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BAUMOL'S DISEASES: A MACROECONOMIC PERSPECTIVE

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ABSTRACT

William Baumol and his co-authors have analyzed the impact of differential productivity growth on the health of different sectors and on the overall economy. They argued that technologically stagnant sectors experience above average cost and price increases, take a rising share of national output, and slow aggregate productivity growth. Using industry data for the period 1948-2001, the present study investigates Baumol's diseases for the overall economy. It finds that technologically stagnant sectors clearly have rising relative prices and declining relative real outputs. Additionally, technologically progressive sectors tend to have slower hours and employment growth outside of manufacturing. Finally, sectoral shifts have tended to lower overall productivity growth as the share of stagnant sectors has risen over the second half of the twentieth century.

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In a series of pioneering works, William Baumol and his co-authors have analyzed the impact of differential productivity growth on the health of different sectors and on the overall economy.[3] They hypothesize that sectors whose productivity-growth rates are below the economy's average (call them stagnant) will tend to experience above average cost increases. The resulting "cost disease" may lead stagnant sectors to experience above-average price increases, declining quality, and financial pressures. Additionally, there may be a reduction in the economy's overall rate of productivity and real output growth because of the drag from stagnant sectors. This work suggests that a taste for the output of stagnant sectors may lead to secular stagnation and declining real-income growth as consumers increasingly demand labor-intensive services where productivity growth is intrinsically limited.

Baumol et al. applied these ideas to several sectors, including higher education, cities, health care and hospitals, the performing arts, handicrafts, *haute cuisine*, custom clothing, and stately houses. The studies provoked a flood of criticisms and analysis on industrial

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[3] William J. Baumol and William G. Bowen, "On the Performing Arts: The Anatomy of their Economic Problems." *The American Economic Review,* Vol. 55, No. 2, 1965, pp. 495-502; William J. Baumol and William G. Bowen, *Performing Arts: The Economic Dilemma*, New York: The Twentieth Century Fund, 1966; William J. Baumol, "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," The American Economic Review, Vol. 57, No. 3, June, 1967, pp. 419-420; William J. Baumol, Sue Anne Batey Blackman, and Edward N. Wolff, "Unbalanced Growth Revisited: Asymptotic Stagnancy and New Evidence," *The American Economic Review*, Vol. 75, No. 4., Sept, 1985, pp. 806-817.

productivity studies, but at the end of the day, it remains difficult to determine the net result.[4]

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[4] Peter S. Albin, "Poverty, Education, and Unbalanced Economic Growth," The *Quarterly Journal of Economics*, Vol. 84, No. 1, Feb., 1970, , pp. 70-84; Carolyn Shaw Bell, "Macroeconomics of Unbalanced Growth: Comment (in Communications)," *The American Economic Review*, Vol. 58, No. 4, Sept., 1968, pp. 877-884; Albert Breton, "The Growth of Competitive Governments," *The Canadian Journal of Economics,* Vol. 22, No. 4, Nov., 1989, pp. 717-750; Cristina Echevarria, "Agricultural Development vs. Industrialization: Effects of Trade," *The Canadian Journal of Economics*, Vol. 28, No. 3, Aug., 1995, pp. 631-647; Cristina Echevarria, "Changes in Sectoral Composition Associated with Economic Growth," *International Economic Review*, Vol. 38, No. 2, May, 1997, pp. 431-452; Norman Gemmell, "A Model of Unbalanced Growth: The Market versus the Non-Market Sector of the Economy," *Oxford Economic Papers*, Vol. 39, No. 2, June, 1987, pp. 253-267; Charles R. Hulten, "Productivity Change in State and Local Governments," *The Review of Economics and Statistics*, Vol. 66, No. 2, May, 1984, pp. 256-266; William D. Nordhaus, "The Recent Productivity Slowdown," *Brookings Papers on Economic Activity*, 3:1972, pp. 493-536; Joan Robinson, "Macroeconomics of Unbalanced Growth: A Belated Comment (in Communications)," *The American Economic Review*, Vol. 59, No. 4., Sept., 1969, p. 632; David Throsby, "The Production and Consumption of the Arts: A View of Cultural Economics," *Journal of Economic Literature*, Vol. 32, No. 1, Mar., 1994, pp. 1-29; Jack E. Triplett and Barry P. Bosworth, " 'Baumol's Disease' Has Been Cured," *Federal Reserve Bank of New York Economic Policy Review*, September 2003, pp. 23-33; Edward N. Wolff, "Industrial Composition, Interindustry Effects, and the U.S. Productivity Slowdown," *The Review of Economics and Statistics*, Vol. 67, No. 2, May, 1985, pp. 268-277; Michael C. Wolfson, "New Goods and the Measurement of Real Economic Growth," *The Canadian Journal of Economics*, Vol. 32, No. 2, Special

The purpose of this study is to analyze various Baumol-type diseases using detailed data on economic activity by industry. This reevaluation is motivated by the availability of more comprehensive data on output, prices, and productivity by industry as well as by improved approaches to measuring price and output indexes. The discussion proceeds in five sections. The first section describes briefly the different Baumol-related diseases that will be examined. The second section lays out an analytical framework for examining Baumol's diseases, while the following section describes the data used for the analysis. The fourth section applies the theory and data to examine the impact of differential productivity growth by sector on the structure of industry and examines the impact of the cost disease on the economy's overall rate of productivity. The final section summarizes the results.

I. Variants of Baumol Diseases

There are several syndromes that might arise from differential rates of productivity growth. Here are some important ones:

1. *Cost and price disease.* We would generally expect that average costs and prices in stagnant industries – ones with relatively low productivity growth – would grow relative to the average.

Issue on Service Sector Productivity and the Productivity Paradox, Apr., 1999, pp. 447-470.

2. *Stagnating real output.* Additionally, because of the rapid rise in relative prices, we would expect that real output in low-productivity-growth industries would grow slowly relative to the overall economy.

3. *Unbalanced growth.* The impact of low productivity growth on nominal shares is ambiguous because it depends on the interaction of rising relative prices and declining relative outputs. Baumol sometimes assumed that demand would be price-inelastic, so low productivity growth would generally lead to rising shares of nominal output in stagnant industries.

4. *Impact on employment and hours.* The impact of low productivity growth on labor inputs will depend on the impact on output as well as on the structure of production. Generally, those industries with price-elastic demand for output will experience a positive impact of productivity growth on employment, and contrariwise for industries with price-inelastic demand.

5. *Impact on factor rewards.* An important question concerns who captures the gains from higher productivity growth, and who loses from stagnant productivity. In their 1965 article, Bowen and Baumol argued that stagnant industries such as the performing arts were likely to be financially stressed because of rising costs and prices. What are the facts?

6. *Impact on aggregate productivity growth.* Will stagnant industries have rising shares of total output? If so, will this tend to reduce overall growth in productivity and living standards? This important question

will depend upon the composition of output and is an intriguing question raised by the earlier studies.

II. Analytical Framework for Baumol's Cost Disease

Most of the early studies of the various Baumol hypotheses used either a stylized two-sector analysis or Laspeyres output indexes or both. This section examines the interpretation of the propositions for many sectors and in the context of current superlative measures of output.

Assume that the economy is composed of a large number of non-durable final goods and services. The notation used for different variables is shown in the accompanying box. The general notation is that upper-case roman letters represent levels, lower-case roman letters represent natural logarithms, and Greek letters represent parameters or random terms. We define the logarithmic growth rate of a variable as a lower-case roman letter with a circumflex; therefore, $\hat{a}_t = a_t - a_{t-1} = \Delta ln(A_t)$ is the growth rate of productivity.

We can write a simplified production, cost, supply and demand structure as follows. Each industry has a Cobb-Douglas value-added production function in capital, labor, and time-varying exogenous technology.[5] The derivation here uses the growth rates of variables in

[5] An alternative approach would be to use total output rather than value added. This approach has been used, for example, in Dale W. Jorgenson, Mun Ho, and Kevin J. Stiroh, "Growth of U.S. Industries and Investments in Information Technology and Higher Education" in Carol Corrado, John

the production and demand functions to be consistent with superlative output measurement. The exposition assumes that all industries are vertically integrated. The error term is interpreted as production shocks (such as measurement errors) that do not enter into costs.

(1) Production: $\hat{x}_{it} = \hat{a}_{it} + \beta_{it}\hat{m}_{it} + (1 - \beta_{it})\hat{k}_{it} + \varepsilon_{it}^{x}$

Under the assumption of cost minimization, the unit cost function is the dual of (1). It excludes the error in (1) but includes random cost errors. Note that by duality, the production and cost elasticities in (1) and (2) are identical.

(2) Cost: $\hat{z}_{it} = -\hat{a}_{it} + \beta_{it}\hat{w}_{it} + (1 - \beta_{it})\hat{c}_{it} + \varepsilon_{it}^{z^*}$

Pricing is assumed to be a markup over cost. In this specification, marginal and average costs are equal, so no ambiguity arises with respect to which cost is involved in pricing. The price function may include monopolistic elements as well as random elements and drift.

(3) Price: $\hat{p}_{it} = \gamma_i + \theta_i\hat{z}_{it} + \varepsilon_{it}^{p}$

Haltiwanger, and Daniel Sichel, eds., *Measuring Capital in the New Economy*, University of Chicago Press, Chicago, 2005. The relative merits of value-added output and total output are discussed below.

Industrial variables for industry i in period t::
A_{it} = productivity (either total factor or labor)
B_{it} = index of inputs (either total or labor)
C_{it}= cost per unit capital services
K_{it} = capital inputs
M_{it} = labor inputs
P_{it} = price
R_{it} = rate of profit on capital
S_{it} = share of nominal output
V_{it} = share of total inputs
W_{it} = cost per unit labor
X_{it} = real output
Z_{it} = unit cost of output

Aggregate variables for period t:
A_t = aggregate productivity
B_t = index of aggregate inputs
P_t = aggregate price index
X_t = aggregate real output
Q_t = aggregate nominal output

Natural logarithms of variables:
$a_{it} = ln(A_{it})$
$x_t = ln(X_t)$
etc.

Parameters and random errors:
$\alpha, \beta, \gamma, \lambda, \mu, \theta, \chi, \sigma$ = parameters of functions or equations
η_i = own-price demand elasticity in demand system
ε_t^k = random error for variable k in period t

Logarithmic rate of growth between period t-1 and t:
$\hat{a}_t = a_t - a_{t-1} = \Delta ln(A_t)$ = rate of growth of productivity
$\hat{x}_t = x_t - x_{t-1} = \Delta ln(X_t)$ = rate of growth of aggregate real output
etc.

The factor shares are determined by the income identity:

(4) Income $$Q_{it} \equiv P_{it} X_{it} \equiv R_{it} K_{it} + W_{it} M_{it}$$

Note that the rate of profit on capital (R_{it}) includes not only the cost per unit capital input in (2) but also any returns to market power, innovation, risk-bearing, and other non-labor returns.

Consumer demand for output from the different sectors is a variant of the almost ideal demand system, in which expenditure shares are determined by relative prices and total income.[6] In the version used here, we simplify by assuming that all cross-elasticities of demand are proportional to output shares; we further have prices and total output determine the logarithm of the shares. Working in the rates of growth, and solving for real output growth, we then write the simplified almost ideal demand system (SAIDS) as:

(5) $$\hat{x}_{it} = \lambda_i + \eta_i (\hat{p}_{it} - \hat{p}_t) + \mu_i \hat{x}_t + \varepsilon_{it}^s$$

In this equation, η_i is the own price-elasticity of demand for industry i as a function of the price of that good relative to the aggregate price index. The logarithmic changes in the aggregate price and output are Törnqvist indexes, $\hat{p}_t = \sum_{i=1}^{n} \hat{p}_{it} S_{it}$ and $\hat{x}_t = \sum_{i=1}^{n} \hat{x}_{it} S_{it}$, where S_{it} are the Törnqvist shares of nominal output. We have for notational convenience

[6] See Angus Deaton and John Muellbauer, "An Almost Ideal Demand System," *American Economic Review,* vol. 70, no. 3, June 1980, pp. 312-326.

dated the shares concurrently with the growth rates, whereas in the actual calculations for Törnqvist indexes, shares are averages of current and last period shares. Equation (5) has the disadvantage of imposing share proportionality on the cross price elasticities for each good. This is unlikely to have an important practical effect in the current context because the cross effects are omitted from the empirical estimates; in any case, with this large a set of industries, examining the full set of cross effects is effectively impossible.

Econometric Issues in the Specification

The econometric interpretation of the different Baumol laws is as reduced-form equations. More specifically, they are reduced-form equations in which the various endogenous variables (price, nominal output, real output, wages, and profits) are determined primarily by exogenous technological change. This section examines the reduced-form equations and explains the conditions under which the impacts of productivity on the major variables are identified and consistent.

I will discuss this strategy only for one of the reduced-form equations, the output equation, while the others are discussed in the *Accompanying Note*. Estimates of the growth of real output from equation (5) require substituting the determinants of industrial price. To do this, I make the following assumptions: that changes in TFP by industry are independent of shocks to other variables; that unit input costs in different industries move independently of other variables; and that prices are a constant markup over unit costs. The average response will depend upon the statistical average price elasticity, defined as

$\overline{\eta} = E(\eta_i)$, where $\eta_i = \overline{\eta} + \varepsilon_i^{\eta}$. I then solve for real output as a function of TFP growth and shocks, obtaining:[7]

(6) $\hat{x}_{it} = -\overline{\eta}\hat{a}_{it}^{*} + \varepsilon_i^{x1} + \varepsilon_{it}^{x2}$

where

$$\varepsilon_i^{x1} = \lambda_i + \eta_i \gamma_i$$

$$\varepsilon_{it}^{x2} = \eta_i \hat{z}_t + \eta_i \hat{a}_t - \varepsilon_i^{\eta} \hat{a}_{it} - \varepsilon_i^{\eta} \varepsilon_{it}^{a} + \eta_i \varepsilon_{it}^{z} + \eta_i \varepsilon_{it}^{a} + \eta_i \varepsilon_{it}^{p} - \eta_i \hat{p}_t + \mu_i \hat{x}_t + \varepsilon_{it}^{s}$$

In this equation, the average real output response depends upon TFP growth, the average price elasticity of demand ($\overline{\eta}$), as well as shocks from the different equations. Equation (6) will yield accurate estimates of the impact of TFP on real output growth as long as the error ($\varepsilon_{it}^{x1} + \varepsilon_i^{x2}$) is uncorrelated with measured TFP growth. The major concern is measurement error in price deflators, which would bias both TFP growth and real output growth. There are numerous other potential contaminants, but most of the covariances between $\hat{a}_{it}^{*}$ and $\varepsilon_{it}^{x1} + \varepsilon_i^{x2}$ are presumptively zero.[8]

The impacts of technological change on factor rewards are straightforward in a world of competitive factor prices. To be more realistic, we would need to take into account that there are monopolistic elements in factor markets – particularly important are labor unions, monopoly power, and Schumpeterian profits. Statistical tests of the

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[7] The detailed derivation of the equation is shown in *Accompanying Notes* at the end of this paper.

[8] The errors are discussed in detail in *Accompanying Notes* at the end of this paper.

impact of technological change on factor rewards are unbiased as long as there are constant returns to scale and if the feedback from factor prices to technological change (say through induced technological change) is unimportant. These are not likely to be completely accurate in reality, but it seems likely that the major technological trends are determined by other factors than differential factor rewards.

A final statistical question concerns the impact of the business cycle on productivity. This is likely to be a concern for short-period movements. However, we have taken sufficiently long periods (from a decade to a half-century) that cyclical influences are unlikely to be a major determinant of differential trends.

III. Data and Methods

The data used here are a complete set of industry accounts for the period 1948-2001. Most of the data are from the Industry Accounts prepared by the Bureau of Economic Analysis, while some also come from the National Income and Product Accounts. These cover 67 detailed industries and include data on real and nominal value-added output, industry value-added prices, compensation, hours worked, the net capital stock, and profit-type income. Most of these data come directly from the BEA, but data on real output and prices for 1948-76 were derived from earlier BEA data. These data allow construction of indexes of both labor productivity and total factor productivity. The major advantage of this data set is that it is constructed in a consistent manner and (except for the statistical discrepancy and inevitable data inaccuracies) the sectors aggregate to the national aggregates. This data set was used to analyze the productivity slowdown in a companion paper.[9] Unfortunately, because of major changes in industrial classification, the most recent industry data are completely incompatible with the older data used here.[10]

Our approach for testing for each of the Baumol syndromes relies on a variety of sample periods, industry groups, and estimation procedures. The battery of tests used is the following:

- These use three different industry combinations: (1) All 67 detailed industry groups. (2) 14 broad industry groups. (3) 28 industry groups that have relatively well measured output. The exact list of industries for each group is provided in Appendix A.

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[9] William Nordhaus with Alexandra Miltner, "A Retrospective on the Postwar Productivity Slowdown," NBER Working Paper No. 10950, December 2004. That paper includes an appendix describing construction of the data set, and the data are available online.

[10] BEA has recently published estimates of output for the new industrial classification system (the North American Industry Classification System or NAICS) with historical data back to 1947 (see Robert E. Yuskavage and Mahnaz Fahim-Nader, "Gross Domestic Product by Industry for 1947–86: New Estimates Based on the North American Industry Classification System," *Survey of Current Business*, December 2005, pp. 70-84). However, BEA has not yet made the corresponding input data for labor and capital available.

- There are four different sample periods for the estimation. (1) Four subperiods (1948-59, 1959-73, 1973-89, 1989-2001), where the data are estimated in first differences and with industry own effects and time effects. These years are chosen because they are convenient break points in terms of length and quality of data and business cycle position. (2) The same sample as (1), but with the estimates in levels, with industry and time effects. (3) The entire sample, 1948-2001, as a cross section. (4) The period 1977-2000 as a cross section; this later sample is useful because the data for these years are constructed on a consistent basis by the BEA and are probably of better quality than the earlier years; additionally, the end points are roughly comparable in terms of cyclical position.

Two different measures of productivity are examined: (1) Total factor productivity for sectors where capital stocks are available. Output is measured as value added and inputs are the weighted growth of labor and capital inputs. (2) Labor productivity, which is the growth in chained output less the growth in hours.

The current study relies on value-added data for its results. Because many other studies rely upon gross output data, some of the major differences should be discussed. The first question involves the use of value-added output rather than total output in the demand equations. Because people buy cars and hats, not the value added of the automotive or apparel industries, the estimates may miss some of the features of the structure of commodity output.

Additionally, some analysts argue that the total output data are more accurate than the value-added output for use in productivity studies. Some of the early criticisms of value-added output production estimates have been resolved with improved double-deflation procedures and the use of superlative techniques at all stages of data-set construction.[11] Studies indicate that the hypothesis of value-added production functions can be rejected in the sectoral data,[12] but those studies have not been updated to the current techniques. Moreover, estimating the growth of value added (rather than its level), as is the current method used by the BEA, does not require the same separability assumptions in the superlative value-added data as was required in the prior concepts.

The major advantage of using value added output is that it allows us to identify in a more intuitive way the sources of major technological changes. Most important technological advances occur in the value-

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[11] See Moyer, Brian C., Mark A. Planting, Paul V. Kern, and Abigail Kish, "Improved Annual Industry Accounts for 1998-2003," *Survey of Current Business*, vol. 84, June 2004, pp. 21-57 and Brian C. Moyer, Marshall B. Reinsdorf, and Robert E. Yuskavage, "Aggregation Issues in Integrating and Accelerating BEA's Accounts: Improved Methods for Calculating GDP by Industry," in Dale W. Jorgenson, J. Steven Landefeld and William D. Nordhaus, Eds., *A New Architecture for the U.S. National Accounts*, The University of Chicago Press, Chicago, IL, forthcoming, 2006.

[12] See Dale W. Jorgenson, Frank W. Gollop, and Barbara M. Fraumeni, *Productivity and U.S. Economic Growth*, Harvard University Press, Cambridge, MA, 1987

added industries measured in this industry. For example, the rapid productivity growth in electricity production occurred primarily in the generation segment, not in the fuel component. Similarly, it is more instructive to look at the computer and microelectronics sector than to the final output of computers including cardboard boxes and retail and wholesale trade. Accurate measures of all outputs and inputs in principle allow analysts to untangle the sectoral contributions, but if the measures of inputs are inaccurate, the industrial source of the productivity growth can easily be misidentified.

A further qualification arises because our measures are industry output rather than commodity output – for example, the output of the chemical industries rather than the output of pharmaceuticals. For most industries, the difference is small but this difference nonetheless clouds the interpretation of the results. A related issue in all domestic productivity studies is the omission of international trade. These data omit the forces of relative price changes between domestic and foreign goods; this is likely to be a major issue primarily for tradable goods like agriculture and manufacturing.

IV. Results

We now investigate six diseases that might be associated with Baumol's analyses.

1. Does low productivity growth lead to a cost and price disease?

The first question is whether low relative productivity growth leads to high relative price increases. This syndrome is sometimes called "the cost disease of the stagnant services." This was the key contention in many of Baumol's studies. A summary of the point is the following:[13]

> If productivity per man hour rises cumulatively in one sector relative to its rate of growth elsewhere in the economy, while wages rise commensurately in all areas, then relative costs in the nonprogressive sectors must inevitably rise, and these costs will rise cumulatively and without limit…. Thus, the very progress of the technologically progressive sectors inevitably adds to the costs of the technologically unchanging sectors of the economy, unless somehow the labor markets in these areas can be sealed off and wages held absolutely constant, a most unlikely possibility.

A succinct statement was made in Baumol, Blackman, and Wolff:[14]

> With the passage of time, the cost per unit of a consistently stagnant product (for example, live concerts) will rise monotonically and without limit relative to the cost of a consistently progressive product (for example, watches and clocks).

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[13] William J. Baumol, "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," The American Economic Review, Vol. 57, No. 3, June, 1967, pp. 419-420.

[14] Op. cit., p. 806.

From an economic point of view, it would be surprising if lower productivity growth was not substantially passed on to consumers in higher prices. But this tendency might be mitigated if price behavior is sufficiently uncompetitive or if demand shifts dominate supply shifts.

Figure 1 shows a scatter plot of the total factor productivity and price trends over the 1948-2001 period. The negative association is clear. Table 1 shows the battery of tests for price trends. The industries in each segment are listed in Appendix A, while details on the estimation are provided in Appendix B. In each case, we report the coefficient of a regression of the variable listed (average annual logarithmic change in price in this case) on a measure of the annual logarithmic change in productivity.

These tests show that productivity trends are associated almost percentage-point for percentage-point with price declines. The most pertinent results here are for the well-measured industries; the summary coefficient is -0.965. This coefficient is well determined and is not significantly different from one.

The results here are very powerful. They indicate that the major determinant of long-term relative price trends is relative productivity trends. The main notable feature is that consumers capture virtually all the gains from technological change.

Summary diagnosis 1. **The hypothesis of a cost-price disease due to slow productivity growth is strongly supported by the historical data. Industries with relatively lower productivity growth show a**

percentage-point for percentage-point higher growth in relative prices.

2. Does Low Productivity Growth Lead to Stagnating Real Output?

The next question is whether relatively slow productivity growth leads to relatively slow real output growth. This would seems an obvious point but in fact is not. If differential output growth is driven primarily by demand shifts rather than supply shifts, it would be possible that there would be little association between productivity growth and output growth. Baumol states the hypothesis as follows:[15]

> In the model of unbalanced productivity there is a tendency for the outputs of the "nonprogressive" sector whose demands are not highly inelastic to decline and perhaps, ultimately, to vanish....
>
> We see then that costs in many sectors of the economy will rise relentlessly, and will do so for reasons that are for all practical purposes beyond the control of those involved. The consequence is that the outputs of these sectors may in some cases tend to be driven from the market.

The relationship between productivity growth and real output growth was investigated in detail in an earlier section. That section

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[15] William J. Baumol, "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," The American Economic Review, Vol. 57, No. 3, June, 1967, pp. 418, 420.

showed that, under ideal circumstances, the cross section coefficient of real output growth on TFP growth would be (the negative of) the average elasticity of demand in the SAIDS system.

Figure 2 shows the growth of real output and in total factor productivity (TFP) over the 1948-2001 period. There is a clear positive relationship between TFP growth and output growth. Table 2 shows the formal tests of the relationship between real output and productivity growth. Looking across the different specifications, there is a very strong positive association between productivity growth and real output growth. Every single specification has a statistically significant positive coefficient. The summary coefficients – measuring the elasticity of real output with respect to productivity – are between 0.67 and 0.76, and the coefficients are well determined. For the well-measured industries, the relationship is very tight, with a one percentage-point faster productivity growth leading to a 0.76 percentage-point higher growth in real output.

Among industries with well-measured output, the five industries with declining real output over the period, starting from the bottom, are Tobacco products, Local and interurban passenger transit, Personal households, Leather and leather products, and Miscellaneous repair services. Each of these has a tale to tell. Tobacco, local transit, and miscellaneous repair service had negative measured TFP growth over the 1948-2001 period. Tobacco was probably driven to distraction by regulation, and there are no reliable measures of productivity for private households.

Looking at the five industries with the most rapidly rising real output over the 1948-2001 period, starting from the top, we have Transportation by air, Electronic and other electric equipment, Telephone and telegraph, Trucking and warehousing, and Wholesale trade. All five had very dynamic technologies, and all five had high TFP growth over the period.

Summary diagnosis **2. The real output/stagnation hypothesis is strongly confirmed. Technologically stagnant industries have shown slower growth in real output than have the technologically dynamic ones. A one percentage-point higher productivity growth was associated with a three-quarters percentage-point higher real output growth.**

3. Do Industries With Slow Productivity Growth Have Declining Nominal Output Shares?

For the most part, businesses care very little about their real output growth. They care about dollar sales, profits, and employment. What are those relationships? Baumol recognized that there were different possible cases:[16]

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[16] William J. Baumol, "Macroeconomics of Unbalanced Growth: Comment (in Communications)," *The American Economic Review*, Vol. 58, No. 4, Sept, 1968, pp. 897.

> Having predicted a cumulative cost rise for the output of the "nonprogressive sector" of the economy I did not intend to go further and attempt a generalized forecast of the activities that compose it. I meant to suggest a variety of possibilities: that some, like the construction of stately homes, would tend to disappear; that others, such as very fine restaurants, would be reduced to a small number catering almost exclusively to the very affluent; that some, like handmade furniture and pottery, would fall into the hands of amateur craftsmen; and that some, such as education (at least up to this point) would continue to be demanded but would, as a consequence, eat up an ever-growing portion of GNP. I do not believe that any one type of time path will characterize the behavior of every output of the nonprogressive sector in the future any more than it has until now.

In later work, Baumol, Blackman, and Wolff sharpened the view, focusing primarily on services:[17]

> The "rising share of services" turns out to be somewhat illusory. The [real] output shares of the progressive and stagnant sectors have in fact remained fairly constant in the postwar period, so that with rising relative prices, the share of total expenditures on the (stagnant) services and their share of the labor force have risen dramatically (their prices rose at about the same rate as their productivity lagged behind the progressive sectors), just as the model suggests. Similar trends are also found internationally.

[17] Op. cit., p. 815-816.

In fact, the first part of the second quotation – asserting the constancy of real output shares – is incorrect for chained output indexes, as we showed for syndrome 2 above.

What are the analytical presumptions here? The relationship is closely related to the derivation of equation (6) above.[18] Under the assumptions in that section, the coefficient fn TFP growth on nominal output growth will be $-(1+\overline{\eta})$, where $\overline{\eta}$ is the average SAIDS own-price elasticity of demand. Indeed, as long as the independent variables are identical, the coefficients on nominal output should be identical to the sum of the coefficients on price and real output. There are in fact very small deviations from that identity, presumably because the price indexes are not always equal to the deflators.

Figure 3 shows a graph, while Table 3 shows the summary results of the different specifications of the relationship between TFP growth and nominal output growth. The summary statistics show a coefficient in the range of -0.21 to -0.28. For the well-measured industries, the standard error puts the estimated coefficients close to the 10 percent significance level. This result is consistent with the finding in the last section that the statistical average price-elasticity of demand for industry output is around -0.7.

Looking at those industries with slow nominal growth over the 1948-2001 period, the bottom five (starting from the bottom) were Leather and leather products, Railroad transportation, Farms, Coal

[18] See *Accompanying Notes* at the end of this paper.

mining, and Textile mill products. All of these had quite robust productivity growth. Their decline was probably driven largely by income effects, substitute products, or competition from abroad, but the rapid growth in productivity and decline in prices was insufficient to offset other influences.

The most rapid growth in nominal GDP was found in Social services, Business services, Radio and television, Transportation by air, and Health services. With the exception of air, these had low measured TFP growth, although there are serious questions about measurement in most cases.

Summary diagnosis 3: There is a negative association of productivity growth with the growth in nominal output. In other words, stagnant industries tend to take a rising share of nominal output; however, the relationship is only marginally statistically significant.

4. Do Industries With Slow Productivity Growth Have Declining Relative Employment and Hours?

Perhaps the most interesting question from a social perspective is whether stagnant industries are gaining or losing shares of labor inputs – either employment or hours. Baumol, Blackman, and Wolff concluded that the stagnant service sector was demanding an increasing share of labor inputs:[19]

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[19] Op. cit., p. 806.

As the model predicts, the U.S. labor force has been absorbed predominantly by the stagnant subsector of the services rather than the services as a whole.

The analysis of the impact of productivity on labor inputs is similar to that of nominal share of output, with the resulting impact ambiguous. The reduced-form estimates of the impact of total factor productivity changes on employment are derived from those on output but have one additional complication involving the derived demand for labor inputs. Assume that firms in an industry are identical and minimize costs. Further assume that the wages in each industry are exogenous (determined by market power, unions, and other factors). From the earlier analysis, we can derive the following reduced-form equation for the growth of labor inputs:[20]

$$(7) \qquad \hat{m}_{it} = -(1+\overline{\eta})\hat{a}^{*}_{it} - \hat{w}_{it} + \hat{\beta}_{it} + \varepsilon^{m}_{it}$$

where

$$\varepsilon^{m}_{it} = \hat{z}_{t} + \hat{a}_{t} + \varepsilon^{z}_{it} + \varepsilon^{a}_{it} + \varepsilon^{x1}_{i} + \varepsilon^{x2}_{it} + \varepsilon^{e}_{it} - \varepsilon^{\eta}_{i}(\hat{a}_{it} + \varepsilon^{a}_{it})$$

The major new twist here is the variable $\hat{\beta}_{it}$, the rate of change of the elasticity of output with respect to labor. This represents biased technological change in the Cobb-Douglas framework. The errors here were defined above except for ε^{e}_{it}, which is the error in the equation for demand for labor inputs.

[20] See the *Accompanying Notes* at the end of this paper.

Equation (7) shows that the coefficient on TFP growth in the employment equation is $-(1+\overline{\eta})$, which is minus (one plus the average price-elasticity of demand). This indicates that (holding other forces constant) the growth of labor inputs such as employment or hours will be positively or negatively affected by technological change depending upon whether output demand is price-elastic or price-inelastic, respectively. The trend will also be affected to the extent that there is differential wage growth in the industry, or if there is biased technological change (represented by the rate of growth of the output elasticity, $\hat{\beta}_{it}$).

Figure 4 shows the association of hours growth and TFP growth. The negative association – similar to that for nominal output and TFP growth – is evident. Table 4 shows the battery of tests run on hours, which indicates a negative association of hours and productivity. The results are particularly strong for the 1977-2000 period for which the data are most reliable; also, they are uniformly negative for the well-measured industries. The average effect for well-measured industries shows that a 1 percentage-point higher productivity growth is associated with a 0.26 percentage-point lower growth in hours worked. The results for employment are virtually identical, with the coefficients and t-statistics very close to those for hours.

These results are consistent with those for nominal and real output. They suggest that the most important factor driving differential employment growth has been differential technological change across industries. We can also test for the impacts of differential wage growth and biased technological change by including the growth of wages and the change in the share of compensation in the equations. For this purpose, I concentrate only on the results for TFP growth for the detailed industry groups. Adding either or both of wage growth or the rate of growth of the labor share does not change the coefficient on total factor productivity. It is interesting to note that the coefficient on biased technological change is insignificant and very small. This result suggests that, at least in these data, differential technological change was not important in the relative demand for employment across different sectors.

Differing Results for Manufacturing

One interesting extension of findings should be mentioned. The results for manufacturing differ from those for the overall economy. A careful examination of the impact of differential productivity growth on employment and hours for detailed manufacturing industries finds a positive rather than a negative relationship between productivity growth and hours worked.[21] The difference between manufacturing and other industries probably arises because the openness of manufacturing leads to more price-elastic demand for domestic production and therefore to a positive relationship between productivity growth on the one hand and nominal output and hours growth on the other hand. Further research is needed in this area, but the difference between

[21] William D. Nordhaus, "The Sources of the Productivity Rebound and the Manufacturing Employment Puzzle," NBER Working Paper No. 11354, May 2005.

manufacturing and the entire economy suggests the importance of openness to the productivity-employment relationship.

Summary diagnosis 4: **Industries with more rapid productivity growth tend to displace labor and show lower growth of hours and employment. However, this relationship appears to be reversed within manufacturing industries, which show higher growth of labor inputs with higher productivity growth.**

5. Who Captures the Gains From Innovation?

A central question of economic growth concerns the distribution of the fruits of productivity growth. Who captures the gains from innovation, and who suffers losses from stagnation? The results on pricing for syndrome 1 suggest that most of the gains are captured by consumers in the form of lower prices. Are there any residual rewards to either capital or labor? In their studies on the performing arts, Bowen and Baumol argued that the low earnings and stressed financial status in such industries were due to the stagnant productivity performance.[22]

Productivity and wages

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[22] William J. Baumol and William G. Bowen, "On the Performing Arts: The Anatomy of their Economic Problems." *The American Economic Review,* Vol. 55, No. 2, 1965, pp. 495-502. Baumol has written to me that he has changed his view of the relationship between low wages and stagnant productivity sectors since the 1965 article was written and does not believe that stagnant sectors necessarily show low wages (personal communication, October 28, 2004).

The general picture for wages is shown in Figure 5, which indicates little relationship between productivity growth and wage growth. Table 5 shows a battery of tests of the impact of relative productivity growth on relative wages. Higher productivity growth has a small positive impact on wage relative growth with an inconsistent sign. For well-measured industries, the sign is slightly positive. However, for all industries in the cross-section (shown in Figure 5), the sign is negative, reflecting some strange outliers at the upper left. These outliers are tobacco and several service industries, where output is probably poorly measured.

In any case, the relative importance of productivity on differential wages is very small. For example, the unweighted average effect across different specifications is a 0.017 percent increase in wages per percent increase in productivity. If we take the 0.017 coefficient and apply it to the differences in productivity growth across industries, it would yield a maximum wage differential of about 8 percent for the entire 1948-2001 period between the best and worst performer. This predicted impact compares with the range of differential wage growth of 132 percent. This result suggests that the low wages in the performing arts and other stagnant sectors are due to factors other than productivity stagnation, the most likely being a combination of compensating variations and a winner-take-all incentive structure.

Productivity and profits

Estimating the impact on profit-type income presents greater difficulties because of the poor data on depreciation and imprecision in allocation of profits to industries. In a companion paper, I examined the impact of technological change on "Schumpeterian profits" using both aggregate data as well as the data used in this study.[23] I estimated that innovators were able to capture about 4 percent of the total social surplus from innovation. This number results from a low rate of initial appropriability (estimated to be around 10 percent) along with a high rate of depreciation of Schumpeterian profits (judged to be around 20 percent per year). In terms of the rate of profit on capital, the rate of profit on the replacement cost of capital over the 1948-2001 period is estimated to be 0.27 percent per year.

Summary diagnosis 5: The differential impact of higher productivity growth on factor rewards is extremely small. While the impacts are statistically insignificant, there is a suggestion that higher productivity growth leads to slightly higher wage and profit growth, but at least 95 percent of productivity growth is passed on to consumers in lower prices.

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[23] William D. Nordhaus, "Schumpeterian Profits in the American Economy: Theory and Measurement," NBER Working Paper No. 10433, April 2004.

6. Has the economy suffered from a growth disease?

A final and intriguing question is the impact of the changing composition of output on overall productivity growth – a syndrome we denote "Baumol's growth disease." Baumol's growth disease occurs when stagnant sectors (those with relatively slow productivity growth) also have rising nominal output shares. The point can be seen by comparing people with different tastes. Person A's tastes run to computers, software, and consumer electronics, while person B's tend toward New York real estate, Picasso paintings, and three-star Parisian restaurants. Because person A's consumption is tilted toward items whose prices are falling rather than rising rapidly, A's real income will be experiencing a rapid increase relative to B's real income associated with Upper East Side tastes. Baumol's discussion of this tendency was the following:[24]

> An attempt to achieve balanced growth in a world of unbalanced productivity must lead to a declining rate of growth relative to the rate of growth of the labor force. In particular, if productivity in one sector and the total labor force remain constant the growth rate of the economy will asymptotically approach zero.

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[24] William J. Baumol, "Macroeconomics of Unbalanced Growth: The Anatomy of Urban Crisis," *The American Economic Review*, Vol. 57, No. 3, June, 1967, pp. 419. Baumol commented that did not intend to say that the productivity disease would slow growth; he views the disease as a cost disease, not a growth disease (personal communication, October 28, 2004).

Analytics of the growth disease

The macroeconomics of the growth disease can be seen by examining the growth of real output. Using the Törnqvist formula, real output growth is equal to the weighted growth of output in different sectors, where the weights are nominal shares of output. If stagnant sectors have rising nominal output shares, then the aggregate growth rate will be reduced as the share of output moves toward the slow productivity-growth sectors.

This tendency can be seen by decomposing aggregate productivity growth.[25] Define $\hat{a}_t$ as aggregate productivity growth and $\hat{b}_t$ as the growth of aggregate inputs. The one-period growth rate of TFP is:

(8) $$\hat{a}_t = \hat{x}_t - \hat{b}_t = \sum_{i=1}^{n} \hat{x}_{it}\, S_{it} \; - \; \sum_{i=1}^{n} \hat{b}_{it}\, V_{it}$$

[25] This derivation relies on value-added superlative production relationships. An alternative approach is used in Kevin Stiroh, "Information Technology and U.S. Productivity Revival: What Do the Industry Data Say?" *American Economic Review,* vol. 92, no. 5, pp. 1559-76. The decomposition for total output is found in Dale W. Jorgenson, Frank W. Gollop, and Barbara M. Fraumeni, *Productivity and U.S. Economic Growth*, Harvard University Press, Cambridge, MA, 1987. One advantage of the decomposition used here is that the redistribution effects are much smaller than those using total output and Domar weights.

Here, $V_{it} = B_{it} / \left(\sum_{j=1}^{n} B_{jt} \right)$ = the Törnqvist share of inputs of industry i in the total. Add and subtract $\sum_{i=1}^{n} \hat{b}_{it} S_{it}$ to (6) and reorganize:

$$(9) \qquad \hat{a}_t = \sum_{i=1}^{n} \hat{a}_{it} S_{it} + \sum_{i=1}^{n} \hat{b}_{it} (S_{it} - V_{it})$$

The two terms on the right-hand side of (9) are a pure productivity term and a redistribution effect. The pure productivity term measures the aggregate growth rate as the weighted sum of industrial growth rates. The second term in (9) captures effects due to the interaction of changing shares and the difference between the input share and the nominal output share of an industry. For total factor productivity with superlative output indexes, the redistribution term is zero as long as output equals income; but this term may be non-zero for labor productivity or if the output index is a Laspeyres index.[26]

[26] An interesting off-stage actor in this drama concerns the output indexes. Baumol, Blackman, and Wolff and Wolff analyzed the effects of industry composition on aggregate productivity using fixed-year-weights for output indexes (or Laspeyres indexes). (See William J. Baumol, Sue Anne Batey Blackman, and Edward N. Wolff, "Unbalanced Growth Revisited: Asymptotic Stagnancy and New Evidence," *The American Economic Review*, Vol. 75, No. 4., Sept, 1985, pp. 806-817.; and Edward N. Wolff, "Industrial Composition, Interindustry Effects, and the U.S. Productivity Slowdown," *The Review of Economics and Statistics*, Vol. 67, No. 2, May, 1985, pp. 268-277.) To interpret their results, we would need to add a third term to equation (9) – which might be called the "fixed-weight drift term" – to represent the difference between the growth rates of chain-weighted output and the growth of fixed-year-

To measure the Baumol growth effect, we estimate the growth rate using nominal output shares for a given year, T, and denote the results as the "fixed-shares growth rate" or "FSGR(T)":

$$\text{(10)} \qquad \text{FSGR(T)} = \sum_{i=1}^{n} \hat{a}_{it} \, S_{iT}$$

By comparing the FSGR(T) for different base years, we can determine the impact of changing output shares on the growth of productivity. If the FSGR is lower for later T, then the Baumol growth effect is negative, indicating that shares are moving in a manner that is unfavorable to growth. If the FSGR is higher for later T, then the Baumol growth effect is positive.

Results

Figure 6 and Table 6 show the FSGR for aggregate total factor productivity, and Figure 7 shows the results for aggregate labor productivity. To get a flavor of the results, examine the last line in Table 6. This shows the aggregate rate of growth of total factor productivity for 1948-2001 where the industries are weighted with nominal output shares for five different years. If we use fixed shares for 1948, the average rate of TFP growth would be 1.49 percent per year, whereas if

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weighted output. The fixed-weight drift term exited the stage when old-style Laspeyres indexes were replaced by superlative indexes, and it will not feature in the discussion here.

we use late shares (2001), TFP growth would average 0.85 percent per year. This indicates that the composition of output reduced output growth by 64 basis points per year over the 1948-2001 period, or slightly more than 1 basis point per year.

Comparing Figures 6 and 7, we see that the Baumol growth effect tended to reduce productivity growth for both productivity concepts and for all periods except but one. In other words, the composition of output definitely tended to shift toward those industries with lower productivity growth. The size of the effect comparing 2001 weights and 1948 weights varied from 27 basis points to 89 basis points depending upon productivity concept and period. A summary estimate is that the changing composition of output decreased overall annual productivity growth by slightly more than ½ percentage point over the last half century.

The results on Baumol's growth disease are consistent with the output patterns and the implicit demand price-elasticities found in earlier sections. Because demand is on average price-inelastic, stagnant industries have experienced rising nominal output shares. As nominal output shares increased in those industries, overall weighted productivity growth slowed.

Summary diagnosis 6: Trends in the composition of output have been unfavorable to overall total factor productivity and labor productivity. The changing shares over the 1948-2001 period had the effect of lowering productivity growth by slightly more than ½

percentage point per year, indicating that Baumol's growth disease was an important factor during this period.

V. Conclusions

The present study has investigated a series of hypotheses concerning the effects of productivity change on economic growth, prices, and factor rewards. Before summarizing, two reservations must be noted. First, the results presented here rely upon data on value-added prices, output, and productivity by industry, such as entertainment and textiles. These data are not completely adequate for questions concerning final goods and services such as concerts or clothing. For most cases, they are close but imperfect substitutes for the ideal data.

Second, the data are sometimes poorly measured estimates of true output and therefore cannot correctly calculate true prices or the correct numerator for productivity. This shortcoming is particularly serious in services such as health, education, and personal services, for which the output measures are in reality measures of inputs. We have dealt with measurement issues by taking different slices of the data, such as examining data for different periods or for subsets of industries that are well-measured, but we cannot wholly overcome the mismeasurement difficulties.

Subject to these reservations, the results here speak clearly on many of the hypotheses put forth by Baumol and his co-authors. The data are particularly useful because they are a comprehensive account of the market economy of the United States for more than a half-century. Here are the major results.

First, Baumol's hypothesis of a cost-price disease due to slow productivity growth is definitely confirmed by the data. Industries with relatively low productivity growth ("stagnant industries") show a percentage-point for percentage-point higher growth in relative prices. This result indicates that most of the economic gains from higher productivity growth are passed on to consumers in lower prices. Moreover, differences in productivity over the long term of a half-century explain around 85 percent of the variance in relative price movements for well-measured industries. While the underlying forces driving technological change remain a challenge, the impacts of differential technological change on prices stand out clearly.

Second, the real output stagnation hypothesis is strongly confirmed. Industries that are technologically stagnant tend to have slower growth in real output than do the technologically dynamic ones, with a one percentage-point lower productivity growth being associated with a three-quarters percentage-point lower real output growth. Moreover, the statistical association of output growth and productivity growth is highly significant. The mechanism by which productivity affects output is clearly through the price mechanism of the cost-price disease.

Third, beyond the price and real output effects, the associations become murkier. One interesting question is how higher industrial productivity growth affects jobs. Industries with higher productivity growth generally had declining employment and hours growth when all industries are considered. However, this relationship was reversed for internationally open manufacturing sectors.

Fourth, the differential impact of higher productivity growth on factor rewards is extremely small. There is a suggestion that higher industrial productivity growth leads to slightly higher industrial wage growth and to higher profits, but the fraction of productivity retained as higher factor rewards is very small. For the most part, industrial wage and profit trends are determined by the aggregate economy and not by the productivity experience of individual sectors.

Perhaps the most important macroeconomic result is the operation of Baumol's growth disease over the last half of the twentieth century. The hypothesis underlying the growth disease is that – because the composition of output has shifted away from industries with rapid productivity growth like manufacturing toward those with stagnant technologies like government, education, and construction – aggregate productivity growth has slowed. There has indeed been a tendency for changes in spending shares to slow economic growth. The growth disease has lowered annual aggregate productivity growth by slightly more than one-half percentage point over the last half century.

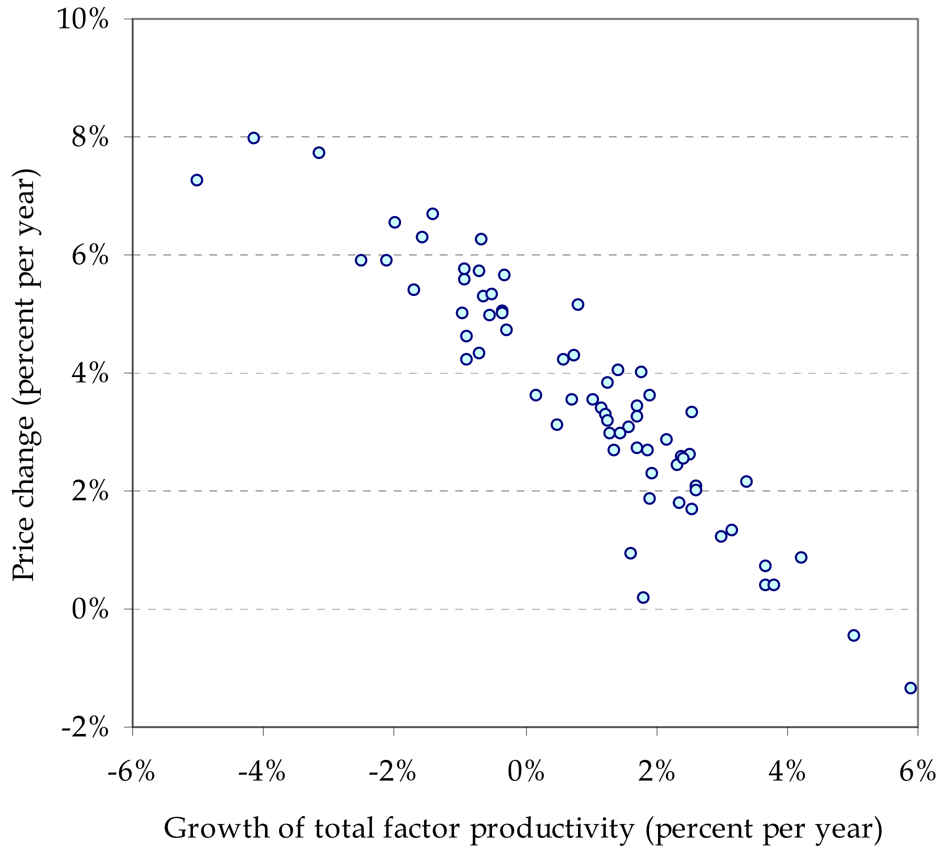

Figure 1. Price and Total Factor Productivity Trend from 1948 to 2001

Figures 1 through 6 show the annual logarithmic rate of change of variables, generally total factor productivity and an associated variable, for 58 industries.

	Coefficient	Standard error	t-statistics	Observ-ations
28 well-measured industries				
Total factor productivity				
4 subperiod, difference	-1.232	0.153	-8.06	84
4 subperiod level	-0.887	0.079	-11.17	112
1977-2000 cross section	-0.972	0.070	-13.90	28
1948-2001 cross section	-0.968	0.088	-11.03	28
28 well-measured industries				
Labor productivity				
4 subperiod, difference	-1.100	0.154	-7.14	84
4 subperiod level	-0.800	0.079	-10.09	112
1977-2000 cross section	-0.872	0.065	-13.39	28
1948-2001 cross section	-0.891	0.065	-13.68	28
14 major industries				
Total factor productivity				
4 subperiod, difference	-1.184	0.256	-4.63	36
4 subperiod level	-0.816	0.177	-4.61	48
1977-2000 cross section	-1.157	0.133	-8.68	12
1948-2001 cross section	-0.975	0.218	-4.46	12
14 major industries				
Labor productivity				
4 subperiod, difference	-1.073	0.277	-3.87	42
4 subperiod level	-0.731	0.135	-5.42	56
1977-2000 cross section	-1.000	0.145	-6.90	14
1948-2001 cross section	-0.921	0.097	-9.52	14
59 detailed industries				
Total factor productivity				
4 subperiod, difference	-0.539	0.087	-6.22	164
4 subperiod level	-0.734	0.052	-13.99	223
1977-2000 cross section	-1.008	0.041	-24.54	56
1948-2001 cross section	-0.904	0.051	-17.62	57
67 detailed industries				
Labor productivity				
4 subperiod, difference	-1.016	0.109	-9.31	183
4 subperiod level	-0.885	0.076	-11.64	251
1977-2000 cross section	-1.021	0.052	-19.52	62
1948-2001 cross section	-0.931	0.040	-23.22	63
Summary statistics				
All regressions				
Weighted	-0.956	0.129	-7.38	
Unweighted	-0.942	0.167	-5.66	
Well-measured industries				
Unweighted	-0.965	0.131	-7.38	

Table 1. Impact of Productivity Growth on Price Change

(For a discussion of the specification and variables, see Appendix B.)

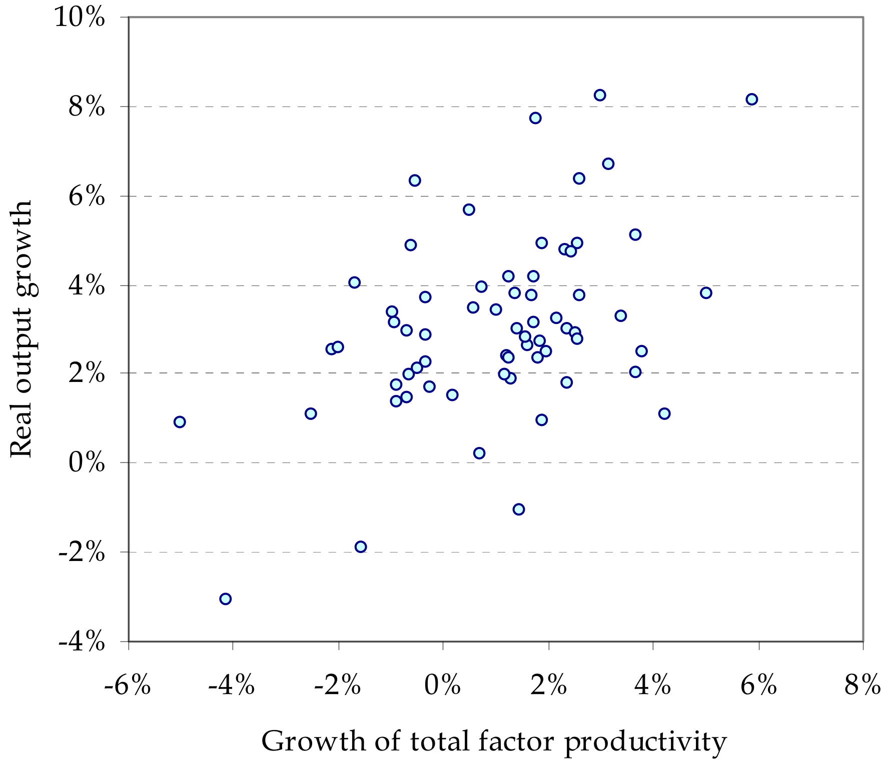

Figure 2. TFP Growth and Real Output Growth, 1948-2001

(annual average percent per year)

	Coefficient	Standard error	t-statistics
28 well-measured industries			
Total factor productivity			
4 subperiod, difference	0.783	0.145	5.40
4 subperiod level	0.946	0.083	11.42
1977-2000 cross section	0.737	0.157	4.69
1948-2001 cross section	0.803	0.269	2.98
28 well-measured industries			
Labor productivity			
4 subperiod, difference	0.629	0.147	4.27
4 subperiod level	0.805	0.089	9.04
1977-2000 cross section	0.650	0.144	4.51
1948-2001 cross section	0.716	0.240	2.98
14 major industries			
Total factor productivity			
4 subperiod, difference	0.706	0.112	6.32
4 subperiod level	0.924	0.110	8.38
1977-2000 cross section	0.638	0.272	2.35
1948-2001 cross section	0.599	0.332	1.80
14 major industries			
Labor productivity			
4 subperiod, difference	0.610	0.136	4.49
4 subperiod level	0.549	0.116	4.74
1977-2000 cross section	0.682	0.231	2.95
1948-2001 cross section	0.673	0.167	4.02
59 detailed industries			
Total factor productivity			
4 subperiod, difference	0.313	0.061	5.11
4 subperiod level	0.513	0.050	10.32
1977-2000 cross section	0.662	0.093	7.13
1948-2001 cross section	0.475	0.118	4.02
67 detailed industries			
Labor productivity			
4 subperiod, difference	0.773	0.069	11.25
4 subperiod level	0.852	0.055	15.43
1977-2000 cross section	0.630	0.101	6.26
1948-2001 cross section	0.409	0.122	3.35
Summary statistics			
All regressions			
Weighted	0.670	0.160	4.20
Unweighted	0.670	0.162	4.12
Well-measured industries			
Unweighted	0.759	0.094	8.07

Table 2. Impact of Productivity Growth on Real Output Growth

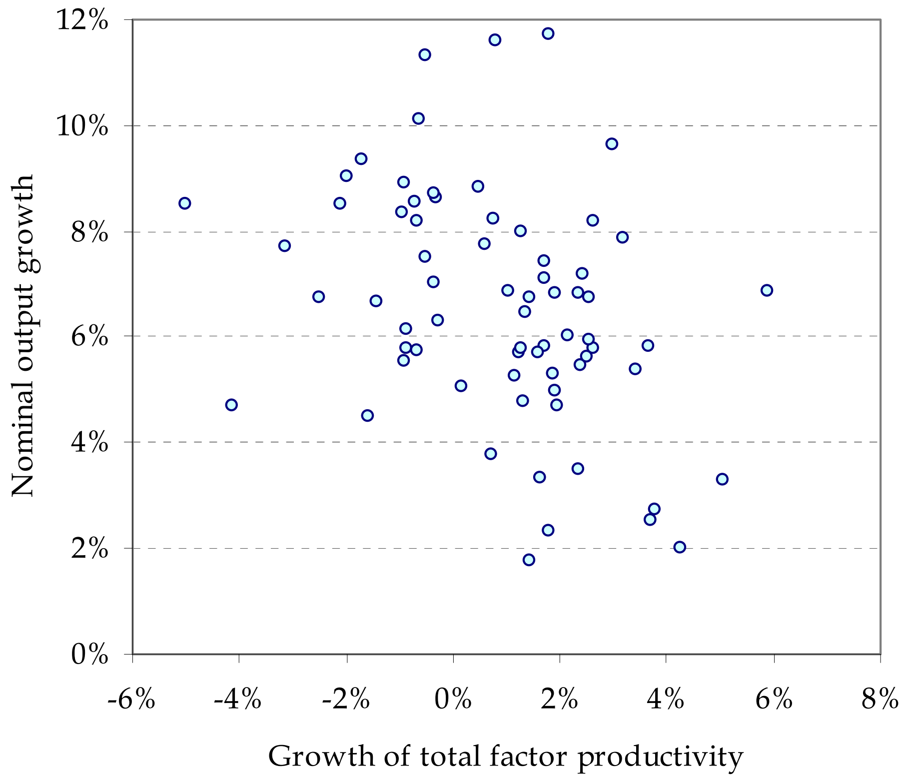

Figure 3. Growth of TFP and nominal output, 1948-2001 (annual average percent per year)

	Coefficient	Standard error	t-statistics
Summary statistics			
All regressions			
Weighted	-0.276	0.198	-1.39
Unweighted	-0.272	0.195	-1.40
Well-measured industries			
Unweighted	-0.206	0.176	-1.18

Table 3. Impact of productivity growth on nominal output growth

Note: the coefficients of nominal output growth are very close to the sum of the coefficients of price plus real output growth (see text)

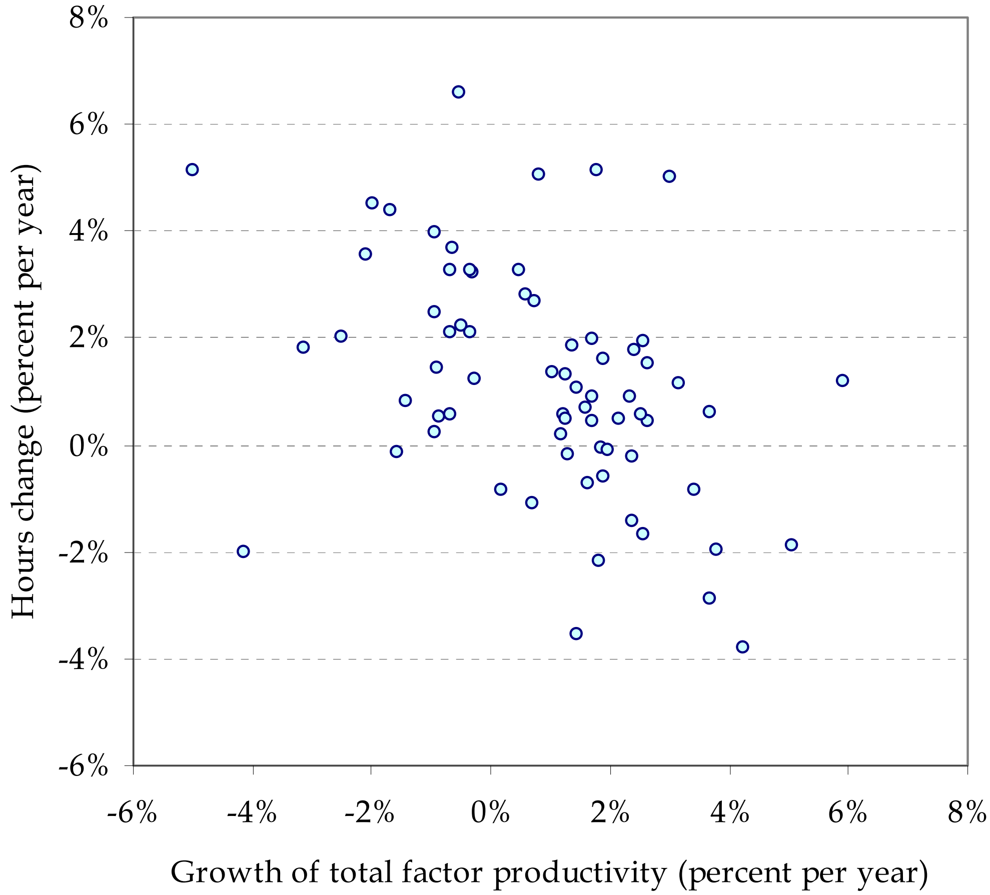

Figure 4. Growth of TFP and hours, 1948-2001

	Coefficient	Standard error	t-statistics
28 well-measured industries			
Total factor productivity			
4 subperiod, difference	-0.206	0.162	-1.27
4 subperiod level	-0.066	0.097	-0.68
1977-2000 cross section	-0.351	0.163	-2.15
1948-2001 cross section	-0.248	0.272	-0.91
28 well-measured industries			
Labor productivity			
4 subperiod, difference	-0.369	0.147	-2.51
4 subperiod level	-0.195	0.089	-2.19
1977-2000 cross section	-0.350	0.144	-2.43
1948-2001 cross section	-0.284	0.240	-1.19
14 major industries			
Total factor productivity			
4 subperiod, difference	-0.102	0.135	-0.76
4 subperiod level	0.121	0.146	0.83
1977-2000 cross section	-0.311	0.324	-0.96
1948-2001 cross section	-0.459	0.351	-1.31
14 major industries			
Labor productivity			
4 subperiod, difference	-0.392	0.136	-2.89
4 subperiod level	-0.451	0.116	-3.89
1977-2000 cross section	-0.317	0.231	-1.37
1948-2001 cross section	-0.327	0.167	-1.96
59 detailed industries			
Total factor productivity			
4 subperiod, difference	0.053	0.050	1.06
4 subperiod level	0.097	0.041	2.35
1977-2000 cross section	-0.253	0.103	-2.47
1948-2001 cross section	-0.453	0.128	-3.53
67 detailed industries			
Labor productivity			
4 subperiod, difference	-0.226	0.069	-3.29
4 subperiod level	-0.148	0.055	-2.68
1977-2000 cross section	-0.370	0.101	-3.67
1948-2001 cross section	-0.591	0.122	-4.83
Summary statistics			
All regressions			
Weighted	-0.282	0.150	-1.87
Unweighted	-0.258	0.193	-1.34
Well-measured industries			
Unweighted	-0.259	0.096	-2.69

Table 4. Impact of productivity growth on hours growth

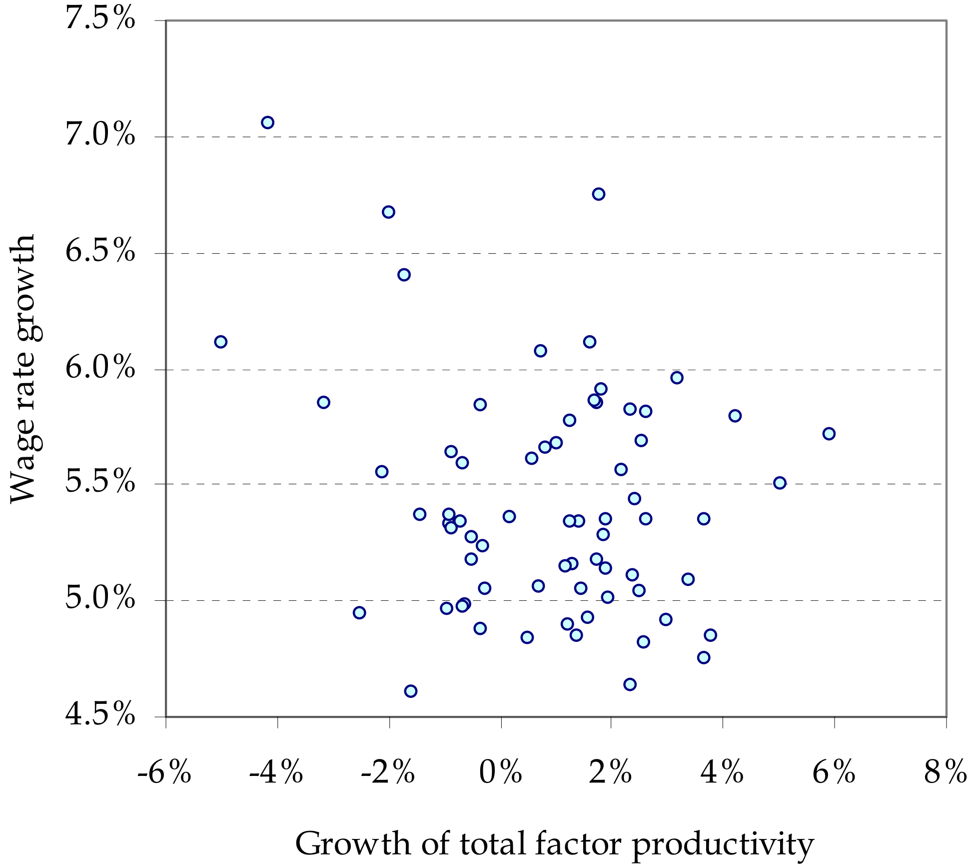

Figure 5. Productivity growth and wage growth by industry, 1948-2001 (annual average percent per year)

	Coefficient	Standard error	t-statistics
28 well-measured industries			
Total factor productivity			
4 subperiod, difference	-0.082	0.064	-1.28
4 subperiod level	0.086	0.045	1.90
1977-2000 cross section	0.086	0.058	1.47
1948-2001 cross section	0.079	0.054	1.46
28 well-measured industries			
Labor productivity			
4 subperiod, difference	-0.022	0.062	-0.36
4 subperiod level	0.105	0.042	2.50
1977-2000 cross section	0.109	0.050	2.16
1948-2001 cross section	0.115	0.045	2.55
14 major industries			
Total factor productivity			
4 subperiod, difference	-0.135	0.105	-1.28
4 subperiod level	0.065	0.088	0.75
1977-2000 cross section	-0.018	0.180	-0.10
1948-2001 cross section	0.004	0.130	0.03
14 major industries			
Labor productivity			
4 subperiod, difference	0.013	0.117	0.11
4 subperiod level	0.089	0.069	1.29
1977-2000 cross section	0.017	0.125	0.13
1948-2001 cross section	0.019	0.062	0.30
59 detailed industries			
Total factor productivity			
4 subperiod, difference	0.026	0.024	1.10
4 subperiod level	-0.005	0.021	-0.24
1977-2000 cross section	-0.088	0.037	-2.36
1948-2001 cross section	-0.052	0.031	-1.66
67 detailed industries			
Labor productivity			
4 subperiod, difference	0.018	0.036	0.49
4 subperiod level	0.076	0.028	2.74
1977-2000 cross section	-0.056	0.039	-1.43
1948-2001 cross section	-0.029	0.031	-0.94
Summary statistics			
All regressions			
Weighted	-0.001	0.078	-0.02
Unweighted	0.017	0.074	0.23
Well-measured industries			
Unweighted	0.059	0.067	0.88

Table 5. Coefficient of wage growth on productivity growth, alternative specifications

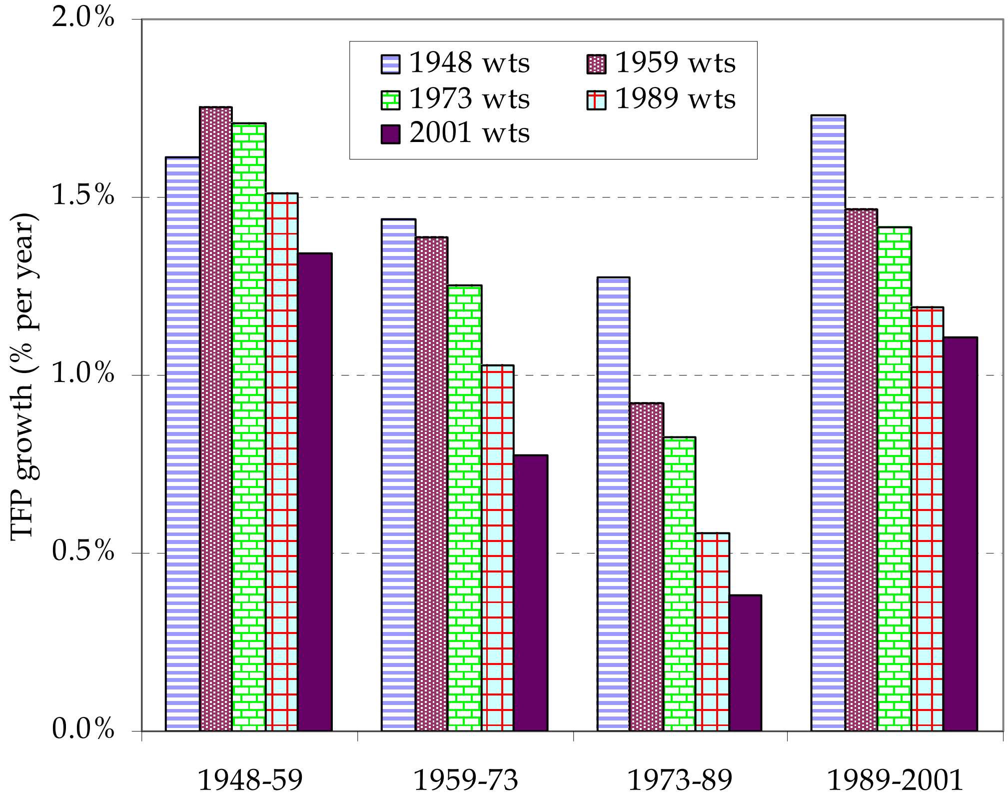

Figure 6. Fixed-shares growth rate of total factor productivity for different base years and periods

This figure shows the fixed-shares growth rate of total factor productivity for the aggregate of BEA industries for which capital stocks are available. These comprised 83 percent of GDP in 2001. The calculations show FSGR(T) = $\sum_{i=1}^{n} \hat{a}_{it} S_{iT}$ using fixed nominal shares for the five periods shown. The declining rates show that the Baumol growth disease had a major impact on overall productivity growth during this period.

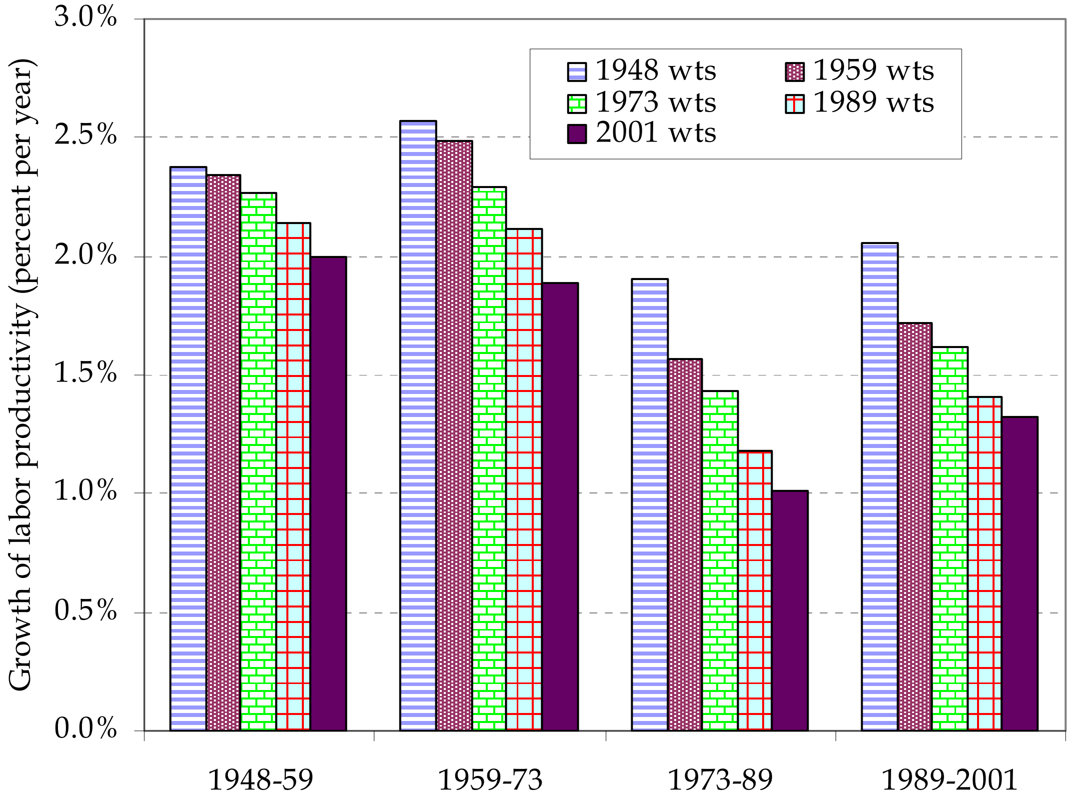

Figure 7. Fixed-shares growth rate of labor productivity for different base years and periods

This figure shows the growth of labor productivity for gross domestic product. The calculations show FSGR(T) = $\sum_{i=1}^{n} \hat{a}_{it}\, S_{iT}$ using nominal shares for the five base years shown.

Productivity growth for:	Fixed output-share weights for period					Current weights
	1948	1959	1973	1989	2001	
	[percent per year, logarithmic growth]					
1948-59	1.61	1.75	1.71	1.51	1.34	1.64
1959-73	1.44	1.39	1.26	1.03	0.78	1.32
1973-89	1.27	0.92	0.83	0.56	0.38	0.59
1989-2001	1.73	1.47	1.42	1.19	1.11	1.13
1948-2001	**1.49**	**1.34**	**1.26**	**1.02**	**0.85**	**1.12**

Table 6. Fixed-shares growth rate for total factor productivity for different weights and periods

Table shows the fixed-share growth rates, FSGR(T) = $\sum_{i=1}^{n} \hat{a}_{it} S_{iT}$, for total factor productivity, for different base years. The last column shows the current-year (Törnqvist) growth in TFP. For the entire period, the annual average difference between 1948 weights and 2001 weights is 0.64 percentage points.

Appendix A. Industry definitions in regressions

Industry definitions correspond to the 1987 SIC industry code. Included industries in the different samples are as follow.

<u>All 67 detailed industries</u>

(Asterisks denote industries that do not have total factor productivity estimates because BEA does not publish capital stock data.)

Farms

Agricultural services, forestry, and fishing

Metal mining

Coal mining

Oil and gas extraction

Nonmetallic minerals, except fuels

Construction

Lumber and wood products

Furniture and fixtures

Stone, clay, and glass products

Primary metal industries

Fabricated metal products

Industrial machinery and equipment

Electronic and other electric equipment

Motor vehicles and equipment

Other transportation equipment

Instruments and related products

Miscellaneous manufacturing industries

Food and kindred products

Tobacco products

Textile mill products

Apparel and other textile products

Paper and allied products

Printing and publishing

Chemicals and allied products

Petroleum and coal products

Rubber and miscellaneous plastics products

Leather and leather products

Railroad transportation

Local and interurban passenger transit

Trucking and warehousing

Water transportation

Transportation by air

Pipelines, except natural gas

Transportation services

Telephone and telegraph

Radio and television

Electric, gas, and sanitary services

Wholesale trade

Retail trade

Depository institutions

Nondepository institutions

Security and commodity brokers

Insurance carriers

Insurance agents, brokers, and service

Nonfarm housing services

Other real estate

Holding and other investment offices

Hotels and other lodging places

Personal services

Business services

Auto repair, services, and parking

Miscellaneous repair services

Motion pictures

Amusement and recreation services

Health services

Legal services

Educational services

Social services*

Membership organizations*

Other services*

Private households*

Federal general government*

Federal government enterprises*

State and local general government*

State and local government enterprises*

All 28 Well-Measured Industries

Farms

Metal mining

Coal mining

Nonmetallic minerals, except fuels

Lumber and wood products

Furniture and fixtures

Stone, clay, and glass products

Primary metal industries

Fabricated metal products

Industrial machinery and equipment

Electronic and other electric equipment

Motor vehicles and equipment

Other transportation equipment

Food and kindred products

Textile mill products

Apparel and other textile products

Paper and allied products

Printing and publishing

Chemicals and allied products

Rubber and miscellaneous plastics products

Leather and leather products

Railroad transportation

Trucking and warehousing

Transportation by air

Telephone and telegraph

Electric, gas, and sanitary services

Wholesale trade

Retail trade

One-Digit Industries

Farms

Mining

Construction

Durable goods

Nondurable goods

Transportation

Communications

Electric, gas, and sanitary services

Wholesale trade

Retail trade

Finance, insurance, and real estate

Services

Federal government

State and local governments

Appendix B. Notes on the Estimates in Tables 1 to 6

Details of Estimation for Tables 1 through 5

The results in Tables 1 through 5 were estimated using twenty-four different specifications. One set uses two different measures of productivity (labor productivity and total factor productivity). A second set is three different industry combinations as described in Appendix A. A third specification involves four different time periods.

The specifications for the different time periods will be described in this Appendix. The first two equations in each block are panel estimators with fixed effects, while the last two are cross-sections over long timer periods.

As an example, the panel estimate in the second equation of Table 1 is:

(B-1) $\hat{p}_{it} = \gamma_{0i} + \gamma_1 \hat{a}^*_{it} + \gamma_2 D_t + \varepsilon^p_{it}$

where $\hat{p}_{it}$ is the average annual change in the logarithm of price between year 1948 and 1959 for t = 1, 1959 and 1973 for t = 2, 1973 and 1989 for t = 3, and 1989 and 2001 for t = 4. $\hat{a}_{it}$ is the average annual change in the logarithm of calculated industry productivity over the same periods, D_t is a panel of time effects for the different periods, ε^p_{it} is a random disturbance, the γ_{0i} are industry effects, while γ_1 and γ_2 are coefficients. The first equation in each block takes the first difference of equation in (B-1). The last two sets of equations are cross sections for either the shorter period for which the data are better or for the entire period. The equations are estimated using the panel estimator and ordinary least squares in Eviews 5.0.

The summary statistics at the bottom of each table are calculated under the assumption that each equation is independent. While this assumption is clearly not the case, it is a convenient way of organizing the different results. The weighted summary statistics take the estimates shown in the columns above it and weight the coefficients by the number of observations for each equation. The unweighted statistics weight each equation equally.