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Capital Adjustment in U.S. Agriculture and Food Processing

A Cross-Sectoral Model

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Abstract

Significant differences exist in the rates of capital adjustment in the four major sectors (agriculture, food processing, manufacturing, and services) of the U.S. economy. The properties of a quadratic value function from a multi-output adjustment cost model are used to derive dynamic supply and investment demand of the four sectors, which are then fitted to time series data. Our estimates show that capital in agriculture and manufacturing is almost fixed and adjusts toward longrun equilibrium at a rate of about 2 percent per year. The food processing and services sectors are more flexible in that their capital stocks fully adjust in less than 5 years. Theoretically consistent supply elasticities further validate the results. Strong linkages among the four major sectors of the economy are also identified. The rates of capital adjustment help explain the pattern of capital's contribution to growth in the various sectors of the economy.

Keywords: Adjustment Costs, Dynamic Supply and Investment Demand, Agriculture, Food Processing.

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Summary

Capital is a crucial input to the growth of the U.S. economy and has contributed about 40 percent of the growth in Gross Domestic Product (GDP). However, significant differences exist in its contribution to the growth of various sectors of the economy. For instance, capital contributed less than 3 percent to the growth in agricultural output, while it accounted for about one-third and one-fourth of the growth in food processing and manufacturing sectors. The above pattern reflects, in part, the ability of the sectors to adjust their capital, and thus, to augment output.

Capital adjustment was estimated using a specific-factors model for four sectors of the U.S. economy. Over the period 1959-91, the average rate of capital adjustment in agriculture and manufacturing was about 2 percent per year. The food-processing and services sectors are more flexible in the sense that their capital stocks fully adjusted in less than 5 years. Longrun and shortrun elasticities of supply and investment demand were also estimated. Most of the elasticities were consistent with those predicted by theory, further validating the above adjustment rates. The magnitude of the cross-price elasticities suggests strong linkages among the four major sectors of the economy.

The rates of capital adjustment help explain the pattern of capital's contribution to growth in the various sectors of the economy. As agricultural capital remains relatively fixed, productivity growth appears to be the major source of future agricultural growth.

Capital Adjustment in U.S. Agriculture and Food Processing: A Cross-Sectoral Model

Carlos Arnade and Munisamy Gopinath

Introduction

Capital is a crucial input to the growth of the U.S. economy. Over 1948-92, capital accumulation has contributed, on average, about 40 percent of the growth in Gross Domestic Product (GDP) of the United States (Jorgenson et al. 1987; Gopinath and Roe 1996). However, significant differences exist in its contribution to the growth of various sectors of the economy. Capital contributed less than 3 percent to the growth in agricultural output, while it accounted for about one-third and one-fourth of the growth in food processing and manufacturing sectors over the period 1959-91 (Ball et al., 1995; Gopinath et al., 1996; U.S. Department of Labor). The above pattern reflects, in part, the ability of the sectors to adjust their capital, and thus, to augment output.[1]

The agricultural sector is unique among the sectors of the economy because its production depends on weather and involves long time lags. As a result, once invested, agricultural capital stays fixed within the sector and is often used beyond its productive life. Johnson and Quance (1972) assert that if an asset's value in use is less than its acquisition price but greater than its salvage value, then assets can become trapped in their current uses. Others (Vasavada and Chambers 1986; Luh and Stefanou 1993) have empirically demonstrated the fixity of agricultural capital.

Capital fixity and, thus, its slow rate of adjustment in agriculture imply that (i) the creation of new capital to augment output or its reallocation to alternate uses is slow, and (ii) it takes a long time for the adoption of new technology embodied in capital inputs. Conversely, if capital in other sectors adjusts faster, these sectors may use relatively newer capital equipment, which could give them a productivity advantage. This could make agriculture a less than attractive investment in capital markets. Hence, capital investment in agriculture will stay low suggesting that agricultural growth should arise from other inputs or technology.

Following Epstein's (1981) demonstration of the applicability of dynamic duality theory, a number of empirical studies have attempted to measure the rate of input adjustment in individual sectors (for agriculture--Vasavada and Chambers 1986; Howard and Shumway 1988; Luh and Stefanou 1993; for manufacturing--Epstein and Denny 1983; Meese 1980). Applications both to agriculture and manufacturing have been partial equilibrium in nature and have ignored the linkages among the major sectors of the economy. The focus on individual sectors is important

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[1]Other factors like capital-saving or labor-using technical change can also explain the pattern of capital's contribution to growth in various sectors.

but provides little insight into the differences in input adjustment behavior between the sectors. For instance, if capital is relatively fixed in agriculture, a decline in its terms of trade with the rest of the economy would not only lower returns to capital in agriculture, but would also hinder the reallocation of resources between sectors. Thus, fixity affects both the returns to agricultural capital and the growth of the agricultural sector.

Taxpayer subsidization of research and development (R&D), and extension in agriculture is a recurring policy issue, despite strong evidence on the linkages between public agricultural R&D and total factor productivity (TFP) growth (Huffman and Evenson 1993; Alston and Pardey 1996; Gopinath and Roe 1995). With a fixed capital, if productivity growth is not forthcoming, then the agricultural sector is unlikely to grow significantly.

The objective of this paper is to estimate the rates of capital adjustment and the resulting divergence between the shortrun and longrun responses of supply and capital demand in four major sectors of the U.S. economy. Specifically, we test whether (i) agriculture is constrained by sluggish capital adjustment relative to the rest of the economy and, (ii) agricultural output is more responsive to economy-wide changes than other sectors of the economy.

A multi-output framework with profit-maximizing forward-looking agents and capital adjustment costs is used to represent economic decisions. Capital is assumed to be specific to each of the four sectors. Labor is treated as an input that is mobile among the four sectors. Dynamic output supply and quasi-fixed factor investment are derived from a dynamic optimization problem and econometrically estimated as a system of simultaneous equations. For this purpose, annual time series data for the period 1958-91, from National Bureau of Economic Research (NBER) productivity database (Bartelsman and Gray, 1994) and U.S. Department of Commerce, are used.

The paper is organized as follows: the next section outlines the dynamic adjustment cost framework, followed by the presentation of estimation results. Summary and policy implications are discussed next. Data are briefly described in the Appendix.

The Model

The existence of input adjustment costs has provided the basis for many dynamic models in the economic literature (Sargent 1978; Epstein 1981; Vasavada and Chambers 1986). A multi-output adjustment cost model assumes the existence of a transformation function:

$$F(y, x, I, K, t) = 0, \qquad (1)$$

where y is a vector of outputs, x a vector of variable inputs, K is a vector of quasi-fixed inputs, I is a vector representing new investment in the quasi-fixed input, and t is time. F is a continuous, twice differentiable function that is strictly increasing in y, decreasing in x and K, and strictly increasing in I.[2] The final assumption represents adjustment costs. New investment must be transformed into capital stock. This transformation requires resources in the short run. Therefore capital investment has the opposite influence on the function F(.) as does the level of capital, K. If there were one output and the equation were explicitly solved for that output, production would appear as decreasing in investment (I). Investment activity diverts resources rendered toward production and temporarily decreases output. For example, production lines are often temporarily shut down when new equipment is installed.

Profit-maximizing firms that have adjustment costs make dynamic decisions in a forward-looking manner, i.e., a choice on investment influences output across a range of time periods.

$$\max_{(y,\, I,\, x)} \{ \int_0^\infty e^{-rt} (p^T y - c^T x - w^T K)\, dt \}$$
$$\text{s.t.} \quad \dot{K} = I - \delta K; \quad F(y,\, x,\, I,\, K,\, t) = 0; \quad K(0) = K_0 \text{ given,} \tag{2}$$

where p is a vector of output prices, c is a vector of variable input prices, w is a vector of rental rates of quasi-fixed factors, δ represents the rate of depreciation, and s.t. represents the phrase "subject to." The solution to the problem in equation 2 is the value function J(p,c,K,t), which is a function of output and input prices, and levels of the quasi-fixed factors (Epstein, 1981). The firm expects prices at t=0 to persist indefinitely, but as new prices are observed, the firm continuously revises its previous plans. *Thus, only the t=0 part of the plan is carried out.* An alternative formulation of the problem in equation 2 is the Hamilton-Jacobi equation (Intriligator, 1971). Letting $J(p,c,w,K_0,t)$ denote the optimal value for the problem in equation 2, the Hamilton-Jacobi equation takes the form,

$$r\, J(p,c,w,K_0,t) = \max_{(y,I,x)} \{p^T y - c^T x - w^T K + J_{K_0} (p,c,w,K_0,t)^T (I - \delta K_0)\} + J_t\,. \tag{3}$$

Note that J denotes the total value of the firm over the infinite horizon (a stock), while, rJ denotes a single-period flow. Intuitively, the problems in equations 2 and 3 are equivalent in the sense that the solution to equation 3 (one-period choice) lies in the path derived by equation 2.

The advantage of the above formulation is that it is possible to utilize the envelope properties of the optimal value function, which were derived by Epstein (1981), without explicitly solving the dynamic problem. The properties of the value function are explained in detail elsewhere (Epstein, 1981). The supply, variable input demand, and quasi-fixed factor investment are derived from the value function as follows:

[2]F is closed and convex in y, x, K, and I.

$$y = rJ_p - J_{K_0 p}\dot{K} - J_{tp},$$

$$x = -rJ_c + J_{K_0 c}(I - \delta K_0) + J_{tc}, \quad \dot{K} = [J_{K_0 w}]^{-1}(rJ_w + K_0 - J_{tw}), \tag{4}$$

where J_i denote the derivative of the value function with respect to i=c,w, p, K. We consider four outputs, agriculture, food processing, manufacturing and services; one variable input, labor; four quasi-fixed and sector-specific capital stocks, one each for agriculture, food processing, manufacturing, and services. We specify a function that uses the properties in equation 4 to derive the output supply, variable input demand, and quasi-fixed investment as functions of (p,c,w,K,t). Thus, equation 4 along with an assumed quadratic functional form provides the basis for an empirical investigation into supply and investment demand. A normalized (on labor price) quadratic value function is given by:

$$J(p,c,w,K,t) = a_o + \sum_{i=1}^{4} a_i * p_i + \sum_{j=1}^{4} b_j * w_j$$
$$+ 1/2 \sum_{i=1}^{4}\sum_{l=1}^{4} a_{il} * p_i * p_l + 1/2 \sum_{j=1}^{4}\sum_{m=1}^{4} b_{jm} * w_j * w_m + 1/2 * \sum_{i=1}^{4}\sum_{j=1}^{4} c_{ij} * p_i * w_j \tag{5}$$
$$+ \sum_{i=1}^{4}\sum_{n=1}^{4} d_{i,n} * p_i * K_n + \sum_{j=1}^{4}\sum_{n=1}^{4} e_{jn} * w_j * K_n) + \sum_{i=1}^{4} g_i * t * p_i + \sum_{j=1}^{4} h_j * t * w_i + q * t,$$

where (p_1, p_2, p_3, p_4) are output prices for agriculture, food, manufacturing and services respectively; (w_1, w_2, w_3, w_4) and (K_1, K_2, K_3, K_4) are the rental rates and levels of respective capital in the four sectors; and t is a trend variable that is a surrogate for technological change. All prices in the value function were normalized on the price of labor.

Classification of capital into four distinct types represents one aspect of a specific factors model. To ensure that capital adjustment in each sector is a function of the type of capital used in that sector only, the following restriction on the coefficients of the function in equation 5 are imposed:

$$e_{jn} = 0, \text{ if } j \neq n; \ j, \ n = 1,2,3,4 \tag{6}$$

Note that equation 5 satisfies the condition for consistent aggregation over firms $J_{KK} = 0$. The empirical counterparts to equation 4, supply and investment equations for four outputs and four capital stocks, can then be derived from equation 5. The estimated equation representing the supply of agriculture is:

$$Y_1 = r(a_1 + \sum_{l=1}^{4} a_{1l} * p_l + \sum_{j=1}^{4} c_{1j} * w_j + \sum_{n=1}^{4} d_{1n} K_n)$$
$$-\sum_{n=1}^{4} d_{1n} * (I_n - \delta K_n) + g_1 * t - g_1 \tag{7}$$

where I_n is investment in capital K_n. Similar equations are specified for the other three outputs.

Using equation 4 and the derivatives of the value function, the equation representing changes in capital, K_1 (in agriculture) is:

$$\dot{K}_1 = \frac{K_1 + r\,(b_1 + \sum_{m=1}^{4} b_{1m} * w_m + \sum_{i=1}^{4} c_{i1} * p_i + e_{11} * K_1 + h_1 * t) - h_1}{e_{11}} \tag{8}$$

Similarly, investment equations for food processing, manufacturing, and services are derived from equation 5. Though supply and variable input demand equations are linear in parameters, the capital investment equation is not. However, the investment equation can be rearranged and estimated in linear form. For example, rewrite equation 8 as:

$$\dot{K}_1 - rK_1 = \theta_1 * K_1 + \theta_2 * r + \sum_{m=1}^{4} \alpha_{1m}(w_m * r) + \sum_{i=1}^{4} \beta_{i1}(p_i * r) + \gamma_1 * t - \gamma_1,$$
$$\text{where,} \quad \theta_1 = \frac{1}{e_{11}}; \quad \theta_2 = \frac{b_1}{e_{11}}; \quad \alpha_{1m} = \frac{b_{1m}}{e_{11}}; \quad \beta_{i1} = \frac{c_{1i}}{e_{11}}; \quad \gamma_1 = \frac{h_1}{e_{11}}. \tag{9}$$

Equations 7 and 9 form a system of simultaneous equations which can be estimated using linear estimation techniques. Note that our system of equations in 8 can be simplified to be linear in the parameters as in equation 9 because of the univariate-flexible accelerator form of the model. This simplification is possible because the model was specified as restricting one sector's capital investment to be independent of the level of capital in other sectors. When a system of equations is nonlinear in parameters, iterative search routines are used to obtain parameter estimates. Often in nonlinear estimation, final parameter estimates are sensitive to an analyst's estimate of starting values, the algorithm used, the step size used over a grid search, and the convergence criteria. However, the cost of simplifying the model would be that we cannot perform hypothesis tests on the individual parameters of the ratios described in equation 9.

Recall that all prices must be normalized on one of the prices because equation 5 represents a normalized quadratic value function. The price of labor (wage) was chosen to be the numeraire for the system. Since there are four specific factors, the estimated system contained four supply equations and four capital adjustment equations. Following conventional practice (Chambers and Vasavada, 1986; Howard and Shumway, 1988) changes in quasi-fixed factors were represented by first differences of annual data. Right-hand side values of K in equation 7 and 9 were represented by capital lagged by one period. A fixed interest rate of 5.5 percent was used in the estimation.[3] In addition, the agricultural output price index was lagged by one period to account for the lag in production. The SYSLIN procedure in SAS was used to estimate four output supply and four investment equations, using 3SLS (instrumental variables, Bowden and Turkington, 1983). Symmetry among output equations was imposed, but it was not possible to impose the complete set of symmetry restrictions, as investment equations are specified in reduced form. Tests failed to reject the null hypothesis of symmetry among the output equations. In addition, the vital statistics of the model appeared to depend on the imposition of the symmetry restrictions. The parameter estimates of the eight equations are presented in tables 1A and 1B. High t ratios and a system R-square of 97 percent suggest that the model is a good fit to the data.[4]

Results

In this section, we first discuss the rates of adjustment of capital in the four sectors of the U.S. economy. This will set the stage for a comparison of shortrun and longrun elasticities because a slow rate of adjustment would imply larger differences between these elasticities. In addition, theoretically consistent elasticities also validate the results on the rates of adjustment.

Capital Adjustment

Notice that the equations in 9 can be rewritten to represent a univariate-flexible accelerator model with constant adjustment coefficients as:

$$\dot{K}^{*} = M\ (K - \bar{K}) \quad . \tag{10}$$

where M is a diagonal matrix as capital is assumed to be sector specific. The diagonal elements of the matrix, which are the constant rates of adjustment of capital in each of the four sectors, is given by $(\theta + r)$ where r is the interest rate and θ is the estimated (reduced-form) parameter on lagged capital from equation 9. A system likelihood ratio test for instantaneous adjustment of capital was performed. The constraint $\theta_i = -1+r$, $(i=1,..4)$ was imposed (Howard and Shumway,

[3]Note that the constant terms in equation 7 and 9 become reduced-form parameters because of the fixed interest rates.

[4] Non-static output price expectations were incorporated as additional laws of motion into the problem in equation 2. Equations 7 and 9 were then derived under linear and quadratic price expectations. Unfortunately all supply elasticities were negative and large under these specifications. Hence, the results from the model with static expectations alone are reported.

1988), and the system of equations was reestimated. This equation-by-equation test failed to accept the null hypothesis of instant adjustment at the 99-percent level of confidence. The chi-square statistic with 1 degree of freedom was 107.6 for agriculture, 39.4 for food processing, 20.5 for manufacturing, and 23.8 for services. The estimated adjustment rates are reported in the last three columns of table 2. The 95-percent confidence intervals (upper and lower bounds) for the adjustment rates were also derived.

The adjustment coefficients for agriculture, food processing, and services sectors are significant at the 5-percent level of confidence. They suggest that the rate of adjustment of capital (in percent) in the food processing sector is relatively fast and falls in the interval [35.4 percent, 46 percent], while that of the services sector falls in [23.9 percent, 36.3 percent]. The calculated rates for the manufacturing sector indicate relatively low rates of adjustment of capital in that sector (annual average of 2.2 percent per year). Epstein and Denny (1983) reported a relatively low adjustment rate of capital in manufacturing at 12 percent per year for the period 1947-76, while Meese (1980) found quarterly adjustment rates of 3 percent, which translates into 12.6 percent per year. As our sample includes the 1980's, which witnessed a relative decline of the manufacturing sector, the slow adjustment is not surprising. As mentioned earlier, these rates of capital adjustment are consistent with the observed pattern of capital's contribution to GDP growth. In the more dynamic sectors like food processing, capital's contribution to growth is high.

Capital adjustment in agriculture indicates that its capital behaves almost like a fixed factor. Our estimate of the rate of adjustment of agricultural capital is 2 percent per year, which is smaller than most studies (Vasavada and Chambers 1986, Howard and Schumway 1988, Luh and Stefanou 1993). However, our sample is different from the other studies and includes the 1980's.

The agricultural and manufacturing sectors' rates of capital adjustment are low compared with those of other sectors of the U.S. economy. For any given change, it takes under 5 years for the services and food processing sectors to adjust to their levels of steady-state capital, while the manufacturing and agricultural sectors take more than 30 years to adjust. Such resource fixity makes the returns to capital highly variable. It also makes the returns to capital relatively low because the marginal product of capital remains fixed while the real price index of agriculture and manufacturing are falling (Gopinath and Roe, 1996). In particular, agriculture's ability to grow by increasing capital is negatively affected. As a result, the sector is more responsive to other nonconventional sources of growth, particularly technological change. This view is consistent with several studies that show that total factor productivity (TFP), which includes technological change, has been the major contributor to agricultural growth over the post-war period (Ball et al. 1995; Jorgenson et al. 1987; Gopinath and Roe 1995).

Supply and Capital Demand Elasticities

Capital is fixed in the short run, but is allowed to adjust in the long run. Shortrun elasticities are those obtained when quasi-fixed factors are held fixed. Longrun elasticities are the responses given quasi-fixed factors have fully adjusted to their longrun optimal or desired levels (steady state). The lower the rates of capital adjustment in these sectors, the larger will be the difference between the shortrun and longrun elasticities. In the short run, the supply and capital demand responses need not be consistent with what static economic theory would predict, because there are adjustment costs to quasi-fixed factors. However, in our case, we obtain theoretically consistent supply elasticities both in the short run and long run. In the case of capital demand equations, only one of the four own-price demand elasticities (manufacturing sector) has the wrong sign in the short run and long run.

Shortrun supply and input (capital) demand elasticities are presented in table 3. (P1, P2, P3, P4) and (CP1, CP2, CP3, CP4) are output prices and capital rental rates, respectively. Elements in rows and columns 1 to 4 represent own- and cross-price supply elasticities. Agriculture's own-price response is 0.22, the smallest among the four sectors, while the other 3 sectors are relatively more responsive to prices. Most partial equilibrium studies report relatively large own-price supply elasticities for agriculture, but general equilibrium studies that take into account sector-specific resource constraints have found low supply elasticities (Binswanger 1989, Gopinath and Roe 1996). The food processing sector appears to be complementary to agriculture. In general, the large cross-price elasticities suggest strong linkages among these four sectors of the economy.[5]

An increase in the rental rate of agricultural capital decreases its output (-0.1), as expected. Similar responses are obtained for the manufacturing and services sectors. However, the effect on food processing output from an increase in its capital's rental rate is positive, but note that shortrun responses need not be of the right sign.

Capital adjustment in agriculture and manufacturing is found to be relatively lower than the rates of adjustment in services and food processing sectors (table 2). The diagonal elements of the matrix formed by rows and columns 4 through 8 suggest sluggish adjustment of capital in all four sectors. The shortrun response of capital in food processing to an increase in its rental rate is the largest (-0.16), followed by that of services and agricultural capital (-0.07 and -0.01, respectively). The positive sign on manufacturing capital's own-price demand elasticity is not contradictory, but consistent with most empirical adjustment cost models where shortrun responses can be of different sign (Treadway, 1970). The capital response to output price changes is also of interest. The demand for capital in agriculture increases as the price of agricultural output increases (0.06). Similar responses are found for the food processing, manufacturing, and services sectors (0.10, 0.11 and 0.33, respectively).

Longrun elasticities of supply and capital demand are presented in table 4. The formula used for deriving the longrun elasticities is as follows:

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[5]Note that the labor share of value added is about 70 percent in the U.S. economy. Hence, a mobile labor can bring about large cross-price responses.

$$\epsilon_{ij}^{L} = \left(\frac{\partial Y_i}{\partial p_j}\right)\left(\frac{p_j}{Y_i}\right) = \left[\left(\frac{\partial Y_i}{\partial p_j}\right)_{k=\bar{k}} + \sum_{i=1}^{4}\left(\frac{\partial Y_i}{\partial K_j^*}\right)\left(\frac{\partial K_j^*}{\partial p_i}\right)\right]\frac{p_j}{Y_i} \tag{11}$$

where K* is the steady-state capital, which was derived by setting investment equal to zero in the investment demand equations in 8.

All own-price supply elasticities are positive in the long run and are larger than their shortrun counterparts. However, the elasticities of manufacturing and food processing are relatively larger than the rest. The cross-price elasticities are qualitatively similar to the shortrun elasticities. The own-price capital demand elasticities are larger for all the sectors in the long run, except manufacturing. As before, the manufacturing sector's response has the wrong sign. One reason for the large elasticities in the long run is that these responses require all four capital stocks to adjust to steady-state levels. Since it takes substantially longer for the capital stocks of agriculture and manufacturing to adjust to their steady-state levels, we obtain large longrun elasticities. Compared with static models with constant returns to scale technologies, where such elasticities are infinite, our adjustment cost model provides plausible results.

Conclusions

Private capital adjustment behavior in the four major sectors, agriculture, food processing, manufacturing, and services of the U.S. economy are tested using a multi-output adjustment cost model. An analysis of supply and capital demand in the four major sectors is also undertaken within this longrun profit-maximizing framework. Capital adjustment rates are calculated for each sector. The resulting shortrun and longrun output and capital response to prices and rental rates are also calculated. The estimated supply elasticities are theoretically consistent and further validate the adjustment rates.

The agricultural sector's rate of capital adjustment is relatively low compared with that of other sectors of the economy, suggesting fixity of its capital. The services and food processing sectors are more flexible in the sense that their capital stocks adjust to their longrun levels in less than 5 years, while manufacturing capital takes more than 25 years to adjust. The observed rates of adjustment are consistent with capital's contribution to growth in various sectors of the U.S. economy. In the more dynamic sectors like food processing, we observe a higher contribution from capital to growth, unlike primary agriculture. Our elasticities suggest that agriculture's supply response is small, contrary to most partial equilibrium studies. The processed food and agricultural sectors are complementary and thus, a rise in the price index of food processing will increase agricultural supply. Cross-price elasticities show strong linkages among the four major sectors of the U.S. economy.

The estimated capital fixity for agriculture implies highly variable returns to agricultural capital because the residual returns from production are attributed to capital. Moreover, with fixed marginal products, falling real prices of agriculture will cause lower returns to capital in agriculture. These slow rates of capital adjustment also imply that the adoption of any technology which is embodied in new capital inputs will take longer in agriculture. It has been shown elsewhere that productivity growth in agriculture has occurred through public investments in research and development, and extension. As agricultural capital remains relatively fixed, the focus on agricultural output growth moves toward the issue of improving productivity growth.

Table 1A. Supply Equations Parameter Estimates

Variable	Agriculture	Food	Manufacturing	Services
P1	3.60	11.98	-86.92	-10.53
	(1.29)	(1.02)	(-2.03)	(-0.54)
P2	11.98	46.62	-449.83	-70.81
	(1.02)	(0.52)	(-1.75)	(-0.53)
P3	-86.95	-449.83	2303.2	682.28
	(-2.03)	(-1.75)	(2.40)	(1.60)
P4	-10.53	-70.81	682.28	183.24
	(-0.54)	(-0.53)	(1.60)	(0.74)
CP1	-8.87	-76.96	313.95	16.88
	(-0.75)	(-1.48)	(1.52)	(0.19)
CP2	15.18	61.26	-112.07	171.54
	(1.25)	(1.34)	(-0.61)	(1.86)
CP3	35.84	177.02	-496.14	-107.51
	(1.84)	(1.75)	(-1.25)	(-0.60)
CP4	-162.95	-803.79	2406.8	2.68
	(-1.86)	(-1.81)	(1.38)	(0.003)
K1P	-2.01	-8.75	51.59	12.10
	(-2.05)	(-1.48)	(2.49)	(1.22)
K2P	2.02	-11.27	33.35	47.36
	(0.85)	(-1.04)	(0.85)	(2.56)
K3P	0.15	1.65	-8.14	-3.48
	(1.23)	(2.57)	(-2.87)	(-2.87)
K4P	-0.20	-1.03	6.32	1.81
	(-2.48)	(-2.74)	(3.39)	(2.39)
TR	-0.001	-0.008	0.11	0.07
	(-1.33)	(-1.84)	(5.46)	(9.70)

1=Agriculture, 2=Food Processing, 3=Manufacturing and 4=Services; (P1, P2, P3, P4) are output prices normalized by price of labor; (CP1, CP2, CP3, CP4) are capital rental rates normalized by price of labor; (K1P, K2P, K3P, K4P) is the left-hand side of equation 9; TR is time trend.

Table 1B. Investment Demand Equations Parameter Estimates

Variable	Agriculture	Food	Manufacturing	Services
K1L	-0.0752	-0.4622	-0.0767	-0.3561
	(-1.97)	(-3.33)	(-0.73)	(-7.64)
P1	3.98	0.268	9.95	-6.82
	(3.40)	(0.71)	(1.44)	(-1.06)
P2	23.20	3.35	-15.2	-95.71
	(4.51)	(2.04)	(-0.50)	(-3.26)
P3	-35.06	3.84	52.80	1.98
	(-3.79)	(1.17)	(0.96)	(0.05)
P4	-60.95	2.25	-120.70	402.16
	(-4.53)	(0.49)	(-1.63)	(5.47)
CP1	-1.37	2.75	-2.71	-6.05
	(-0.23)	(1.41)	(-0.08)	(-0.18)
CP2	-16.34	-7.46	-49.082	179.41
	(-1.89)	(-2.90)	(-1.18)	(4.10)
CP3	16.01	-0.23	48.92	94.39
	(3.34)	(-0.16)	(1.68)	(3.69)
CP4	-19.71	11.61	-41.58	-978.45
	(-0.67)	(1.25)	(-0.25)	(-5.93)
TR	-0.003	0.001	0.01	0.036
	(-1.34)	(3.01)	(0.46)	(6.56)

1=Agriculture, 2=Food Processing, 3=Manufacturing and 4=Services; (P1, P2, P3, P4) are output prices normalized by price of labor; (CP1, CP2, CP3, CP4) are capital rental rates normalized by price of labor; (K1L, K2L, K3L, K4L) are lagged stock of capital; TR trend.

Table 2. Adjustment Rates of Capital

	θ	Standard Error (θ)	Adjustment Rates	95% conf. Interval	
				Lower	Upper
Agriculture	-0.0752	0.0383	**-0.020**	-0.036	-0.005
Food Processing	-0.4622	0.1387	**-0.407**	-0.460	-0.354
Manufacturing	-0.0767	0.1054	**-0.022**	-0.055	0.011
Services	-0.3561	0.0466	**-0.301**	-0.363	-0.239

Table 3. Shortrun Elasticities of Supply and Input Demand

	P1	P2	P3	P4	CP1	CP2	CP3	CP4
Supply								
Agriculture	0.22	0.56	-3.81	-0.40	-0.10	0.53	1.43	-0.54
Food Processing	0.40	1.16	-10.55	-1.45	-0.47	1.14	3.79	-1.43
Manufacturing	-0.18	-0.70	3.39	0.88	0.12	-0.13	-0.67	0.27
Services	-0.02	-0.11	0.98	0.23	0.01	0.20	-0.14	0.001
Capital Demand								
Agriculture	0.06	0.25	-0.35	-0.53	-0.01	-0.13	0.15	-0.02
Food Processing	0.01	0.10	0.10	0.05	0.02	-0.16	-0.01	0.02
Manufacturing	0.03	-0.04	0.11	-0.23	-0.002	-0.08	0.10	-0.01
Services	-0.01	-0.10	0.01	0.33	-0.002	0.14	0.08	-0.07

1=Agriculture, 2=Food Processing, 3=Manufacturing and 4=Services; (P1, P2, P3, P4) are output prices normalized by price of labor; (CP1, CP2, CP3, CP4) are capital rental rates normalized by price of labor.

Table 4. Longrun Elasticities of Supply and Input Demand

	P1	P2	P3	P4	CP1	CP2	CP3	CP4
Supply								
Agriculture	1.36	6.38	-12.15	-10.72	-0.18	-0.51	4.27	-0.97
Food Processing	1.38	13.65	-31.83	-12.42	-0.53	-0.05	-1.57	-0.63
Manufacturing	-0.60	-6.07	12.36	6.68	-0.07	1.09	-2.40	0.61
Services	-0.06	-0.52	-2.93	0.62	0.01	0.26	-0.26	0.06
Capital Demand								
Agriculture	2.77	11.81	-16.69	-25.22	-0.17	-6.14	6.99	-0.71
Food Processing	0.03	0.24	0.25	0.13	0.05	-0.39	-0.01	0.06
Manufacturing	1.49	-1.68	5.45	-10.83	-0.07	-4.00	4.61	-0.32
Services	-0.03	-0.32	0.01	1.11	-0.01	0.45	0.27	-0.23

1=Agriculture, 2=Food Processing, 3=Manufacturing and 4=Services; (P1, P2, P3, P4) are output prices normalized by price of labor; (CP1, CP2, CP3, CP4) are capital rental rates normalized by price of labor.

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Data Appendix

Time series data on prices and value of output in each of the four 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, and NBER manufacturing productivity database (Bartelsman and Gray, 1994) for the period 1958-91. The data on value of output are based on establishment surveys using revised SIC codes (1987). The agricultural sector consists of primary (raw) farm products. The food processing sector includes meatpacking, milk and other animal products, grain and baking products, processed vegetables, tobacco and other processed crop products. The major industrial products include mining, manufacturing (durables and non-durables, excludes food processing) and construction. Services include finance, insurance, real estate, health, legal and educational services, 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 in each of the four sectors 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 (Fixed Reproducible Tangible Wealth in the U.S. 1929-93 for more details). Labor is given by the number of full-time equivalent employees in the economy.