the rate of adoption of new information technology equipment will continue to be as responsive to price reductions as in recent years, our baseline projection incorporates continued substantial reductions in the relative price of investment goods.

With regard to the alternative scenarios, those for demographic change indicate that F.E. GDP growth would average 0.39 percentage points higher over 2001-2020 if population follows the Census’s high rather than its middle projection; the rate would be 0.27 lower if population follows Census’s low projection. The projections for F.E. productivity are almost the same for the three alternative population paths. The higher and lower population paths translate into faster and slower growth in employment and hours, with correspondingly higher or lower growth of F.E. output.

If the rate of technical progress and the growth rates of the labor composition index and the determinants of capital deepening are held constant, our model has a unique steady-state growth path for labor productivity. A sustained increase in the assumed rate of technical progress results in a larger increase in F.E. productivity growth in the model, equal to that in the standard neoclassical model.
REFERENCES


FIGURE 1. LABOR FORCE SHARE OF WORKERS AGED 16-24, 1960-2000
FIGURE 2. UNEMPLOYMENT RATES, 1960-2000

2A. AGGREGATE UNEMPLOYMENT AND HP TREND

2B. AGGREGATE AND NATURAL UNEMPLOYMENT

3A. TECHNICAL PROGRESS

3B. SOLOW RESIDUAL
FIGURE 4. ALTERNATIVE MEASURES OF TECHNICAL PROGRESS, GROWTH RATES, 1952-1999

SOLOW RESIDUAL  ----  MULTIFACTOR PRODUCTIVITY
FIGURE 5. ACTUAL AND POTENTIAL OUTPUT MEASURES, 1960-2000

NONFARM BUSINESS

BILLIONS OF CHAINED 1996 DOLLARS

REAL GDP

BILLIONS OF CHAINED 1996 DOLLARS

NFB OUTPUT GAP

PERCENT

GDP OUTPUT GAP

PERCENT
FIGURE 6. OUTPUT AND UNEMPLOYMENT GAPS, 1960-2000

REAL GDP GAP

UNEMPLOYMENT GAP
Table 1. Analytical Decompositions, 1961-2000
Average Annual Growth Rates (Percent)

A. Actual Output, Productivity, and Hours

<table>
<thead>
<tr>
<th>Period</th>
<th>Output</th>
<th>Prod</th>
<th>Hours</th>
<th>GDP</th>
<th>Prod</th>
<th>Hours</th>
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<tr>
<td>1961-1969</td>
<td>4.81</td>
<td>2.98</td>
<td>1.83</td>
<td>4.52</td>
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<td>1970-1981</td>
<td>3.07</td>
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<td>1.39</td>
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<td>1982-1990</td>
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<td>1991-2000</td>
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<td>1.62</td>
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<td>1991-1995</td>
<td>2.68</td>
<td>1.51</td>
<td>1.16</td>
<td>2.35</td>
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<td>1996-2000</td>
<td>4.61</td>
<td>2.53</td>
<td>2.08</td>
<td>4.02</td>
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<td>1.52</td>
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B. F.E. Output, Productivity, and Hours

<table>
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<td>4.70</td>
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<td>1970-1981</td>
<td>3.29</td>
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<td>1982-1990</td>
<td>2.95</td>
<td>1.28</td>
<td>1.67</td>
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<td>1991-2000</td>
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<td>1.77</td>
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<td>3.54</td>
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C. Decomposition of F.E. Hours, Nonfarm Business

<table>
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<th>Period</th>
<th>NFB Hours</th>
<th>Average Emp Rate</th>
<th>F.E. Hours/ Tot Emp Rate</th>
<th>Part Rate</th>
<th>Nonins Rate</th>
<th>Emp Rate</th>
<th>Pop Rate</th>
<th>Emp Rate</th>
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<tr>
<td>1961-1969</td>
<td>1.67</td>
<td>-0.39</td>
<td>0.28</td>
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<td>1970-1981</td>
<td>1.65</td>
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<td>0.01</td>
<td>-0.24</td>
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<td>1.97</td>
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<td>1.67</td>
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<td>0.05</td>
<td>0.08</td>
<td>0.42</td>
<td>1.18</td>
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<td>0.35</td>
<td>0.25</td>
<td>0.10</td>
<td>1.03</td>
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<tr>
<td>1991-1995</td>
<td>1.52</td>
<td>0.06</td>
<td>0.17</td>
<td>0.22</td>
<td>0.09</td>
<td>0.97</td>
<td>1.46</td>
<td>1.29</td>
</tr>
<tr>
<td>1996-2000</td>
<td>2.02</td>
<td>0.00</td>
<td>0.54</td>
<td>0.27</td>
<td>0.12</td>
<td>1.09</td>
<td>2.02</td>
<td>1.48</td>
</tr>
</tbody>
</table>

D. Decomposition of F.E. Productivity, Nonfarm Business

<table>
<thead>
<tr>
<th>Period</th>
<th>F.E. Prod</th>
<th>Cap Deep</th>
<th>Tech Prog</th>
<th>Labor Comp</th>
<th>Adj Resid</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961-1969</td>
<td>3.39</td>
<td>1.17</td>
<td>2.05</td>
<td>0.16</td>
<td>0.05</td>
</tr>
<tr>
<td>1970-1981</td>
<td>1.64</td>
<td>0.50</td>
<td>1.16</td>
<td>0.07</td>
<td>0.04</td>
</tr>
<tr>
<td>1982-1990</td>
<td>1.28</td>
<td>0.51</td>
<td>0.79</td>
<td>0.35</td>
<td>-0.14</td>
</tr>
<tr>
<td>1991-2000</td>
<td>2.07</td>
<td>0.79</td>
<td>1.03</td>
<td>0.41</td>
<td>0.10</td>
</tr>
<tr>
<td>1991-1995</td>
<td>2.02</td>
<td>0.70</td>
<td>0.97</td>
<td>0.49</td>
<td>0.34</td>
</tr>
<tr>
<td>1996-2000</td>
<td>2.11</td>
<td>0.88</td>
<td>1.10</td>
<td>0.33</td>
<td>-0.14</td>
</tr>
</tbody>
</table>

E. Decomposition of F.E. Capital Deepening, Nonfarm Business

<table>
<thead>
<tr>
<th>Period</th>
<th>Cap Deep</th>
<th>Disc+ Depr</th>
<th>Tax Depr</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961-1969</td>
<td>1.17</td>
<td>-0.07</td>
<td>0.24</td>
</tr>
<tr>
<td>1970-1981</td>
<td>0.50</td>
<td>-0.07</td>
<td>-0.05</td>
</tr>
<tr>
<td>1982-1990</td>
<td>0.51</td>
<td>-0.13</td>
<td>-0.06</td>
</tr>
<tr>
<td>1991-2000</td>
<td>0.79</td>
<td>-0.16</td>
<td>-0.04</td>
</tr>
<tr>
<td>1991-1995</td>
<td>0.70</td>
<td>-0.07</td>
<td>-0.08</td>
</tr>
<tr>
<td>1996-2000</td>
<td>0.88</td>
<td>-0.25</td>
<td>0.00</td>
</tr>
</tbody>
</table>
## Table 2. Baseline Projection, 2001-2020
### Average Annual Growth Rates (percent)

<table>
<thead>
<tr>
<th></th>
<th>F.E. Output</th>
<th>F.E. Productivity</th>
<th>F.E. Hours</th>
<th>GDP Growth</th>
<th>F.E. Productivity</th>
<th>F.E. Hours</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Nonfarm Business</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Period</strong></td>
<td><strong>Output</strong></td>
<td><strong>Prod</strong></td>
<td><strong>Hours</strong></td>
<td><strong>GDP</strong></td>
<td><strong>Prod</strong></td>
<td><strong>Hours</strong></td>
</tr>
<tr>
<td>1996-2000</td>
<td>4.12</td>
<td>2.11</td>
<td>2.02</td>
<td>3.65</td>
<td>2.16</td>
<td>1.49</td>
</tr>
<tr>
<td>2001-2010</td>
<td>3.41</td>
<td>2.27</td>
<td>1.15</td>
<td>2.99</td>
<td>2.08</td>
<td>0.91</td>
</tr>
<tr>
<td>2011-2020</td>
<td>2.74</td>
<td>2.25</td>
<td>0.49</td>
<td>2.50</td>
<td>2.11</td>
<td>0.39</td>
</tr>
</tbody>
</table>

### B. Decomposition of F.E. Hours, Nonfarm Business

<table>
<thead>
<tr>
<th></th>
<th>NFB Ave Hours</th>
<th>NFB/ Emp Rate</th>
<th>Nonins Rate</th>
<th>NFB Total Emp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period</strong></td>
<td><strong>Hours</strong></td>
<td><strong>Tot Emp</strong></td>
<td><strong>Pop Emp</strong></td>
<td><strong>Emp</strong></td>
</tr>
<tr>
<td>1996-2000</td>
<td>2.02</td>
<td>0.00</td>
<td>0.54</td>
<td>0.27</td>
</tr>
<tr>
<td>2001-2010</td>
<td>1.15</td>
<td>-0.16</td>
<td>0.24</td>
<td>-0.01</td>
</tr>
<tr>
<td>2011-2020</td>
<td>0.49</td>
<td>-0.10</td>
<td>0.10</td>
<td>0.01</td>
</tr>
</tbody>
</table>

### C. Decomposition of F.E. Productivity, Nonfarm Business

<table>
<thead>
<tr>
<th></th>
<th>F.E. Prod Deep</th>
<th>Cap Deep</th>
<th>Tech Prog</th>
<th>Labor Comp</th>
<th>Labor Adj</th>
<th>Labor Resid</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period</strong></td>
<td><strong>Deep</strong></td>
<td><strong>Prog</strong></td>
<td><strong>Comp</strong></td>
<td><strong>Adj</strong></td>
<td><strong>Resid</strong></td>
<td></td>
</tr>
<tr>
<td>1996-2000</td>
<td>2.11</td>
<td>0.88</td>
<td>1.10</td>
<td>0.33</td>
<td>-0.14</td>
<td>-0.06</td>
</tr>
<tr>
<td>2001-2010</td>
<td>2.27</td>
<td>0.88</td>
<td>1.10</td>
<td>0.29</td>
<td>0.00</td>
<td>0.00</td>
</tr>
<tr>
<td>2011-2020</td>
<td>2.25</td>
<td>0.88</td>
<td>1.10</td>
<td>0.29</td>
<td>-0.03</td>
<td>0.00</td>
</tr>
</tbody>
</table>

### D. Decomposition of Capital Deepening, Nonfarm Business

<table>
<thead>
<tr>
<th></th>
<th>Cap Deep</th>
<th>W/PX</th>
<th>PX/PI</th>
<th>Disc+ Depr</th>
<th>Tax Comp</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Period</strong></td>
<td><strong>Deep</strong></td>
<td><strong>W/PX</strong></td>
<td><strong>PX/PI</strong></td>
<td><strong>Depr</strong></td>
<td><strong>Comp</strong></td>
</tr>
<tr>
<td>1996-2000</td>
<td>0.88</td>
<td>0.49</td>
<td>0.63</td>
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<td>0.00</td>
</tr>
<tr>
<td>2001-2010</td>
<td>0.88</td>
<td>0.57</td>
<td>0.44</td>
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<td>0.00</td>
</tr>
<tr>
<td>2011-2020</td>
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<td>0.56</td>
<td>0.44</td>
<td>-0.12</td>
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</tr>
</tbody>
</table>
Table 3. Full-Employment Projections for Alternative Population Paths, 2001-2020
Average Annual Growth Rates (percent)

A. Low Population Path

<table>
<thead>
<tr>
<th>Period</th>
<th>Nonfarm Business</th>
<th>Total Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F.E.</td>
<td>F.E.</td>
</tr>
<tr>
<td></td>
<td>Output</td>
<td>Prod</td>
</tr>
<tr>
<td>2001-2010</td>
<td>3.12</td>
<td>2.25</td>
</tr>
<tr>
<td>2011-2020</td>
<td>2.39</td>
<td>2.24</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>NFB Ave NFB/ Emp Part Nonins NFB Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours Hours Tot Emp Rate Rate Pop Emp Emp</td>
</tr>
<tr>
<td>2001-2010</td>
<td>0.87 -0.16 0.19 -0.01 0.02 0.83 1.03 0.84</td>
</tr>
<tr>
<td>2011-2020</td>
<td>0.14 -0.11 0.04 0.01 -0.31 0.52 0.25 0.21</td>
</tr>
</tbody>
</table>

B. Middle Population Path

<table>
<thead>
<tr>
<th>Period</th>
<th>Nonfarm Business</th>
<th>Total Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F.E.</td>
<td>F.E.</td>
</tr>
<tr>
<td></td>
<td>Output</td>
<td>Prod</td>
</tr>
<tr>
<td>2001-2010</td>
<td>3.41</td>
<td>2.27</td>
</tr>
<tr>
<td>2011-2020</td>
<td>2.74</td>
<td>2.25</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>NFB Ave NFB/ Emp Part Nonins NFB Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours Hours Tot Emp Rate Rate Pop Emp Emp</td>
</tr>
<tr>
<td>2001-2010</td>
<td>1.15 -0.16 0.24 -0.01 0.04 1.04 1.30 1.07</td>
</tr>
<tr>
<td>2011-2020</td>
<td>0.49 -0.10 0.10 0.01 -0.29 0.79 0.60 0.50</td>
</tr>
</tbody>
</table>

C. High Population Path

<table>
<thead>
<tr>
<th>Period</th>
<th>Nonfarm Business</th>
<th>Total Economy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>F.E.</td>
<td>F.E.</td>
</tr>
<tr>
<td></td>
<td>Output</td>
<td>Prod</td>
</tr>
<tr>
<td>2001-2010</td>
<td>3.81</td>
<td>2.29</td>
</tr>
<tr>
<td>2011-2020</td>
<td>3.27</td>
<td>2.26</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Period</th>
<th>NFB Ave NFB/ Emp Part Nonins NFB Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Hours Hours Tot Emp Rate Rate Pop Emp Emp</td>
</tr>
<tr>
<td>2001-2010</td>
<td>1.52 -0.16 0.30 -0.01 0.06 1.33 1.68 1.38</td>
</tr>
<tr>
<td>2011-2020</td>
<td>1.01 -0.10 0.18 0.01 -0.24 1.17 1.11 0.94</td>
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</table>