U.S. Economic Growth Since 1870: One Big Wave?

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It is now 25 years since the growth rate of labor productivity and of multi-factor productivity (MFP) decelerated sharply both in the United States and in most other industrialized nations. This "productivity slowdown" has eluded many attempts to provide single-cause explanations. Slow productivity growth in the past 25 years echoes slow productivity growth in the late 19th century. Perhaps both were normal, and what needs to be explained is not the post-1972 slowdown, but rather the post-1913 "speedup" that ushered in the glorious 60 years between World War I and the early 1970's in which U.S. productivity growth was much faster than before or after.

This paper makes a sharp distinction between MFP growth calculated from inputs that combine simple measures of labor hours and the capital stock and growth based on measures that adjust for the changing composition of labor and capital. The first step toward an understanding of long-term trends is to compare like with like, splicing MFP data based on unadjusted inputs prior to 1950 with post-1950 data based also on unadjusted inputs, as contrasted to the composition-adjusted inputs that are now desirably incorporated into our official MFP measures.

The MFP record prior to 1929 still rests largely on the monumental work of John Kendrick (1961) which, however, is based almost entirely on input quantities that lack any adjustment for changes in composition. Edward Denison (1962, 1985) and Zvi Griliches (1960) pioneered the development of composition adjustments for labor input. Dale Jorgenson and Zvi Griliches (1967) introduced a framework that treats the problem of composition adjustment in both labor and capital input in an elegant and symmetric fashion. After decades of fruitful research and constructive advocacy by Jorgenson (e.g., Jorgenson, 1990), in 1994 the U.S. Bureau of Labor Statistics (BLS) adopted the Jorgenson framework for composition adjustment for all its publications on MFP growth over the period since 1948.

I. Standard Composition-Unadjusted Data: One Big Wave

The point of departure is the "standard" history of MFP growth since 1870 based on unadjusted inputs, linking Kendrick (1961) and BEA data to post-1948 BLS data "stripped" of the usual composition adjustments. Column (ii) in Table 1 displays the time-series behavior of standard MFP that might be called "one big wave."[1] Annual percentage growth rates are computed over intervals that connect "normal" years and leap over such aberrations as the Great Depression and the two world wars and their aftermaths. This wave-shaped history shows symmetric slow MFP growth at the beginning (1871–1891) and end (1988–1996) of about 0.6 percent per annum, faster growth at the "shoulders" in 1891–1913 and 1972–1988 of 1.0–1.2 percent, near-peak growth rates in 1928–1950 and 1964–1972 of 1.9–2.1 percent, and the "winner and still champion" interval in 1950–1964 with MFP growth of 2.35 percent per annum. World War I and its aftermath (1913–1928) spoil the symmetry somewhat, as there is no postwar parallel to the impressive 1.43-percent MFP growth rate registered in that interval.

The big-wave image raises at least two big questions: (i) "is it real?" and (ii) "what caused it?" This brief paper provides an introduction to both questions. The treatment of "is

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[1] Source notes for the tables are available from the author upon request.

TABLE 1—OUTPUT AND MULTIFACTOR PRODUCTIVITY GROWTH, 1871–1996 (ANNUAL GROWTH RATES PERCENTAGES)

Interval	(i) Output	MFP[a] (ii)	(iii)	(iv)
1871–1891	4.41	0.56	0.21	0.21
1891–1913	4.43	1.20	0.86	0.86
1913–1928	3.11	1.43	1.01	1.01
1928–1950	2.75	1.90	1.01	1.01
1950–1964	3.68	2.35	1.67	1.86
1964–1972	4.23	2.07	1.54	1.69
1972–1979	3.60	1.12	0.75	1.04
1979–1988	3.14	0.90	0.04	0.34
1988–1996	1.98	0.67	0.11	0.26
Slowdown, 1972–1996 vs. 1913–1972	−0.37	−1.02	−1.12	−0.79

Notes: Data refer to the nonfarm, nonhousing, private business sector.

[a] The three columns labelled "MFP" refer to (ii) unadjusted MFP, (iii) MFP adjusted for changes in composition, and (iv) MFP adjusted for composition together with the Gordon capital-quantity adjustment.

TABLE 2—LABOR INPUT, WITH AND WITHOUT ADJUSTMENTS FOR CHANGES IN COMPOSITION

Interval	(i) Hours	Composition adjustment (ii) Denison, original	(iii) Denison, adjusted	(iv) (BLS)	(v) Labor input
1871–1891	3.56		(0.50)		4.06
1891–1913	2.92		(0.50)		3.42
1913–1928	1.42	1.07	0.61		2.03
1928–1950	0.91	1.06	0.50		1.41
1950–1964	1.05	0.72	0.48	0.40	1.45
1964–1972	1.64	0.40	0.25	−0.03	1.61
1972–1979	2.18	0.42	0.37	0.00	2.18
1979–1988	1.85			0.54	2.39
1988–1996	1.16			0.54	2.39
Slowdown, 1972–1996 vs. 1913–1972	0.54			−0.06	0.49

Note: The final column refers to labor input, taking account of the Denison composition adjustment before 1950 and the BLS adjustment thereafter. The numbers in parentheses are the author's extrapolations of the adjusted Denison method.

it real?" combines a broad-brush summary of what is known about composition changes in inputs and some questions about what additional insight has been contributed in the past, or may be contributed in the future, by research on price-measurement biases in both output and inputs. What is known about composition changes in inputs, and composition-adjusted growth in MFP, is summarized in the tables.

II. Composition Adjustments for Labor Input

The BLS composition adjustments in column (iv) of Table 2 combine subcomponents of labor input stratified by age, sex, and educational attainment with weights based on earnings in each cell. The period of zero composition change during 1964–1979 combines a positive contribution of increased educational attainment with an offsetting negative contribution of the age–sex component, which reflects the increasing share of teenagers and females in the labor force during that interval.

Two time series of growth rates covering 1913–1979 have been constructed from Denison's pioneering estimates of labor composition changes. The "original" Denison series combines his earliest (1962) estimates for 1913–1928 with his final (1985) estimates for 1928–1979. The "original" series combines standard adjustments for age–sex composition and increasing years of educational attainment with three controversial procedures that have not been adopted in subsequent work by the BLS or others.

First, Denison made a radical assumption that, at the typical 50–60 hour work week observed in 1929 and prior years, workers were so exhausted that their marginal hours were unproductive. Hence Denison (1962 pp. 35–43) assumed that at 1929 levels of hours per week, any reduction in hours per week created a unit-elastic increase in "efficiency," thus making employment rather than hours the relevant measure for MFP. He reduced the negative response of efficiency to hours reductions from unity at 1929 hours levels to −0.4 in the late 1950's, and lower responses thereafter.

Second, Denison assumed in his early (1962) writing that fully 40 percent of the contribution to earnings of increased educational attainment was due to ability or other factors inherent in individuals and should not be treated as a source of growth. In later writing (e.g., Denison, 1985) the set of factors was broadened to go beyond ability to family educational attainment, and the offset factor was reduced to roughly 20 percent. Third, Denison treated a given percentage increase in days of education per year as contributing to the composition of labor input as the same percentage increase in years of educational attainment.

Since the BLS measures of postwar labor composition changes ignore all three of Denison's factors, I have gone back to Denison's original tables to extract alternative measures of labor composition which are conceptually identical to the current BLS series. The annual growth rates of the original and adjusted Denison series are shown in columns (ii) and (iii) of Table 2, and they differ most during 1913–1950 (due to the importance of Denison's hours–efficiency adjustment) and by an amount diminishing almost to zero by 1972–1979.

III. Composition and Quantity Adjustments for Capital Input

The BLS adjustments for the composition of capital are based on the Jorgenson framework, which reweights components of the capital stock by the user cost of capital. Components with short lifetimes and correspondingly rapid depreciation rates receive higher weights in the composition-adjusted capital input measures (''J'') than in capital stock measures (''K''). Over the postwar period there has been a continuous substitution of equipment for structures and of short-lived equipment like computers for long-lived equipment like furniture. The BLS, which aggregates across categories of capital (equipment, structures, residential rental capital, and inventories), attributes a major composition change to the increased quantity of J-weighted capital relative to the K-stock, and the growth rate of this composition effect is recorded in column (iii) of Table 3.

Sufficient data to extend the BLS technique backward exist only to 1925, and as yet there is no parallel composition-adjustment series available. In my research I have adopted the Jorgenson technique to reweight structures and equipment, but not the individual components thereof, with minimal effects prior to 1928, as seen in column (ii) of Table 3. The sharp increase in the composition adjustment for capital after 1928 reflects the simple fact that there was a steady shift in the share of equipment relative to structures in the capital stock after 1935 but not before. Indeed, the ''structures-intensiveness'' of the capital stock peaked in 1919. The shift from structures to equipment, and within equipment to shorter-lived equipment, suggests deep and difficult issues which are beyond the scope of this paper, particularly whether computers are making a contribution to ''true'' productivity in proportion to the quantity of their attributes (speed, memory, etc.) now embedded in our national income accounts.

Other important measurement issues involving the quantity rather than the composition of capital are explored by Gordon (1998) and are summarized in column (iv) of Table 3. The most important adjustment is to allow for variable retirement ages that respond to net investment rates. Trucks, tractors, and structures were not discarded at some arbitrarily fixed lifetime during the Great Depression and World War II, when private investment was nil. Instead they were ''still there'' to contribute to America's production miracle during World War II. The most important impact is

TABLE 3—CAPITAL INPUT, WITH AND WITHOUT ADJUSTMENTS FOR CHANGES IN COMPOSITION AND QUANTITY

Interval	(i) Capital stock	Composition (ii) Gordon	Composition (iii) BLS	(iv) Gordon quantity	(v) Capital input
1871–1891	4.48	0.01			4.49
1891–1913	3.85	0.02			3.87
1913–1928	2.21	0.03			2.24
1928–1950	0.74	0.45		1.23	1.19
1950–1964	2.45		0.85	−0.71	3.30
1964–1972	3.82		1.29	−0.71	5.11
1972–1979	3.23		1.23	−1.13	4.46
1979–1988	3.31		1.45	−1.13	4.76
1988–1996	1.74		0.59	−0.50	2.33
Slowdown, 1972–1996 vs. 1913–1972	0.83			0.55	1.38

Note: The final column refers to capital input adjusted for composition effects, but not for the Gordon quantity adjustment.

to increase greatly the growth rate of capital input during 1928–1950 and to reduce it thereafter. Additional adjustments are made for government-owned and privately operated capital (e.g., the Ford plant that made B-24's at Willow Run in World War II), which boosts capital growth in 1928–1950 and reduces it thereafter, and also to include parts of government capital to avoid a bias in capital measurement as the nation shifted during the early 20th century from private railway to public highway and airway capital.

IV. Alternative Measures of MFP Growth and the Questions that Arise

I have already examined the standard MFP measures that are not adjusted for changes in the composition of inputs, as displayed in column (ii) of Table 1. An alternative based on the BLS input composition adjustments after 1950 and the adjusted Denison measures for 1913–1950 (and an arbitrary 0.50 labor-composition adjustment for 1870–1913) is shown in column (iii) of Table 1. As shown in the bottom line, where the slowdown (1972–1996 vs. 1913–1972) is displayed, there is virtually no contribution of the labor- and capital-composition measures to explaining the slowdown. If anything, the composition adjustments deepen the puzzle, as they average 0.72 points during 1979–1996 but a smaller 0.52 points during 1913–1972. In contrast to the composition adjustments, which explain none of the slowdown, the Gordon capital-quantity adjustments appear to explain about 30 percent, as shown in column (iv) of Table 3.

V. What Needs To Be Known

There are many questions to raise about these tables and many blank cells to be filled in. However, until now economists have ignored totally a major issue that is perhaps the most elusive blank cell of all, and this is price-index bias. The recent Boskin Commission report offered an estimate that the Consumer Price Index was biased upward by 1.1 percent in 1995–1996, but this is of little relevance for the study of historical changes in the trend of MFP growth.

A bias in capital-input price indexes contaminates both output and input measures, and in the Gordon (1990 p. 557) version it reduced MFP growth by only 0.17 percent over the entire 1947–1983 period, with only a very small difference in the reduction in the rapid-MFP period (1947–1973, 0.19 percent) and the slowdown period (1973–1983, 0.09 percent). One can surmise that improved estimates of price-index errors in earlier periods would largely wash out, if they reveal that most errors involve prices of capital input, both structures and equipment.

Consideration of data gaps points to the history of price changes from 1914 to 1947 as the black hole where little is known. Nothing to match Albert Rees's (1961) seminal breakthrough in measuring prices for the 1890–1914 interval has yet been achieved for 1914–1947. A few building blocks have recently been put in place, with Daniel Raff and Manuel Trajtenberg (1997) demonstrating dramatic declines in the price of automobiles for 1906–1941, and with William White (1998) demonstrating similar declines in the price of tractors over much of the 1910–1955 period. Set against this, however, is a set of my previous findings which suggest that the price index bias could be lower prior to 1947 than after. In extensions of my work on durable equipment prices (Gordon, 1996), I find much smaller rates of bias before 1947. And in more recent work, I find fragmentary evidence that official price indexes may greatly *understate* price changes for housing, shelter, and apparel over the 1930–1970 period. To the extent that there is an upward bias in price indexes for final goods in the 1990's, and a downward bias (or a smaller upward bias) in the 1930's through 1960's, some of the "big wave" of MFP growth might potentially be explained.

VI. Explaining the "Wave"

The research on input composition and quantity summarized here replaces the "big wave" symmetry with a flatter profile of corrected and adjusted MFP growth which proceeds at roughly 1 percent per annum during the periods 1891–1950 and 1972–1979, in contrast to a much higher 1.7–1.8 percent during 1950–1972 and a much lower 0.2–0.3 percent during 1870–1891 and 1979–1996. If that is the best that can be done with measurement, at least for now, what remains to explain this huge difference in MFP growth rates across decades and epochs?

Pending further research on price measurement errors, my basic explanation is perhaps the most obvious but also the most neglected. I believe that the inventions of the late 19th century and early 20th century were more fundamental creators of productivity than the electronic/internet era of today. I classify those earlier inventions into four clusters, starting with electricity (including electric motors, the electric light, and consumer appliances), internal-combustion engines (motor transport, air transport, superhighways, supermarkets, and suburbs), "rearranging molecules" (petrochemicals, plastics, and pharmaceuticals), and communications/entertainment (telephone, radio, movies, and television).[2]

The "big four" were much more profound creators of productivity growth than anything that has happened recently. Much of what we are seeing now is "second order," for example the VCR which combines TV and movies but does not have the fundamental impact of the invention of either, and much of the use of the internet which substitutes one form of entertainment for another. Enthusiasts of the internet might consider that the computer has not created the paperless society, but rather a duplication of electronic activities, all of which generate paper, including the increasing pressure on academic societies to produce alternative paper and electronic versions of their journals and membership lists.

Puzzles in the evolution of long-run economic growth are the ties that bind economic historians, macroeconomists, and microeconomic experts on hedonic price equations and product composition. Yet the more research that emerges on specific questions, the less is learned about the underlying structure of the "big wave." The exercises summarized in this paper place more of the peak of MFP growth during 1950–1972 and less during 1913–1950; yet the underlying question remains intact: why did the fundamental determinants of American economic growth create such a surge between 1913 and 1972, but neither before nor after? I deeply believe that this was a unique event that will not be replicated in the lifetimes of our generation or that which follows us, and I hope the challenge of proving me wrong stimulates a new era of growth research worthy of the pioneering efforts of Kendrick, Denison, Griliches, and Jorgenson.

[2] A broader consideration of consumer welfare, as contrasted with productivity itself, would add a fifth cluster including indoor plumbing and public infrastructure, providing running water and sanitary waste disposal.

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