The Derived Demand for Real Cash Balances in Agricultural Production

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Implications of real cash balances as a productive input in agricultural production are explored. A system of aggregate input demand functions for agriculture including real cash balances is formulated and estimated, assuming that producers minimize input costs for a given output level. Empirical results suggest real cash balances are an important contributor to agricultural production. Their exclusion from production studies may lead to serious specification biases. Tests herein indicate that the demand for cash balances is relatively inelastic with respect to changes in the user cost of money and that real cash balances are a substitute for machinery and capital.

Key words: cost functions, duality theory, input demand, real cash balances.

The effect of real money balances on consumption is well known as the Pigou effect. It asserts that increases in real money balances held by the private sector increase consumption. The role of money in production is, however, less well understood. In fact, Moroney's observation that the theory of money has not been satisfactorily integrated with the pure theory of production remains credible more than a decade later.

One economic rationale for incuding money in the production function is that money services increase the efficiency of obtaining physical inputs necessary for production and marketing. In agriculture, the services from real cash balances may also mitigate problems associated with the timing of input purchases. That is, money services may facilitate the purchase of inputs in situations where the production process is lengthy and the receipt of revenues is delayed. If real cash balances play an important role in agricultural production, and it is the maintained hypothesis of this analysis that they do, then money balances have implications for specifying the "true" production function and empirically estimating the derived demand for inputs.

The objectives of this analysis are twofold. The first objective is to develop and evaluate the reasonableness of an agricultural production model which treats real cash balances as a productive input. The second objective is to evaluate the implications of such a specification for the derived demand for inputs. The approach used for this analysis utilizes results from duality theory on the correspondence between the production and cost function. A system of aggregate input demand functions for agriculture is derived and estimated assuming producers minimize input costs for a given output level. Results suggest real cash balances do play a role in agricultural production decisions.

Money and Production

There are a number of models in the past literature to explain the sources of the firm's demand for money. One explanation for the wide range of models is the absence of a general organizing principle describing a firm's money demand. Past work has identified some of the features needed for a general model. The most familiar models are based on inventory theory. Baumol's early analysis of the firm's demand

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for cash made strong assumptions related to the nature of the contracting and exchange conditions. He assumed that the firm faced fixed cash inflow and outflow patterns and sought to minimize the costs of holding the cash balances necessary for its transactions.

Meltzer, Vogel and Maddala employed a portfolio model allowing the firm to allocate its financial holdings among assets so as to equalize the marginal rates of return, adjusted for the risk involved. A role for holding cash balances exists once payment schedules facing the firm as well as the costs of making financial transactions are considered. The role of uncertainty in receipts (Miller and Orr) was a further refinement. Frost discussed the role of bank services in return for holding cash balances. All of these contributions revolve around modifications in the assumed exchange conditions and reveal the importance of time in the modeling of the firm's production patterns. To develop a more general model, a researcher must recognize firms or farms cannot assemble factor inputs, produce, deliver, and sell their output, and accumulate the receipts from those transactions at each instant. Therefore, the implications of the timing of these actions must be reflected in any model of the firm's or farm's demand for liquidity.

A transactions-cost Austrian model was developed by Gabor and Pearce. Their approach was to add a money-requirements function to a neoclassical production function as a constraint. Money is recognized to be productive. However, "there is an essential difference between money and any other factor. Production conceivably could be carried on without money if other inputs were made available by some dictatorial hand, but the removal of a unit of any other fact would immediately reduce the product. Money capital is a catalyst. It has no direct marginal product but operates only by influencing the way in which other factors are used" (Gabor and Pearce, pp. 540–41). As Dennis and Smith note, it is questionable whether the subtle distinctions highlighted by Gabor and Pearce have significant operational implications. If not, then the money-requirements function can be embedded in the production function (or transactions costs included in the specification of a neoclassical cost function).

The theoretical approach adopted here treats the services from real cash balances as a conventional neoclassical production input. Friedman was among the first to suggest that money should be treated as another productive input rather than as a buffer or shock absorber as in inventory theoretic approaches. Early empirical applications include Johnson, and Levhari and Patinkin, who include real cash balances in an aggregate production function as part of a macroeconomic growth model. Sinai and Stokes tested this approach using a Cobb-Douglas production function. Nadiri, and Dennis and Smith also utilized a neoclassical approach and examined a representative firm's demand for real cash balances.[1] Nadiri's work demonstrates that a firm's demand for real cash balances depends, in part, on the prices of other inputs. Furthermore, his work suggests that the level of money held by the firm affects the cost of adjusting inputs.

The most obvious reason for including money in production models is that firms hold cash balances.[2] The forces compelling firms to hold money are the same forces which compelled the transition of barter to market economies: efficiencies in exchange. Levhari and Patinkin assert "money is held only because it enables the economic unit in question to acquire or produce a larger quantity of commodities in the usual sense of the word." They cite as money's principal contribution to productivity "that an economy without money would have to devote effort (read: labor and capital) in order to achieve the multitude of 'double coincidences'—of buyers who want exactly what the seller has to offer—on which successful barter is based" (pp. 737–38).

A strict interpretation of a production function as an engineering concept tests the credulity of treating real cash balances as a production input.[3] Certainly money is not of the same character as diesel fuel or chemicals and does not directly enter a narrow definition of the production process. However, a broader definition of the production process more con-

[1] The literature distinguishes between macroeconomic and microeconomic applications of real cash balances (Dennis and Smith). It is argued that only microeconomic applications provide sufficient motivation for including real cash balances in production models. The insufficiency of behavioral motivations in macroeconomic models is not, however, unique to this question.

[2] Money or cash balances is liquid fiat serving as a generally accepted means of exchange.

[3] Consider, for example, Shephard's definition of a production function as "a mathematical summary of the output implied by the use of specific inputs within alternative feasible arrangements of the technical process involved in production."

ducive for economic analysis includes not only engineering relationships which transform inputs to outputs but also the production functions performed by money, such as facilitating the purchase of inputs. This characterization follows Fischer's suggestion that economists distinguish between a technical production function and a "delivered output" production function which encompasses the contributions of real cash balances and physical inputs as well.

The delivered output production function is of particular economic interest because abstract engineering or technical renderings of the production process tends to be unrealistic since they depict the flow of production as being instantaneously created. In reality, the flow of production is not instantaneous. Instead, a buildup period occurs where inputs are purchased and accumulated, production is created, output is marketed, and revenue is recovered. It is the time dimension of production flow which argues for including real cash balances in the delivered output production function.

Theoretical Model

The underlying theoretical framework utilizes results from duality theory on the correspondence between the firm's production and cost function (Diewert). If competitive behavior and a well-behaved technology are assumed, then there exists a one-to-one correspondence between a firm's production and cost function. It is possible, therefore, to describe completely a firm's technology from the cost function (McFadden).[4]

The cost function, which assumes cost minimization subject to a given output level, is approximated in this analysis with a translogarithmic function (Christensen, Jorgenson, and Lau).[5] This form does not restrict a priori the nature of substitution possibilities and allows direct testing for the role of real cash balances. The translog cost function is

$$(1)\quad \ln C = a + a_y \ln Y + \tfrac{1}{2} b_{yy} \ln Y^2 + \sum_{i=1}^{n} b_i \ln P_i + \tfrac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij} \ln P_i \ln P_j + \sum_{i=1}^{n} b_{yi} \ln P_i \ln Y,$$

where C is total cost, Y is output, P_i's are factor prices, and a's and b's are parameters. If long-run equilibrium is assumed, then applying Shephard's lemma to the translog cost function implies a cost-share system of the form

$$(2)\quad \partial \ln C/\partial \ln P_i = S_i^* = b_i + \sum_{j=1}^{n} b_{ij} \ln P_j + b_{yi} \ln Y,$$

where S_i^* is the optimal input share for the i^{th} input.

Symmetry and homogeneity of factor prices are imposed by

$$(3)\quad \begin{aligned} & b_{ij} = b_{ji} \\ & \sum_{i=1}^{n} b_{ij} = \sum_{j=1}^{n} b_{ji} = \sum_{i=1}^{n}\sum_{j=1}^{n} b_{ij} = 0, \\ & \sum_{i=1}^{n} b_i = 1. \end{aligned}$$

The equilibrium own-price and cross-price elasticities, holding output constant, are

$$(4)\quad (\partial X_i^*/\partial P_i)(P_i/X_i^*) = [S_i^* - S_i^* + b_{ii}]/S_i^* \qquad i = 1, 2, \ldots, n,$$

$$(5)\quad (\partial X_i^*/\partial P_j)(P_j/X_i^*) = [S_i^* S_j + b_{ij}]/S_i^* \qquad i = j = 1, 2, \ldots, n,$$

where X_i^* is the optimal quantity of the i^{th} input.

The symmetry conditions imposed in equation (3) imply only that

$$(6)\quad \partial X_i/\partial P_j = \partial X_j/\partial P_i \qquad i = j = 1, 2, \ldots, n.$$

Factor price homogeneity implies that the equilibrium price elasticities sum to zero.

Empirical Model

The theoretical model is modified by treating land as a quasi-fixed factor to mitigate the confounding effect of acreage control programs prevalent throughout the 1960s and 1970s as

[4] Our preference for the cost function approach over the profit function approach is based on two issues. First, as Lopez argues, profit maximizing may be more difficult to support in agriculture than cost minimization because of risk-related problems in terms of yield (output) variability. Second, Young et al. note that institutional restrictions imposed by farm programs or contracting practices could make cost minimization subject to an output constraint more realistic for empirical work in the agricultural sector than unconstrained profit maximization.

[5] In this analysis, the translog cost function is interpreted as a second-order approximation to any arbitrary cost function.

well as identification problems frequently encountered when estimating input demand equations for land.[6] If a constant returns-to-scale technology is assumed and homogeneity and symmetry restrictions are imposed, then the ith input share equation is

$$(7) \quad S_i = a_i + \sum_{j=1}^{n-1} b_{ij}\ln(P_j/P_n) + c_i \ln Z + e_i \qquad i = 1, 2, \ldots, n,$$

where Z is the stock of land, c_i is a parameter, and e_i an appended classical error term.[7] The input share system is composed of four variable inputs: labor, machinery (producers durable equipment), money, and intermediate inputs. This share equation is interpreted as being derived from a short-run variable cost function and represents the locus of short-run, cost-minimizing solutions as a function of output, factor prices, and quantities of fixed factors.

Data

The analysis uses aggregate annual time-series data for the years 1955 through 1978. Data consisted of observations on aggregate agricultural output, land, labor, capital, and intermediate materials quantity and prices. A detailed description of data is available in Ball (1985, 1987). The data were aggregated using a discrete Törnquist approximation of a divisia index. Törnquist price indices are computed first, and then implicit quantity indices are computed by dividing value (revenue or expenditures) by the Törnquist price index.

Labor data were formulated to account for differences in the productivity of different types of workers and changes in quality resulting from education. The price index corresponding to the Törnquist index of labor input is defined as the ratio of labor compensation (or imputed compensation) to the Törnquist quantity index. For capital, the separation of price and quantity components of outlays is based on the correspondence between the value of an asset and the discounted value of its services (Griliches and Jorgenson). The service price depends on the asset price, the rate of return, and the rate of replacement. Outlays on capital are separated into prices and quantity components by combining the rate of return with the other components of the service price. Fertilizer information on primary nutrient content is used to account for quality changes.

The implicit rental or service price depends on the asset price, rate of economic depreciation, service life, tax treatment, and the discount rate. Asset prices, the rate of economic depreciation, and service lives are taken from Ball. The tax parameters such as the depreciation method, tax life, and investment tax credit are based on eligibility requirements at the time the asset was purchased. If more than one option was allowable, the method resulting in the lowest rental rate was selected. The marginal *ex ante* federal income tax rates developed for this analysis are interpreted as the expected tax rate an investor or firm would pay on an additional dollar of income prior to undertaking any new investment. These *ex ante* rates are estimated for sole proprietorships from U.S. Department of the Treasury data for 1962–78.

Prior to the Revenue Act of 1964, the lowest marginal tax rate applied to all taxable income below $2,000. It was assumed that the appropriate marginal tax rate corresponded to the lowest tax bracket. Therefore, the *ex ante* marginal tax rate from 1955–61 was 20%.

The discount rate is assumed to be a weighted average of the long-run real interest rate (external financing) and the long-run real return to equity (internal financing). Weights were computed from Bureau of Census data. Interest rates for external financing were computed from rates charged by federal land banks on new farm loans. The long-run rate of return to equity is based on Melichar and Gertel.

Intermediate inputs include feed, seed, purchased livestock, chemical fertilizers, lime, pesticides, petroleum fuels, natural gas, and electricity. Output consisted of an index of 118 agricultural commodities from seven categories: cash grains, field crops except cash grains, vegetables and melons, fruits and treenuts, livestock excluding dairy, poultry and animal specialties, dairy products, and poultry and eggs.

Cash balances are defined as the sum of currency and demand deposits held by the agri-

[6] Chambers and Vasavada note there is "widespread agreement that land is fixed *ex post*" (p. 764) and impose such an assumption in their model. Tweeten, Hathaway, and Brown also affirm this view.

[7] More general specifications which did not impose constant returns to scale were also estimated. A likelihood ratio test of the null hypothesis, (where the null hypothesis is defined as no statistical difference between the general and restricted models) could not be rejected. Therefore, only the constant returns-to-scale model is presented here.

cultural sector (U.S. Department of Agriculture).

Following the approach suggested by Barnett, Offenbacher, and Spindt, monetary assets are viewed as durable goods which provide their holders with a flow of monetary services. These services are priced by the user cost of the monetary asset from which they flow (Barnett). The user cost is a monetary asset analog of the Jorgensonian user cost (rental price) of durable consumer goods. As defined by Barnett, the user cost of money is

(8) $P_{mt} = D_t(R_t - r_t)/(1 + R_t)/ \quad t = 1, 2, \ldots, T,$

where P_m is the user cost of money, D is an aggregate price index of goods and services, R represents the yield on bond holdings, and r is the nominal yield on the monetary asset. Here, R_t is the benchmark rate and represents the yield on assets accumulated for the purpose of transferring wealth between multiperiod planning horizons rather than to provide liquidity or other monetary services during the current period. Although the yield on a completely illiquid asset such as human capital might best fit this description, no satisfactory empirical series for the rate of return on human capital is available.

In this analysis D is the gross national product (GNP) implicit price deflator, R is the yield on Moody's BAA bonds, and r is the yield on three-month commercial paper. Choice of components follow those of Barnett and Spindt in their construction of the implicit rental rate of currency and demand deposits. It is assumed that farmers earn the full competitive rate on their holdings. Using Klein's methodology, an implicit full competitive rate of return on demand deposits is constructed.

Estimated Model

Nonzero interequation covariance was captured by jointly estimating the cost-share equations using a full information maximum likelihood methodology. Because the cost shares sum to unity, the stochastic error term must sum to zero at each observation. This constraint implies the covariance structure is not of full rank and one equation must be dropped before the system is estimated. The maximum likelihood estimator, however, assures the estimated coefficients are invariant to which equation is deleted (Barten). In this analysis, the cost-share equation associated with intermediate materials was omitted.

The estimated parameters of the cost shares and associated asymptotic standard errors and t-statistics are given in table 1. Only two of the twelve estimated parameters have asymptotic t-statistics of less than one. Four of the five parameters associated with money manifest fairly strong t-statistics. Only the parameter associated with money and labor is weak.

Demand price elasticities are derived using the estimated parameters given in table 2 and the relationships described by equations (4) and (5).[8] All the estimated own-price elasticities have the correct negative sign. The estimates indicate what intermediate materials are the least elastic and money the most. Furthermore, the results suggest machinery is a substitute with labor. The machinery-intermediate material elasticity, although negative, is virtually zero. Money is a substitute with both machinery and labor and a complement with only intermediate materials. Therefore, as the cost of holding real money balances rises, labor and machinery are substituted. These results are generally consistent with Dennis and Smith, who found money to be a substitute with capital in all eleven two-digit SIC code industries studied and a substitute with production labor in nine out of eleven industries.

The period of estimation of our empirical model was correlated with a number of important financial and monetary developments. These developments include changes in regulations concerning interest rate ceilings on the deposits of commercial banks and thrift institutions, innovations in short-term financial markets associated with improvement in corporate cash management, increases in the rate of inflation and interest rates as compared with previous postwar experience, and a greater emphasis on monetary aggregates targeted by the Federal Reserve. Innovations in financial arrangements allowed the public to economize on its holdings of transactions balances. Unfortunately, as Judd and Scadding point out, it has not been possible so far to test directly the implications of the financial innovations hypothesis—that is, the hypothesized reductions in transactions costs and variance of cash flow. One possible result of these institutional

[8] Allen partial elasticities of substitution are easily derivable from the input-demand price elasticities and, therefore, are not reported here.

Table 1. Estimated Parameters for U.S. Cost Shares and Associated Statistics

Coefficient	Value	Asymptotic Standard Error	Asymptotic t-Statistic
bm	.07539	.3748	2.01
bmm	.0164	.0013	7.99
blm	−.0014	.0031	−.46
bcm	−.0049	.0027	−1.82
bzm	−.0548	.0286	−1.92
bc	12.66	1.224	10.35
bcc	.1156	.0240	4.81
blc	−.0153	.0261	−.59
bzc	−.9253	.0938	−9.87
bl	−17.42	1.542	−11.30
bll	.0454	.0335	1.35
bzl	1.35	.1182	11.43

Note: Coefficient symbols are defined as follows: b_i intercept parameter, b_{ij} parameter associated with the effect of the jth price on the ith cost share, b_{zi} parameter associated with the effect of land on the ith cost share; where m is money, l is labor, c is machinery, and f is intermediate materials. All input prices P_i are normalized on P_f. The observation period is 1955–78.

factors would be that the estimated own-price elasticity for money would be more elastic over time as less money would be needed to provide the same amount of services.

A likelihood ratio test was conducted to test statistically the alternative hypothesis that a production model which incorporates money is statistically superior to a production model which does not. The test statistic is

$$(9) \qquad -2\ln(L) = T[\ln(|\Omega_R|/|\Omega_u|)],$$

where L is the likelihood ratio, $|\Omega_R|$ is the determinant of the restricted estimator of the variance-covariance matrix for the cost-share equations' errors, $|\Omega_u|$ is the unrestricted estimator of the variance-covariance matrix, and T is the number of observations. This statistic is distributed asymptotically as a chi-square with degrees of freedom equal to the independently imposed restrictions. In this case, five restrictions are imposed, $\ln|\Omega_R| = 18.42$, and $\ln|\Omega_u| = 29.67$. The null hypothesis of no statistical difference between the restricted model (without money) and the unrestricted model (with money) is rejected at any reasonable level of significance.

Model Simulation Results

Real interest rates can transmit changes in macroeconomic policy to the farm sector. The effects of changes in real interest rates on the farm sector can be traced through effects on aggregate supply and demand. The interaction of aggregate supply and demand determines prices and real interest rates that feed back to influence agricultural supply and demand. Changes in real interest rates affect agricultural demand by altering the basket of goods selected by the consumer and agricultural supply by changing the cost of production.

Table 2. Input Demand Price Elasticities

Input	Price: Labor	Machinery	Intermediate Materials	Money
Labor	−.56	.49	.06	.13
Machinery	.24	−.24	−.01	.01
Intermediate material	.09	−.03	−.06	−.01
Money	.22	.40	.05	−.67

Note: Price elasticities are computed at mean values.

Many production decisions in agriculture are potentially affected by changes in real interest rates; carrying inventories, capital accumulation, purchases of variable inputs. In addition to these more obvious effects, changes in real interest rates also affect farm production decisions by altering the relative and absolute cost of holding money as cash balances. For example, higher real interest rates make holding cash expensive. More expensive cash balances suggests a decrease in its demand and an altering of the demand for other inputs in response to the increased cost of money. The linkage between real interest rates and cash balances and the role of cash balances in farm production can be highlighted by holding the prices of all other inputs constant and simulating the effects of an increase in the service price of money.

The importance of changes in interest rates and the cost of holding cash balances is illustrated by simulating the cost-share model for ten years assuming a 10% increase in the user cost of money per year. The effects on cost shares are generally consistent with the estimated elasticities results (table 3). The inelastic demand for real cash balances and the increase in the cost of holding money lead to an increase in its cost share. The declining cost share for intermediate materials and initial in-

Table 3. Simulated Cost Shares

	Cost Shares			
Period	Labor	Machinery	Intermediate Materials	Money
1	.1874	.6089	.1807	.0231
2	.1855	.6197	.1713	.0234
3	.1855	.6193	.1710	.0241
4	.1855	.6189	.1707	.0249
5	.1855	.6185	.1704	.0256
6	.1855	.6181	.1700	.0264
7	.1855	.6177	.1697	.0271
8	.1855	.6173	.1694	.0278
9	.1855	.6169	.1691	.0285
10	.1855	.6165	.1688	.0293

Notes: Simulated cost shares may not sum to 1 due to rounding. User cost of money increases 10% per period for ten periods. All other prices and values (i.e., land) fixed at 1978 levels.

crease in the cost share for machinery adhere to their respective negative and positive cross-price elasticities of demand with respect to real cash balances. For labor, the initial decline in its share is not consistent with its positive cross-price elasticity with respect to money. However, this decline may reflect the increased substitution of machinery initially in production. Labor's constant share after the second simulation period then corresponds to the slight reduction in machinery's share for the remaining simulation periods.

The simulation example illustrates that macroeconomic policies affecting interest rates; and thus the user cost of money will, in turn, affect the composition of inputs used in agricultural production. Although the magnitude of changes in input shares is not large, there are definite effects on other input demands. When *ceteris paribus* assumptions regarding input prices and the general equlibirum effects of macro policy are relaxed, the effect on agricultural structure can be significant.[9]

Summary and Conclusions

In this analysis, real cash balances are integrated into a characterization of aggregate agricultural production. As suggested by Friedman, money is cast as a neoclassical input rather than as a buffer as in inventory theoretic approaches. As opposed to defining production in a strict engineering sense, the production concept is extended to a "delivered output" function which encompasses inputs and the contributions of money. Within this framework, money is cast as an input which facilitates the flow of inputs and outputs in a world where production is not instantaneous.

The empirical results suggest money is an important contributor to aggregate agricultural production, and its exclusion offers the potential for a serious specification bias. The null hypothesis of no statistical difference between an input cost-share system without real cash balances and one with real cash balances is easily rejected. Within this context, the real cash balances version is judged superior for the data used in this analysis. This, of course, is not equivalent to rejecting the restricted (no real cash balances) model. The alternative hypothesis that a different model specification may produce different results cannot be rejected. Estimated parameters are used to calculate input demand elasticities. The results indicate the demand for real cash balances is relatively inelastic to changes in the user cost of money, and real cash balances are a substitute with machinery and capital. Future research should extend the range of financial assets held by farmers into the real cash balances concept.[10] Results from this analysis suggest greater attention to the role of money in agricultural production decision making is warranted.

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[9] As Barnett points out, although the monetary user cost formula does not depend directly upon inflation rates, the nomianl interest rates within the formula can be expected to respond to expected inflation rates. Furthermore, since the well-known user cost formula for nonmonetary durable services does depend inversely upon the expected inflation rate, it follows that the user cost of monetary assets relative to durables increases as the expected inflation rate increases and can cause changes in real resource allocation.

[10] See Barth, Kraft, and Kraft for a discussion of the "moneyness" of financial assets. Fischer argues that delivered output production functions can be extended so that inventories of goods appear as factors.

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