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Sources of Growth in U.S. GDP and Economy-Wide Linkages to the Agricultural Sector

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Sources of growth in U.S. gross domestic product (GDP) are analyzed in a general equilibrium, open economy framework using time-series data. Contributions from labor and capital account for 75% of the economy's average growth, with total factor productivity (TFP) accounting for the remainder. Changes in the domestic terms of trade appear to be biased in favor of the services sector and against the agricultural and industrial sectors. A number of Rybczynski and Stolper-Samuelson-like linkages between the agricultural sector and the rest of the economy are identified. Labor-using technological change and favorable terms of trade appear to be the major contributors to the growth of the services sector. These changes have led to a decline in the competitiveness of the industrial and agricultural sectors for economy-wide resources. Technological change has tended to be neutral towards the production of farm output.

Key words: competitiveness, growth, technological change

Introduction

Studies of factor productivity effects on U.S. agriculture find that technological change has been the major reason for farm output growth (Ball 1985; Jorgenson and Gollop). Over 1947–85 farm output grew by an annual average of 1.92%, about 82% of which is due to growth in total factor productivity. In addition, empirical estimates of agricultural production functions find that the supply response of aggregate farm output is relatively high (Ball 1988; Capalbo and Antle). However, these studies tend to ignore the broader economy's effect on the growth of the farm sector's real value added. Changes in the terms of trade among the major sectors of the U.S. economy and changes in the levels of primary inputs affect the agricultural sector's supply response. In addition, some sectors are likely to bid up the returns to the primary factors of production and, thus, make them more expensive for other sectors. The services sector has doubled its share of gross domestic product (GDP) since 1948 while the industrial and farm sector shares have declined from 0.62 to 0.45 and from 0.09 to 0.01, respectively (U.S. Department of Commerce 1929–92a), and so, these effects are important because they decrease the farm sector's relative capacity to compete for economy-wide resources.

The competition for resources in the presence of growth can occur along different paths. For instance, if the agricultural sector is capital intensive relative to the services sector, then labor-using technological change can increase the relative competitiveness of the services

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sector (Rybczynski effects). The magnitude of these effects are affected by the relative factor intensity and the growth in levels of labor and capital.[1] Changes in the sectoral terms of trade in favor of services may also serve to increase the prices of economy-wide resources (Stolper-Samuelson effects), further decreasing the agricultural sector's capacity to bid for them, thereby inducing a decline in its share of GDP. The magnitude of these effects also depends on the industrial sector and if complementarities exist between sectors. Since value added to primary farm output by the industrial sector is relatively large [U.S. Department of Agriculture (USDA), Food Marketing Review] some complementarity between the sectors may exist where an increase in the value added component of the industrial price index leads to some increase in the supply of farm sector output.

This article provides insights into the nature of these linkages and generally confirms the above discussion. Two separate, though methodologically linked, analyses are undertaken using essentially the same data set. First, a nonparametric method is used to separate the sources of growth in real GDP into price, resource effects, and total factor productivity (TFP) effects. This analysis adopts Diewert's (1976) ideal index framework and extends the indexes derived by Diewert and Morrison. The nonparametric analysis presumes that the economy's GDP function can be expressed as a Taylor series approximation in logarithms of its arguments, that is, a translog functional form. The next step is to posit such a form and, using the envelope properties of the GDP function, to estimate the parameters of the general equilibrium output supply and factor rental rate functions it implies. This component of the analysis follows Kohli's gross national product analysis of the Swedish economy, except that we focus on the GDP function.

The nonparametric results identify capital and labor as the major contributors to growth in real GDP over the 1948–92 period, followed by total factor productivity, and surprisingly, changes in the terms of trade for services. The contributions from each factor show considerable variability, however, and a tendency to decline in the last two decades. The econometric model fits the data well. Rybczynski-like linkages identify the services sector as relatively labor using, while the Stolper-Samuelson-like effects document the increases in factor prices brought about by the industrial and services sectors of the economy. The labor-using technological progress appears to further the expansion of the services sector, and thus, affects the agricultural sector's level of output and share of GDP. Some complementarity between the farm and industrial sector is found.

The performance of the agricultural sector is strongly influenced, as expected, by the changes in domestic terms of trade and levels of primary inputs.[2] Favorable terms of trade for services sector and labor-using technological change at the economy level are the major contributors to the decline in the agricultural sector's share of GDP.

Model

Following Diewert (1974) and Woodland, define the economy's GDP function for each period t by:

[1] The share of GDP attributed to labor has increased from 0.59 to 0.65, while that of capital decreased from 0.41 to 0.35 during the period 1948–92. However, in recent years the shares have stayed almost constant with the share of capital rising in the late eighties. In terms of growth in the level of inputs, productive capital stock has grown faster (3.38%) than work force (1.79%) over the same period.

[2] Note that the price and income elasticity of demand for agricultural and food products are other factors that affect agricultural sector's share of GDP.

$$G^t(p, v) \equiv \max_{y} \{p^{t^T} y^t : (y, v) \in \Gamma^t\}, \tag{1}$$

where (T denotes transpose) omitting time t; $p = (p_A, p_N, p_S)$ is a price vector of net outputs; and $y = (y_A, y_N, y_S)$ of the agricultural (A), industrial (N), and services (S) sectors of the economy. The function $G^t(p, v)$ is the maximum value of domestic output for given levels of primary inputs; $v = (v_L, v_K)$, of labor (L) and capital (K) and the technology set $(y, v) \in \Gamma^t$. For various restrictions on G^t (Diewert 1974, p. 134), G^t completely characterizes Γ^t.

The GDP function maps output prices and factor endowments to returns to the economy's resources presuming a competitive market equilibrium. Consequently, it captures the underlying structure of net supply, factor returns, and their interlinkages. Unlike sectoral profit / revenue functions, G^t provides the economy-wide linkages to the agricultural sector through the competition for primary resources and changes in the domestic terms of trade with other sectors of the economy.

$G^t(p, v)$ is convex and linearly homogeneous in p and concave, nondecreasing, and linearly homogeneous in v. It is important to note that the envelope properties of $G^t(p, v)$ imply the *net output supply* function, $\partial G/\partial p_n = y_n(p_A, p_N, p_S, \bar{v}_L, \bar{v}_K)$ for $n = A, N, S$, and the factor rental rate or inverse demand function, $\partial G/\partial v_m = w_m(p_A, p_N, p_S, \bar{v}_L, \bar{v}_K)$ for $m = L, K$. These envelope properties of $G^t(p, v)$ are exploited to provide a framework for both the nonparametric analysis of contributions to growth in aggregate GDP, and the parametric analysis of sectoral supply and primary factor returns which follow. The nonparametric and parametric framework fit together as follows: the nonparametric analysis presumes that the GDP function can be approximated by a translog. The parametric analysis "confirms" this presumption and, hence, the validity of the nonparametric results. Moreover, the econometric model provides empirical insights into supply response, Rybczynski-, and Stolper-Samuelson-like elasticities.

Nonparametric Framework

The nonparametric analysis draws on the quadratic approximation lemma of Diewert (1976). The purpose of this framework is to identify the *level effects* of prices and inputs and the *rate effects* of TFP on growth of aggregate GDP. The level effects are short run in nature as they are one-time effects, while the rate effects are long-run, dynamic sources of growth. These rate effects are also referred to as efficiency gains or technological progress.

Using (1) for given reference price (p) and input (v) vectors, define the period t theoretical productivity index as:

$$R^t(p, v) \equiv \frac{G^t(p, v)}{G^{t-1}(p, v)}. \tag{2}$$

$R^t(p, v)$ is the percentage increase in GDP (valued at reference prices) that can be produced by the period t technology, holding the level of inputs v. The following two cases of (2) are of special interest:

$$R_L^t \equiv \left[\frac{G^t(p^{t-1}, v^{t-1})}{G^{t-1}(p^{t-1}, v^{t-1})}\right], \quad \text{and} \quad R_p^t \equiv \left[\frac{G^t(p^t, v^t)}{G^{t-1}(p^t, v^t)}\right], \tag{3}$$

where R_L^t is a Laspeyres-type index which uses period $t - 1$ as base, while R_P^t is a Paasche-type productivity index based on period t prices and input quantities. Note that the numerator of R_L^t and the denominator of R_P^t are unknowns. Given a translog functional form for the GDP function, the contribution of Diewert and Morrison permits calculating a geometric mean of R_L^t and R_P^t without knowing the parameters of the translog GDP function [hence the term nonparametrics (Kohli)].[3]

Given a competitive profit maximizing framework, it follows that GDP should equal payments to primary factors:

$$G^t(p, v) \equiv p^{t^T} y^t \equiv w^{t^T} v^t, \tag{4}$$

where w is a vector of rental rates of primary inputs, and

$$\begin{aligned} \ln G^t(p, v) \equiv \alpha_0^t &+ \sum_{n=A,N,S} \alpha_n^t \ln p_n + \left(\frac{1}{2}\right) \sum_{i=A,N,S} \sum_{j=A,N,S} \alpha_{ij} \ln p_i \ln p_j \\ &+ \sum_{m=L,K} \beta_m^t \ln v_m + \left(\frac{1}{2}\right) \sum_{i=L,K} \sum_{j=L,K} \beta_{ij} \ln v_i \ln v_j \\ &+ \sum_{n=A,N,S} \sum_{m=L,K} \gamma_{nm} \ln p_n \ln v_m, \end{aligned} \tag{5}$$

with the following restrictions on parameters to assure the properties of (1):

$$\sum_{n=A,N,S} \alpha_n^t = 1; \quad \sum_{m=L,K} \beta_m^t = 1; \quad \sum_{i=A,N,S} \alpha_{ij} = 0; \quad \sum_{j=A,N,S} \alpha_{ij} = 0;$$

$$\sum_{i=L,K} \beta_{ij} = 0; \quad \sum_{j=L,K} \beta_{ij} = 0; \quad \sum_{n=A,N,S} \gamma_{nm} = 0; \quad \sum_{m=L,K} \gamma_{nm} = 0.$$

Then,

$$(R_L^t R_P^t)^{1/2} = \left(\frac{a}{bc}\right), \tag{6}$$

where,

$$a = \frac{p^{t^T} y^t}{p^{t-1^T} y^{t-1}}, \tag{7}$$

$$\ln b = \sum_{n=A,N,S} \left(\frac{1}{2}\right) \left[\left(\frac{p_n^t y_n^t}{p^{t^T} y^t}\right) + \left(\frac{p_n^{t-1} y_n^{t-1}}{p^{t-1^T} y^{t-1}}\right) \right] \left[\ln\left(\frac{p_n^t}{p_n^{t-1}}\right) \right], \quad \text{and} \tag{8}$$

$$\ln c = \sum_{m=L,K} \left(\frac{1}{2}\right) \left[\left(\frac{w_m^t v_m^t}{w^{t^T} v^t}\right) + \left(\frac{w^{t-1} v_m^{t-1}}{w^{t-1^T} v^{t-1}}\right) \right] \left[\ln\left(\frac{v_m^t}{v_m^{t-1}}\right) \right]. \tag{9}$$

Note that the right-hand side of (6) can be evaluated using aggregate price and quantity data.[4] Given data on the value share of net outputs and price indexes [for equation (8)], and value share of primary inputs in GDP and their endowments [for equation (9)], growth in real value of output a can be decomposed into level effects (price effects b

[3] The approach departs from Diewert and Morrison and Kohli in that the properties are derived for the GDP function (i.e., returns to U.S. factor endowments) rather than the GNP function.

[4] We derive the real prices p^t and p^{t-1} by deflating the sectoral price indices by a GDP deflator, in principle, discounting them for average price increases in the economy.

and input level effects *c*) leaving the residual (*a*/*bc*) to be accounted by rate effects or growth in TFP.[5]

Insights into individual "real" price and input contributions can be obtained by disaggregating (8) and (9). For instance, b_n (c_m) is interpreted as the change in GDP (between periods $t - 1$ and t) attributable to change in real price of *m*th good (level of *n*th input) from p_n^{t-1} to p_n^t (from v_m^{t-1} to v_m^t), holding others constant.[6] Equations (7), (8), and (9) constitute the key components of the nonparametric analysis.

Econometric Model

The GDP function maps output prices and factor endowments to returns to the economy's resources presuming a competitive market equilibrium. The parametric analysis draws upon the envelope properties of $G^t(p, v)$ along the lines of Kohli to capture the underlying structure of net supply, factor returns, and their interlinkages. Using (5), these properties imply the net output share equations ($n = A, N, S$):

$$S_n^t = \alpha_n^t + \sum_{i=A,N,S} \alpha_{ni} \ln p_i + \sum_{j=L,K} \gamma_{nj} \ln v_j, \tag{10}$$

and the primary input share equations ($m = L, K$):

$$S_m^t = \beta_m^t + \sum_{j=L,K} \beta_{mj} \ln v_j + \sum_{i=A,N,S} \gamma_{mi} \ln p_i, \tag{11}$$

where $S_n^t = (p_n^t y_n^t / p^{t^T} y^t)$ and $S_m^t = (w_m^t v_m^t / w^{t^T} v^t)$ are shares of outputs and primary inputs, respectively. From the parameter estimates of (10) and (11), the response of net output supplies and primary input rental rates to changes in output prices and levels of primary inputs can be computed (Takayama, pp.147–49, for the derivation of supply and factor rental rate elasticities).

The time dependent constant terms (α_n^t, β_m^t) in (10) and (11) are replaced by ($\alpha_0^n + \alpha_1^n t$, $\beta_0^m + \beta_1^m t$), where t denotes a trend variable "time." Following Jorgenson, these measures (α_1^n, β_1^m) are referred to as technical change (productivity growth) biases, as these parameters account for changes in shares that are not accounted for by the changes in prices and factor endowments. However, other factors, such as efficiency gains from organizational innovations, may well be captured by these parameters. Thus, these parameters represent the biases of productivity growth, to the extent that time is a surrogate for technical change. For α_1^n positive, technical change is referred to as output augmenting, and for β_1^m positive (negative), technical change is referred to as input using (input saving). In other words, technological progress appears to favor (using) a particular output (input) relative to the others. These parameters indicate "relative" rates of change since the first-order parameters of (5), that is, α_0^t, α_n^t, β_m^t, do not provide adequate structure to identify the sources of technological change. These parameters translate into semielasticities of supply of outputs and returns to factors with respect to the time index as (following Kohli):

$$\epsilon_{nt} = \frac{\partial \ln y_n}{\partial t}; \qquad \text{and} \qquad \epsilon_{mt} = \frac{\partial \ln w_m}{\partial t}. \tag{12}$$

[5] b and c are obtained by calculating the exponents of $\ln b$ and $\ln c$, respectively. It is fairly simple to derive these indexes using a spreadsheet.

[6] $\ln b_n = \left(\frac{1}{2}\right)\left[\left(\frac{p_n^t y_n^t}{p^{t^T} y^t}\right) + \left(\frac{p_n^{t-1} y_n^{t-1}}{p^{t-1^T} y^{t-1}}\right)\right]\left[\ln\left(\frac{p_n^t}{p_n^{t-1}}\right)\right].$

The semielasticities represent the relative effects of technical change on output supplies and factor returns for a unit change in the technical change (time) index. In the case of the translog GDP function, these semielasticities are derived as:

$$(13) \qquad \epsilon_{nt} = \frac{\alpha_n^1}{S_n} + \frac{\partial \ln G}{\partial t}; \qquad \text{and} \qquad \epsilon_{mt} = \frac{\beta_m^1}{S_m} + \frac{\partial \ln G}{\partial t}.$$

A discrete measure to approximate $\partial \ln G/\partial t$ as suggested by Jorgenson, is employed to evaluate these elasticities at average shares (S_n and S_m).

While the agricultural and industrial sectors are composed of goods that are either import or export competing, the services sector comprises many goods that are not traded internationally. The economy implied by (1) can be viewed as being in a short-run Walsrasian equilibrium. Hence, all output (including nontradables) and input markets clear. In a Hecksher-Ohlin-Samuelson economy (with two traded goods, one nontradable, and two primary factors), the nontradable goods market clearing condition is given by $y_s(p, v) - \phi_d(p, GDP) = 0$, where ϕ_d is the demand for nontradables which is a function of prices and income/GDP (Woodland, ch. 8). The price of services p_S is solved for from this condition, and a reduced form for the price of services is specified as:

$$(14) \qquad \ln p_S^t = \delta_0 + \sum_{n=A,N} \delta_n \ln p_n^t + \sum_{m=L,K} \delta_m \ln v_m^t + \nu_t.$$

The restriction that the price of services is homogeneous of degree one in traded goods prices and homogeneous of degree zero in endowments (Woodland, ch. 8) is accepted by data. The price of services also appears on the right-hand side of the share equations, and hence, (10), (11), and (14) form a system of simultaneous equations.

Since the shares sum to one, one equation from the output side (farm goods) and one from the input side (capital) are omitted from the system. The restrictions pertaining to homogeneity and symmetry properties of the GDP function are imposed on the system and used to obtain parameter estimates of the omitted equations. Most of the restrictions cannot be rejected by the data. Hence, the share equations of industrial goods, services, and labor along with the equation for the price of services (nontradables) are estimated after correcting for serial correlation (a first-order vector autoregressive process).

Assume that the unexplained variation in the dependent variables, as depicted by the residual terms (ϵ_{nt}, ϵ_{mt}, ν_t) for (10) and (11) and (14), respectively, are random and normally distributed with zero mean and constant variance. However, initial results suggest that the residuals are correlated across equations and time periods as a first-order vector autoregressive (VAR) process. The correction proceeds as follows. Residuals ($\hat{\epsilon}_{nt}$, $\hat{\epsilon}_{mt}$, $\hat{\nu}_t$) obtained from applying OLS to the system are regressed on all ($\hat{\epsilon}_{n,t-1}$, $\hat{\epsilon}_{m,t-1}$, $\hat{\nu}_{t-1}$) to obtain the matrix of parameters for the VAR process. Note that the system is symmetric with four endogenous variables (two net supply shares, one input share, and the price of nontradables) and four exogenous variables (price indexes of agricultural and manufacturing sectors, capital and labor endowments). Hence the matrix (4×4) of parameters of the first-order VAR process is used to transform the dependent (4×1) and independent (4×1) variables, and the system was estimated in SAS using iterative three-stage least squares (I3SLS). See Bowden and Turkington (pp.144–48) for a more detailed exposition of the estimation procedure.

Data

Time-series data on prices and value of output in each of the three sectors, quantities of primary inputs (employment and capital input), and shares of labor and capital in GDP are obtained from the National Income and Product Accounts of the Bureau of Economic Analysis, U.S. Department of Commerce, for the period 1948–92. The data on value of output are based on establishment surveys using revised SIC classification (1987). Agricultural sector consists of primary (raw) farm products. The major industrial products include mining, manufacturing (durables and nondurables, including food processing), and construction. Services include finance, insurance, real estate, health, legal, educational, government, and others. Since GDP is defined as the value of output produced by labor and property located in the United States, the output measures are value added by each sector (gross output less payments to intermediate inputs).

The productive capital stock (in constant 1987 billions of dollars) series is derived as gross stock (perpetual inventory) less depreciation (hyperbolic decay), by the U.S. Bureau of Labor Statistics. The Bureau of Labor Statistics accounts for quality improvements in the capital stock by adjusting the producer price indexes that value the structures and equipment.[7] A number of other choices of capital input measures are available. Boskin and Lau use utilized capital. Their proxy for economy-wide utilized capital is the capacity utilization rates in manufacturing. Since their experience with use of this proxy was not entirely satisfactory, it is not used here. The question of vintage effects of capital on productivity has been discussed by Jorgenson, Gollop, and Fraumeni. They decompose output growth attributable to capital into growth attributable to their measure of capital quality and to increases in capital stock. Their results suggest that increases in capital stock contribute substantially more to total growth from capital than the growth accounted for by the quality of capital. Hence, the use of the quality-adjusted capital input series seems a reasonable trade-off between maintaining a rather uncomplicated method, while also lowering the addition of unintentional errors from approximating the economy's capacity utilization rates of the productivity of capital of various vintages. Labor is given by the number of full-time equivalent employees in all three sectors. Quality adjustments on labor were not considered due to the nonavailability of data for our longer time series. Moreover, results in table 1 indicate that the differences between the nonparametric estimates of this study and the one with quality-adjusted data by Jorgenson, Gollop, and Fraumeni are very small. Land was not considered as a separate input in production. The share of land in agricultural value added was 18% (Ball 1985); however, its share in aggregate GDP was under 1%, on average over the sample period.

Results

Nonparametric Analysis of Sources of Growth

Nonparametric estimates of the contribution of prices (8), endowments (9), and TFP [right side of (6)] to GDP growth are presented in table 1. Growth in real GDP (7) is discounted for growth arising from real prices [b in (8)] and input levels [c in (9)], and

[7] See U.S. Department of Commerce (1929–92b) for more details.

Table 1. Components of U.S. GDP Growth—Averages (%)

Years	GDP Growth	TFP Growth	Agri-culture Price	Industry Price	Service Price	Labor	Capital
1948–52	5.40	1.96	−0.10	0.18	0.31	1.61	1.33
1953–57	2.52	0.39	−0.19	−0.11	0.70	0.48	1.24
1958–62	3.00	1.26	0.00	−0.34	0.58	0.49	0.97
1963–67	4.77	0.92	−0.01	−0.09	0.22	2.02	1.64
1968–72	2.98	0.53	0.02	−0.31	0.39	0.88	1.45
1973–77	2.64	−0.01	−0.02	0.17	−0.11	1.36	1.22
1978–82	1.28	−1.10	−0.06	0.05	0.14	0.98	1.28
1983–87	3.85	1.03	−0.08	−0.64	0.75	1.74	1.00
1988–92	1.91	0.60	−0.04	−0.48	0.49	0.62	0.70
1948–92	3.15	0.62	−0.05	−0.17	0.39	1.13	1.20
		(20)	(−2)	(−5)	(12)	(36)	(39)
Standard deviation	2.52	1.60	0.11	0.15	0.21	0.94	0.20
Denison (1948–73)	3.65	1.52				1.42	0.71
		(42)				(39)	(19)
Jorgenson (1948–79)	3.24	0.81				1.05	1.56
		(24)				(31)	(45)
Boskin-Lau (1948–85)	3.10	1.52				0.84	0.74
		(49)				(27)	(24)

Note: Figures in parentheses are percent contributions to growth in real GDP.

the residual [*a*/*bc* in (6)] is attributed to growth in TFP. Two results stand out. First, TFP dominates the contribution to growth in GDP from either capital or labor in the initial years only, and then declines, accounting for an average of about 20% of GDP growth over the 1948–92 period. The contribution of labor and capital together account for 74% of the average annual rate of growth in GDP. The rapid decline in TFP's contribution to growth from the 1970s onward is consistent with the findings of Denison and Jorgenson, Gollop, and Fraumeni for the U.S. and for other countries (e.g., Switzerland: Kohli; Japan, W. Germany, France, and U.K.: Boskin and Lau), although controversy tends to surround the reasons for the decline.

Some (Griliches; Boskin and Lau) suggest that the energy price shock just revealed what was already there—a decline in the underlying trend of technical change particularly in the U.S. economy—that growth opportunities of the postwar period are becoming exhausted and convergence in technology, at least, among industrialized countries has lowered the U.S.'s competitive edge. The most notable among these is attributing the slowdown to diminishing returns to science and technology. In contrast, Griliches argues that the contribution of science and technology to TFP growth has been increasing (with quality adjusted data in the computer industry). He suggests that the "immeasurable" sectors like construction, trade, services, and government lie at the core of the problem to measure TFP contributions.

Jorgenson, Gollop, and Fraumeni's estimates of TFP's contribution to U.S. GDP growth is 24%, while that of Denison and Boskin and Lau are 42% and 49%, respectively. These estimates differ, in part, due to different time periods and do not include real price effects.

The second result is the small total contribution to growth from changes in relative prices but a strong contribution from changes in the prices of services alone.[8] The total contribution only averages 0.17% (or 5% of average growth) for the sample period. However, a decomposition of these effects reveals a strong positive contribution from changes in the relative price of services, accounting for an average 12.25% of the average growth in GDP. Five-year averages of the effects of the price of services show a decline until the early eighties and an increasing contribution thereafter. The farm goods price effects have been consistently close to zero in spite of the fact that farm prices have been falling relative to the prices of industrial goods and services.

The rise in the relative price of services, with its favorable contribution to growth, has (as will be seen later) been the major contributor to an increase in labor wage and labor's share in GDP. The relative rise in the price of services can be viewed as contributing to a decline in the share of other sectors in the economy and forcing them to compete more dearly for labor. The real growth in price of services likely reflects both improvements in the quality of services provided (particularly in electronics and information processing) and the growth in demand from rising real incomes.

Growth attributable to changes in individual input quantities (labor and capital) suggests that labor's contribution to GDP growth averages about 36%, but its contribution is highly variable, exhibiting cyclical behavior. The variability in labor's contribution has been explained largely by factor market rigidities. During the down side of business cycles, firms are able to reduce costs more quickly by cutting their work force than by idling plant and equipment for which debt and equity payments are largely independent of the degree of capacity utilization (Hansen). Hence, the burden of adjustment to business cycles tends to fall disproportionately on the labor market.

Changes in capital input is the single largest contributor to growth (39%) and the most consistent, although its contribution has also been on the decline since late sixties. If technological progress is labor using, a declining contribution to growth from capital is not surprising. Table 1 compares this study's estimates with those of Denison; Jorgenson, Gollop, and Fraumeni; and Boskin and Lau. This study's estimates of input contributions are similar to that of Jorgenson, Gollop, and Fraumeni.

The Econometric Results on the Linkages to Farm Sector

Insights into the competition for resources among the three sectors with emphasis on the farm sector is provided by econometric estimates of the parameters of the share equations (10) and (11). The econometric model appears to fit the data surprisingly well, as indicated by the high t ratios in table 2 and the system R^2 of 98%. The property that (5) is convex in prices implies that the matrix of second-order derivatives corresponding to the price vector is positive semidefinite. This means that the characteristic roots (eigenvalues) of the matrix formed by columns 1 to 3 and rows 1 to 3 of table 2 are all positive. Computation of the roots revealed all three to be positive. Specific attention is given to supply response from changes in labor and capital endowments (Rybczynski-like effects) and returns to labor and capital from changes in output prices (Stolper-Samuelson-like

[8] The net contribution of price changes to growth is small because, changes in terms of trade to one sector are partially compensated for gains in another sector.

Table 2. Share Equations Parameter Estimates and *t*-Ratios

Shares	Agri-culture Price	Industry Price	Services Price	Labor	Capital	Time
Agriculture	0.037	0.069	−0.106	−0.007	0.007	−0.0003
	(3.1)	(8.9)	(−10.1)	(−1.5)	(1.5)	(−0.5)
Industry	0.069	0.276	−0.345	0.096	0.096	−0.0071
	(8.9)	(12.1)	(−15.3)	(−7.8)	(7.8)	(−13.8)
Services	−0.106	−0.345	0.450	0.103	−0.103	0.0074
	(−10.1)	(−15.3)	(17.9)	(7.2)	(−7.2)	(14.0)
Labor	−0.007	−0.096	0.103	0.061	−0.061	0.0013
	(−1.5)	(−7.8)	(7.2)	(8.5)	(−8.5)	(6.5)
Capital	0.007	0.096	−0.103	−0.061	0.061	−0.0013
	(1.5)	(7.8)	(−7.2)	(−8.5)	(8.5)	(−6.5)

effects).[9] In general, results imply that changes in sectoral terms of trade and economy-wide factor availability affect the farm sector so that, in principle, the evolution of the sector, and its contribution to GDP growth cannot be viewed in isolation from the rest of the economy.

Rybczynski-like Linkages. The Rybczynski elasticities (supply response to changes in primary inputs) are computed from the parameter estimates of share equations in table 2 and are reported in table 3 (columns 4 and 5, rows 1 to 3). For a Heckscher-Ohlin-Samuelson economy (two outputs—two inputs), the Rybczynski theorem essentially states that the industry which uses a factor relatively intensively will expand more than proportionately to an increase in the factor's supply, while the other industry will decline. The theorem does not generalize per se for the three-by-two economy modeled here, although it can be shown that the sector using an input intensively will expand relative to other industries, unless production is joint. Specifically, the results suggest that the farm sector responds to the pattern of growth of labor and capital resources in a manner

[9] We refer to these as "like" effects, since Rybczynski and Stolper-Samuelson theorems do not necessarily apply to the general case (Woodland).

Table 3. Net Supply and Factor Return Elasticities

	Elasticity					
	Agri-culture Price	Industry Price	Services Price	Labor	Capital	Time
Supply						
Agriculture	0.14	2.62	−2.76	0.42	0.58	−0.004
Industry	0.16	0.05	−0.21	0.47	0.53	−0.008
Services	−0.22	−0.28	0.50	0.89	0.11	0.022
Factor Returns						
Labor	0.02	0.40	0.58	−0.27	0.27	0.008
Capital	0.05	0.82	0.13	0.47	−0.47	−0.002

similar to the industrial sector. The net (output) supply elasticities of farm and industrial sectors with respect to capital (0.58 and 0.53, respectively) are larger than are the elasticities with respect to labor (0.42 and 0.47); however, the reverse is the case for services. The services sector is more responsive to changes in labor than to capital (0.89 vs 0.11). These factor intensities are consistent with the findings of Jorgenson, Gollop, and Fraumeni that the share of labor in services sectors and the share of capital in farm and industrial sectors are large and increasing.

Supply Response. The price effects on net supply are presented in table 3 (columns 1 to 3, rows 1 to 3). The direct farm price elasticity of 0.14 falls within the 0.10 to 0.23 range obtained from the studies reviewed by Binswanger. The direct price elasticity is expected to be more inelastic than the direct price elasticity of individual crops. The industrial sector's supply response to its own price is inelastic (0.05) in contrast to the services sector (0.50). The presence of a fairly large and positive cross-price elasticity between net farm supply and industrial sector prices (2.62) and a positive cross-price elasticity between net industrial supply and farm sector prices (0.16) suggests that intermediate products link the sectors in a complementary way. The industrial sector includes food processing and marketing (nondurables) which adds value to a large proportion of farm goods, while the farm sector uses a number of intermediate inputs, such as chemicals and farm machinery, produced by the industrial sector. The U.S. Department of Agriculture's Food Marketing Review reports that the food marketing system (processing, wholesaling and retailing, transportation, and others) added an estimated $614 billion to agriculture and fishery's raw product base of $137 billion.[10] Hence, an increase in demand for value added increases the price index of industrial product which in turn, results in an increase in supply of the farm sector's product.

The negative farm and industrial cross-price elasticities with respect to services, and those of services with respect to farm and industrial prices, are indicative of the competition between these two sectors and the services sector for resources induced by changes in sectoral terms of trade. The relative magnitude of these elasticities suggests that the prices of industrial and service outputs have relatively large effects on farm product supply, perhaps owing to the farm sector's small share of total GDP.

Stolper-Samuelson-like Linkages. The Stolper-Samuelson elasticities are reported in table 3 (elements in columns 1 to 3 and rows 4 and 5). Stolper-Samuelson-like effects suggest that if the farm and industrial sector use capital intensively relative to labor, and services use labor intensively relative to capital (as the results discussed in the previous section imply), then an increase in the relative price of farm and/or industrial goods should have a greater impact on the price of capital than labor. The Stolper-Samuelson theorem essentially states that the rental rate of a factor will rise more than proportionately to a rise in the output price of the industry which uses this factor relatively intensively. The theorem does not hold for the case of joint production nor does the proportionality condition necessarily hold in the three-by-two economy modeled here. Further, an increase in the price of services should have a larger impact on wages than on capital rental rates. In general, these are the results obtained. A rise in the price of farm output causes a larger impact on the rental rate of capital than on wages (0.05 vs 0.02). A rise in the price of industrial sector likewise causes the rental rate of capital to rise relative

[10] The farm sector receives, on average, only 38 cents of the consumer's dollar spent on all food products as return to resources, leaving 62 cents to pay for the resources adding value to the its product.

to wages (0.82 vs 0.40). The industrial sector has a greater impact on rental rates than the farm sector because it employs relatively more labor and capital. An increase in the price of services has a large impact on wages relative to capital rental rates (0.58 vs 0.13). Hence, labor benefits the most from a rise in the price of services and capital from a rise in the price of industrial goods. While a rise in the price of services bids up wages, the consequent contraction of the farm and industrial sector tends to decrease the net demand for capital causing capital rental rates to fall. The price of farm goods has little impact on factor returns and, hence, GDP, while the price of industrial goods has the largest impact (0.40 and 0.82, respectively). Or, put another way, a percentage rise in the price of industrial goods, all else constant, will tend to raise the *costs of production* more than the same change in the relative output price of either of the other two sectors.

The results obtained support the notion that the production of industrial goods is capital intensive while services output is labor intensive relative to other sectors of the economy. In addition, the hypothesis that an increase in output price tends to have the largest effect on the rental rate of the factor that is used intensively in the sector is well supported by these results.

Factor Substitution. The elasticities presented in columns 4 and 5 and rows 3 and 4 of table 3 show the effects of factor rental rate's response to an increase in its own and other factor supplies. The own factor price to factor level elasticities for labor and capital are -0.27 and -0.47, respectively, which suggests that labor is relatively inelastic to changes in wages compared with capital. Although trivial, the substitutability between the two inputs is apparent from the positive cross-price elasticities.

The Pattern of Productivity Growth. The effects of technological change on supply and factor rental rates are measured, up to a factor of proportionality, by the coefficients of a trend variable (time) in the share equations (table 2). The empirical model does not have sufficient structure to identify the sources of technological change. However, it is possible to draw inferences on the relative rates of augmentation of outputs and utilization of inputs at the economy level.

All of the parameter estimates of the time variable are significant except for the farm sector. They suggest that the relative effect of efficiency gains has been to increase the production of services and to decrease the production of industrial goods, with possibly some tendency to be neutral to the production of farm goods. Jorgenson and Gollop find that technological change is the primary source of output growth in agriculture and is biased in the direction of using capital. The results here may suggest that this source of the sector's growth is likely to be just sufficient, in relative terms, to overcome the growth in labor-using technological change that benefits the services sector. These estimates also suggest that the cause for efficiency gains can be attributed to an increase in the productivity of labor. The parameter estimate of time (0.0013) in the labor share equation implies that technological change has increased labor's share of GDP relative to capital. Hence, technological change over the period appears to have been biased in the direction of using labor and saving capital, thus providing a positive incremental effect on real wages. Since the services sector is labor intensive, a rise in labor productivity causes this sector's share of GDP to expand, while the shares of other sectors contract. The augmentation in labor productivity has increased the services sector's capacity to, at the margin, bid primary resources away from the other sectors. Hence these results are consistent with the Rybczynski theorem. They are also consistent with the findings of Jorgenson, Gollop, and Fraumeni that labor-using productivity growth predominates for the U.S. economy as a whole. While Berman, Bound, and Griliches find that the industrial sector has experienced labor-saving capital using technological change, as has the farm sector (Hayami and Ruttan), these results suggest that the productivity growth of labor dominates that of capital. Assuming equal incremental costs of obtaining efficiency gains in labor and capital, technological change appears not to have been of the nature that has saved the economies most scarce resource (labor). Education and other factors augmenting human capital likely increase efficiency economy wide; whereas, efficiency gains from capital may be specific to sectors.

To gain additional insights into these relative rates of technological change, two additional forms of the trend variable are specified. First, a square of the trend variable time was included in addition to the linear trend. The coefficients of the trend are similar to the one obtained earlier, but the coefficients of the square of the trend are neither significant nor of a different sign. Second, to test for significant difference in these rates before and after the energy price shock, a dummy $\delta_1\, dt$ and $\delta_2(1 - d)t$, where $d = 1$ for the years 1972–92, t is the trend, and (δ_1, δ_2) are the parameters, is added instead of the trend. Both the coefficients are significant, but their magnitudes are not significantly different at a 95% confidence level.

The semielasticities of supply of outputs and factor returns with respect to the time trend, equation (17), are in the last column of table 3. Results suggest that the technological change augmented the output of services sector at an annual average rate of 2.2%, while having a tendency to decline the output of the industrial sector (−0.8%). However, the relatively small semielasticity of agricultural output (−0.4%) lends additional support to the earlier claim that technological change has tended to be relatively neutral towards farm output.

Contributions to Predicted Sector Shares. As a sector's share of GDP rises, the sector also employs a larger share of the economy's resources. The next step is to use the estimated parameters to measure the contribution of prices, inputs, and technological change to the predicted value of each sector's share of GDP; effectively, this analysis identifies the factors contributing to a sector's competitiveness. To illustrate, the predicted output share of a sector is given by

$$(15) \qquad \left(\frac{dS_n}{dt}\right)\left(\frac{1}{S_n}\right) \equiv \hat{S}_n^t \equiv \sum_{i=A,N,S} \hat{\alpha}_{ni}\frac{d \ln p_i^t}{dt} + \sum_{j=L,K} \hat{\beta}_{nj}\frac{d \ln v_j^t}{dt} + \hat{\alpha}_{nt}\, dt.$$

The results of fitting (21) are reported in table 4. The negative (positive) numbers at the bottom of the table sum the total contributions for sector's whose share of GDP has declined (increased) over the period 1948–92. Positive numbers in the body of the table indicate the percentage contribution of the row variable to increasing the sector's predicted share while negative numbers indicate a negative contribution to the sector's predicted share of GDP.

The largest single contributor to the decline in farm and industrial sectors' share of GDP (−252, −161) is the change in the terms of trade in favor of services sector relative to the other two sectors. The favorable terms of trade for services increased its capacity to bid labor and capital away from the other sectors, causing, all else constant, a larger percent increase in labor's share of GDP than in capital's share. The growth in labor contributed a small negative amount (−6 and −16%, respectively) to the decline of the farm and industrial sectors' share of GDP. This result follows from the relative labor intensity of the services sector. The growth in capital contributed slightly larger positive effects to the farm and industrial share of GDP (11 and 29%, respectively), owing to

Table 4. Contributions to Predicted Sectoral Shares of GDP

	Agriculture	Industry	Services	Labor	Capital
Prices					
Agriculture	123	96	−100	−7	211
Industry	42	15	−20	−4	10
Services	−252	−161	176	105	−305
Endowments					
Labor	−6	−16	14	22	−63
Capital	11	29	−26	−41	118
Time	−18	−64	57	25	−72
Sum	−100	−100	100	100	−100

Note: A negative sum implies negative average share changes over the period 1949–92.

their relative capital intensity. Interestingly, technological change overall contributed insignificantly to the farm sector's share (−18%) but negatively to the industrial sector's share (−64%). While productivity growth is neutral towards the production of farm output, the rate of technological change is higher (lower) in the services (industrial) sector. These results are consistent with Jorgenson, Gollop, and Fraumeni that some services sectors like air transportation, water and sanitary services among others had productivity growth greater than 5%, while the rate of technological change in farm output is about 1.5% per annum.

Changes in industrial and services sector shares are affected positively by growth in levels of capital and labor, respectively, owing to their relative factor intensities; whereas the effect on the farm sector is relatively neutral. The result that the effect of technical change on the farm sector is not significant (−18) relative to the industrial sector suggests that technical change within the sector is large enough to compensate for the productivity growth that increased the capacity of firms in the services sector to bid for resources. As noted earlier, labor's share of GDP has grown until 1972 but declined only in the late eighties. The favorable terms of trade for services and technological change are the major factors accounting for the growth in labor's share, while they are also the major factors contributing to a decline in capital's share of GDP. Changes in the price of farm goods, in contrast to changes in the price of industrial goods, have a surprisingly strong effect (211) on increasing capital's share of GDP. The contribution to labor's share from the growth in labor (22%) is lower than the contribution to capital's share from growth in capital (118%). The growth in capital had a larger impact on reducing labor's share of GDP (−63) than did the growth of labor on capital's share (−43).

Summary and Conclusions

The average contributions to GDP growth, ranked from highest to lowest, are changes in the levels of capital and labor, which together account for almost 80% of average growth, TFP, and changes in sectoral terms of trade in favor of services. While considerable year-to-year variation in contributions to growth exists, the contribution from changes in capital show a pronounced decline starting in the mid-1960s and a downward trend in all factors since the late 1970s.

Rybczynski-like effects appear to prevail with the farm and the industrial outputs responding positively to positive changes in the levels of capital and negatively to positive changes in the level of labor. The services sector is found to respond positively (negatively) to positive changes in labor (capital). These, together with other results, suggest that the services sector employs labor intensively relative to the farm and industrial sectors. All else constant, as labor grows relative to the growth in capital, the output of services tends to grow relative to the growth in output of the farm and manufacturing sectors. Positive cross-price elasticities between the farm and industrial sector suggest some complementarity between the sectors, which is conjectured to result from the industrial sector adding value to a large portion of the farm sector's output, and to the farm sectors use of inputs manufactured by the industrial sector. Growth in demand for attributes added to food and fiber outputs of the farm sector by the industrial sector appear to have a positive effect on the supply of farm sector output.

The services sector appears to be the major contributor to GDP growth due to favorable changes in its terms of trade, growth in labor levels, and technological change that, at the economy-wide level, is labor using. Each of these changes have helped to increase the sector's share of GDP at the expense of other sectors, and through Stolper-Samuelson-like effects, to have increased labor's share of GDP (and thus decreasing capital's share). Not surprisingly, given the observed time trends in the levels of labor, capital, the prices of traded goods, and the labor using technological change, the farm sector output share is far more strongly affected by the the industrial and services sectors of the economy than its effect on them. Relative technological change has favored the services sector, while staying neutral towards the production of farm goods. Hence, it is likely that technological change within the farm sector, which this approach is unable to identify at this level of aggregation, has played a major role in helping the sector compete for economy-wide resources. Agriculture is strongly influenced by the rest of the economy and the neutrality of overall technical change has been significant to the growth of farm output.

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