Borrowing Constraints and the Agricultural Investment Decision Process

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ABSTRACT

This paper develops a dynamic intertemporal model under the hypothesis of asymmetric information for the analysis of the rate of investment in the agricultural sector. The model stresses the importance of borrowing constraints for the investment decision of firms. Using the model we derive, following Abel and Blanchard’s (1986) approach, an estimate for marginal Tobin’s Q. We find that this series is positively and strongly related to the agricultural rate of investment in Italy during the period of 1960–1996.

1. INTRODUCTION

Agricultural investments tend to rely heavily on banks for debt financing and often have few, if any, sources of equity financing. In light of these characteristics, the availability of competitively priced credit for farmers remains an important agricultural policy issue. During recent years, many models have been proposed that extend the conventional neo-classical Jorgenson model (Jorgenson, 1963) incorporating a role for “financing constraints” in determining investment.\(^1\) As is well known, if all firms have equal access to capital markets, differences in investment decisions deriving from changes in the user cost of capital will depend only on differences in investment demand. In this case internal and external funds are perfect substitutes and a firm’s investment decisions is independent of its financial condition. However, when there are “imperfections” in the capital markets—due to, for example, the presence of asymmetric information that increases the cost for banks to evaluate the quality of farmers’ investment decisions—the cost of external finance may differ substantially from the opportunity cost of internal finance (Hubbard & Kashyap, 1992; Whited, 1992).

Recently, models have been proposed to analyze the connection between the user cost of capital and financial constraint in the agricultural sector. For example, Lagerkvist (1998), estimating the user cost of capital in the agricultural sector, introduced in the optimization problem a constraint on the total amount of external funds attainable by the firm. In this case external funds are a constant fraction of the current value of the total capital

\(^{1}\)For a survey on this theme, see Hubbard (1998).
stock. Hubbard and Kashyap (1992), using U.S. agricultural data, estimated a firm’s Euler equation to model its investment decision where borrowing constraints are explicitly analyzed in the context of dynamically optimizing economic agents. Moreover, Benjamin and Phimister (1997), using a balanced panel of French farms, showed that a model that assumes perfect capital market is rejected by the data when compared with a model where adjustment costs in investment and financial constraints affect investment. Finally Freeman, Ehui, and Jabbar (1998) showed that borrowing constraints have substantial impacts on smallholder farms.

In an attempt to provide an empirical basis for explaining the effects of financial constraints on the agricultural investments, this study supplies a methodology to compute the expected marginal stream of profits per unit of invested capital when imperfections in capital markets, such as credit rationing or agency costs, can influence borrowing conditions. Second, we use the estimated shadow cost of capital to derive a measure for Tobin’s marginal-Q. We show that this variable is positively and strongly related to the rate of investment in the agricultural sector in Italy during the period 1960–1996.

In Section 2 we briefly review the literature on investment decisions assuming perfect substitution between internal and external finance. We include a financial constraint on the use of external finance by farmers and, as we will see, the result is that in this case marginal-Q will be negatively influenced. Section 3 shows a method, largely derived from Abel and Blanchard (1986), to compute the shadow cost of capital while in the Section 4 we provide an estimate by using vector autoregression estimation methods. Moreover, we present results for a set of regressions where the relationship between the rate of investment and marginal Tobin’s Q for the agricultural sector in Italy during the period 1960–1996 is analyzed. In Section 5 we present our conclusions.

2. THE MODEL

Farms maximize the following present discounted value, $V$, of the profits flows $\Pi$ from investments

$$V_0 = E_0 \sum_{t=1}^{\infty} \left( \prod_{j=0}^{t-1} \beta_j \right) \Pi_t$$

where $\beta_t$ is the discount factor at time $t$. The maximization takes place subject to the following constraint: $K_t = I_t + (1 - \delta)K_{t-1}$, where $I$ and $K$ represent, respectively, investment and capital stock, and $\delta$ is a constant rate of economic depreciation. Profit $\Pi_t$ at the time $t$ can be defined as the difference between the before-taxes net revenue and income taxes

$$\Pi_t = (1 - \mu_t)[p_tF(K_{t-1}, L_{t-1}, N_t) - w_tN_t - l_tL_{t-1}] - (1 - k - z)p_tI_t$$

where $N$ is a vector of variable factors of production, $w$ is a vector of factor prices, $L$ is the land, $l$ the rental rate on land, $p$ the effective price of capital goods, $\mu$ the income tax rate on firm’s income, $k$ the investment tax credit, and $z$ the depreciation allowance per unit of investment for tax purposes.\(^2\) Finally, $F(K_{t-1}, L_{t-1}, N_t)$ is the production function for which we assume that $F' > 0$ and $F'' < 0$. All prices and values are expressed relative

\(^2\)In order to simplify the analysis, $k$ and $z$ parameters are assumed constant.
to the general price deflator. In this case real profits will be maximized. Let $q_t$ be the multiplier associated with the capital accumulation constraint; the first-order conditions with respect to $N_t, L_t, I_t,$ and $K_t$ are given by

\begin{equation}
(1 - \mu_t)(p_tF_N - w_t) = 0 \tag{2.1}
\end{equation}

\begin{equation}
E_t[(1 - \mu_t)\beta_t[p_{t+1}F_L - l_{t+1}]] = 0 \tag{2.2}
\end{equation}

\begin{equation}
-(1 - k - z)p_t + q_t = 0 \tag{2.3}
\end{equation}

\begin{equation}
E_t[\beta_t(1 - \mu_t)p_{t+1}F_K] - q_t + E_t[\beta_t(1 - \delta)q_{t+1}] = 0. \tag{2.4}
\end{equation}

From equations (2.1) and (2.2) we derive the usual first-order conditions that the marginal revenue product of variable inputs must be equal to factor input prices. Substituting the result of equation (2.3) into equation (2.4) we end up with the following expression for the shadow price of capital

\begin{equation}
q_t = E_t[\beta_t(1 - \mu_t)p_{t+1}F_K] + E_t[\beta_t(1 - \delta)q_{t+1}] \tag{3}
\end{equation}

The left-hand side of equation (3) is the marginal shadow price of buying a unit of capital in the period $t$. This value must be equal to the sum of the expected marginal gain from using that additional unit in the production plus the gain from selling the remaining capital (after depreciation) at the time $t + 1$. If farmers are risk neutral, $\beta_t$ is not only deterministic but also constant and equal to $1/(1 + \bar{r})$, where $\bar{r}$ is a deterministic discount rate. Assuming that future values of capital productivity and expected output price and income tax rate remain at the same level as today, the differential equation (3) for $t \to \infty$ can be solved, giving rise to the well known Jorgenson (1963) first-order condition

\begin{equation}
c = p_t(1 - k - z) \frac{(\bar{r} + \delta)}{(1 - \bar{\mu})} \text{ and } F_K = \frac{c}{p} \tag{4}
\end{equation}

where $c$ is the user cost of capital—i.e., the price paid for the use of capital resources.

The standard, neoclassical Jorgenson investment model ignores the presence of adjustment costs connected to changes in the capital stock. In this model, firms may instantaneously purchase (sell) and install (not install) a block of capital without incurring costs. The existence of such costs is usually explained by the reorganization or retraining costs involved in the use of new equipment.

Following the literature on investment determinants, which started with the seminal works of Eisner and Strotz (1963) and Lucas (1967), we introduce the function $C(K_{t-1}, L_t)$, which represents the cost for the firm of adjusting the capital stock in equation (2). We assume that this function is increasing and convex both in $I$ and $K$. In this case we have that $C_I(\cdot) > 0$, $C_K(\cdot) > 0$, and $C_{II}(\cdot) > 0$, $C_{KK}(\cdot) > 0$. Finally $C(0) = 0$. These hypotheses, which can usually be found in the literature, imply that it is costly for a firm to increase or decrease its capital stock, and that the marginal adjustment cost increases in line with the size of adjustment. When we introduce the cost of adjusting the capital in equation (2), and writing for brevity $(1 - k - z)p_t = p_{ht}$, profits must be rewritten as

\begin{equation}
\Pi_t = (1 - \mu_t)[p_tF(K_{t-1}, L_{t-1}, N_t) - w_tN_t - l_tL_{t-1} - C(K_{t-1}, I_t)] - p_{ht}I_t. \tag{5}
\end{equation}
Maximizing equation (5) subject as before to capital constraint, we note that the first-order conditions (2.1) and (2.2) still hold, but the first-order conditions with respect to $I$ and $K$ are now given by

$$-(1 - \mu_i)C_i(K_{t-1}, I_t) - p_t^r + q_t = 0$$

$$E_i[\beta_i(1 - \mu_i)\left(p_{t+1}F_K - C_K(K_t, I_{t+1})\right)] - q_t + E_i[\beta_i(1 - \delta)q_{t+1}] = 0$$

From (5.4), the shadow price of a unit of installed capital can now be written as

$$q_t = E_i[\beta_i(1 - \mu_i)\left(p_{t+1}F_K - C_K(K_t, I_{t+1})\right)] + E_i[\beta_i(1 - \delta)q_{t+1}]$$

We can immediately see that this expression is the analogue of the equation from which we derive Jorgenson’s result, except for the presence of the marginal adjustment costs, and the stationary solution for (6) may be written as

$$q_t = E_i\left\{\sum_{s=0}^{\infty} \left(\prod_{j=1}^{s+1} \beta_j\right) [(1 - \delta)^{-1}(1 - \mu_{t+s})(p_{t+s}F_K - C_K(K_{t+s}, I_{t+s+1}))]\right\}$$

where the discount factor is now written as $\beta_t = \beta_i(1 - \delta)$.

From (7), the shadow price of installed capital is equal to the expected present discounted value of the stream of marginal profits attributable to a unit of capital installed at time $t$. Note from (5) and (2) that $q_t = \delta V/\partial K_t$ and dividing both sides by $p_t^r$ we obtain the “marginal Tobin-Q.” As is well known, Tobin (1969) formalized a theory of investment where the incentive to invest in new capital is positively related to the ratio between the average value of the capital stock, $\overline{V}/K$, and the price of a unit of capital, usually labeled as average-Q. Therefore, Tobin’s Q measure is different from our definition where marginal-Q instead of average-Q is really relevant for investment. Hayashi (1982) showed the conditions under which marginal-Q is equal to average-Q. The key assumption is that profits function must be a linearly homogeneous function of the variables $K$, $\mathbb{N}$, $L$, and $I$.

Recent research developments on the link between financial markets and investment suggest that firms may be affected by “financial constraints.” Assume that a firm does not have sufficient internal cash to undertake a desirable investment project. It must seek funds from external sources. External finance may be more costly than internal funds for a variety of reasons. Fazzari, Hubbard, and Petersen (1988) show that these costs, usually associated with transaction costs, can be quite substantial. Therefore, an investment project that would be undertaken if the firm had sufficient internal cash to finance it might be postponed, or not carried out at all, if the firm has to rely on more costly external funds. Financial constraints on investment may arise for many reasons. The literature emphasizes the asymmetric information available to borrowers and lenders, which can lead to many nontraditional results. For example, credit may be rationed, meaning that the interest rate does not equate to supply and demand for loans, leaving some firms without finance and limiting their ability to invest. Furthermore, whether a firm can undertake an investment project may depend not only on the economic fundamentals of the project under consideration, but also on the firm’s financial condition. Again, the same project in which a firm would invest if it had sufficient internal funds might not be undertaken if the firm had to raise external funds to finance the project.
In order to take financial constraints into account we introduce net debt in the profits equation (5)

$$\Pi_t = (1 - \mu_t)[p_t F(K_t, L_t, N_t) - w_t N_t - I_t L_t - C(K_t, I_t) - r_{t-1} B_{t-1}]$$

$$- p_t^* I + B_t - (1 - \tau_t^*) B_{t-1}$$

(8)

where $B$ is the value of debt outstanding (one-period loans), $r$ the nominal interest rate on loans and $\tau_t^*$ the expected inflation rate at time $t$. Following Hubbard and Kashyap (1992) and Whited (1992), we introduce a firm constraint on the use of external finance by farmers. In particular, they assume that the outstanding debt set at time $t$, $B_t$, must be less or at most equal to an exogenously given debt ceiling $B^*$. If we let $\omega_t$ be the Lagrange multiplier associated with the constraint, that $B_t \leq B^*$ and maximizing (8) subject to capital constraint as well as debt constraint, we must add to the previous first order conditions (5.3), (5.4) and (2.1), (2.2), the following condition with respect to $B^*$

$$1 - E_t \{ \beta_t [1 + (1 - \mu_t) r_t - \tau_t^*] \} - \omega_t = 0$$

(9)

The shadow price of a unit of installed capital will be now influenced by the presence of a financial constraint. Remembering that $\hat{\beta}_t = \beta_t (1 - \delta)$ and solving $\beta_t$ for expression (9), we can now write the discount factor as $\hat{\beta}_t = (1 - \omega_t) (1 - \delta) / [1 + (1 - \mu_t) r_t - \tau_t^*]$, which is the ex-ante one period discount factor. We have now that using (9) and (5.3) and (5.4) the following expression holds

$$q = E_t \left\{ \sum_{j=0}^{\infty} \prod_{j=1}^{i+5} \hat{\beta}_j M_{t+j} \right\},$$

(10)

where $M_{t+i} = (1 - \delta)^{-1} (1 - \mu_{t+i}) [p_{t+i} F_K - C_K(K_{t+i}, I_{t+i})]$.

This expression is quite similar to expression (7) except for that now we have a new definition for the discount term. When the debt constraint holds $\omega_t > 0$, and the expected present discounted value of the stream of marginal profits attributable to a unit of capital installed at time $t$ is correspondingly reduced. Thus, financial constraints alter the firm’s decision of investment by reducing the shadow price of capital.

3. THE EMPIRICAL DERIVATION OF $Q_T$

To compute $q_t$, from (10) we must calculate the expectations of a long series of random variables. Abel and Blanchard (1986) suggest a procedure for obtaining a series which is an approximation of $q_t$. We follow substantially the same procedure but we permit for the presence of financial constraints.

\[ \lim_{T \to \infty} \prod_{t=0}^{T-1} \beta_t B_t = 0 \quad \forall t \]

i.e., farmers cannot accumulate an infinite amount of debt.
The approach requires a linear approximation of (10) around $\tilde{\beta}_{t+j} = \tilde{\beta}$ and $M_{t+j} = \tilde{M}$, for $j = 0, 1, 2, \ldots$, where $\tilde{\beta}$ and $\tilde{M}$ are respectively the sample means of $\hat{\beta}_t$ and $M_t$

$$q_t \approx \bar{q} + \tilde{M}(1 - \bar{\beta})^{-1} \sum_{j=0}^{\infty} \tilde{\beta}^j (\tilde{\beta}_{t+j} - \bar{\beta}) + \sum_{j=0}^{\infty} \tilde{\beta}^{j+1} (M_{t+j} - \tilde{M})$$

(11)

and $\bar{q} = \tilde{M}\bar{\beta}(1 - \bar{\beta})^{-1}$.

The second step is related to the hypothesis that $\tilde{\beta}_t$ and $M_t$ are both generated by a linear combination of the elements of some observable vector $\tilde{Y}_t$ which evolves according a vector autoregressive process of order $p$, $\text{VAR}(p)$. In this case, we can write the relationships between $\tilde{\beta}_t$ and $M_t$ and $\tilde{Y}_t$ as

$$\tilde{\beta}_t = E(\tilde{\beta}_t|\Omega_{t-1}) = b'A\tilde{Y}_{t-1}$$

(12.1)

$$M_t = E(M_t|\Omega_{t-1}) = a'A\tilde{Y}_{t-1}$$

(12.2)

where $A$ is the companion square matrix ($Kp \times Kp$) estimated from a $\text{VAR}(p)$, $K$ is the number of variables used, $\tilde{Y}_t$ is a $(Kp \times 1)$ vector written in mean-adjusted form, i.e., $\tilde{Y}_t = Y_t - \bar{Y}$, and $\Omega_{t-1}$ is the set of information available at the beginning of period $t-1$. Our specification is completed once we define the $(1 \times Kp)$ vectors $a$ and $b$. These are vectors of known constants. Inserting, for example, in $E$, the variables $\tilde{\beta}_t$ and $M_t$ respectively in the first and second column, it follows immediately from (12.1) and (12.2) that $b' = [1 \ 0 \ \ldots \ \ 0]$ and $a' = [0 \ 1 \ \ldots \ \ 0]$. Note that we require that $\text{det}(I_{Kp} - Az) \neq 0$ for $|z| < 1$, i.e., we require that $\tilde{Y}_t$ is a stable process. Substituting (12.1) and (12.2) in (11), $q_t$ can be computed as

$$q_t = E[q_t|\Omega_{t-1}] = \bar{q} + L(\tilde{\beta}_t) + L(M_t),$$

(13.1)

$$L(\tilde{\beta}_t) = \tilde{M}(1 - \bar{\beta})^{-1} b'(I - A\bar{\beta})^{-1} A\tilde{Y}_{t-1},$$

(13.2)

$$L(M_t) = \beta a'(I - A\bar{\beta})^{-1} A\tilde{Y}_{t-1}.$$  

(13.3)

where (13.1) is expectations of $q_t$ conditional on the information set $\Omega_{t-1}$.

The term $L(\tilde{\beta}_t)$ captures the effects on $q$ of changes in the cost of capital and the term $L(M_t)$ the effects of variability in the marginal profit of capital. Finally, we have to address the question of delivery lags, i.e., the question about the time lag between ordering new capital goods and their installation. When capital requires $n$ periods for delivery, then investment orders at time $t$ will depend on $E(q_{t+n}|\Omega_{t-1})$. We can simply incorporate delivery lags in equation (13.1)–(13.3) by noting that

$$E(\tilde{Y}_{t-1}|\Omega_{t-n}) = A^{n-1} \tilde{Y}_{t-n}$$

and thus $q_t$ can be written as

$$E(q_t|\Omega_{t-n}) = c'(I - A\bar{\beta})^{-1} A^n \tilde{Y}_{t-n}$$

where $c = \tilde{M}(1 - \bar{\beta})^{-1} b + \tilde{\beta} a$ and $\Omega_{t-n}$ is the set of information available at the beginning of period $t-n$. Now, the value of $q_t$ will depend on investment expenditures between the
time $t - n$ and $t$. As we will see in the empirical section, we will find the best relationship with the rate of investment when $n$ assumes the value of two.

Before introducing the empirical work, we must parameterize the adjustment cost function $C(K_{t-1}, I_t)$. Following a number of authors—Summers (1981), Poterba and Summers (1983), Hubbard and Kashyap (1992), Gilchrist and Himmelberg (1995)—we assume that the cost adjustment function is quadratic. More specifically

$$C(K_{t-1}, I_t) = \frac{\alpha}{2} \left( \frac{I_t}{K_{t-1}} - \nu \right)^2 K_{t-1}$$

where $\nu$ can be interpreted as a “normal” rate of investment. This formulation implies that the derivative of the adjustment costs function $C$ respect to the investment $I_t$, $C_{I_t}$, is a linear function of the rate of investment whereas the derivative of $C$ with respect to the capital stock $K_t$, $C_{K_t}$, is a quadratic function of the rate of investment.

4. DATA SETS AND EMPIRICAL RESULTS

We test the model using Italian agricultural data during the period of 1960–1996 as a sample for the analysis. Our data set consists of variables from Eurostat for investment, capital stock and investment deflator for the agriculture, forestry, and fishery sector. Data for rate of interest on debt is collected from INEA (National Institute of Agricultural Economics) as well as the data on the real price of land that, as we will see, will be used as proxy for assets that can be collateralized. Average profits are computed as the ratio of net, from income taxes, operating surplus to nominal capital stock. As previously seen, average profits are equal to marginal profits when the sector is perfectly competitive, firms are price takers and face no quantity constraints in output markets or factors markets (Hayashi, 1982). It is worth mentioning that these assumptions are widely employed when analyzing agricultural sector.

Before introducing the vector autoregression specification, we briefly summarize the main facts regarding the variables involved in the empirical analysis, using the data presented in Table 1.

During the period 1960–1996, the rate of investment in the agricultural sector was equal, on average, to 5.8% and decreased from 7.4% in the 1970s to an average of 3.2% during the years 1991–1996. Marginal profits followed the same pattern and the strong

<table>
<thead>
<tr>
<th>Period</th>
<th>$I_t/K_{t-1}$</th>
<th>Nominal Interest Rate</th>
<th>Net Operating Surplus to Capital</th>
<th>Annual Average Growth Rate Real Agricultural Value Added Deflator</th>
<th>Annual Average Growth Rate Real Land Prices</th>
</tr>
</thead>
<tbody>
<tr>
<td>1961–1970</td>
<td>0.069</td>
<td>7.07</td>
<td>0.33</td>
<td>3.13</td>
<td>3.74</td>
</tr>
<tr>
<td>1971–1980</td>
<td>0.074</td>
<td>12.22</td>
<td>0.19</td>
<td>14.69</td>
<td>3.78</td>
</tr>
<tr>
<td>1981–1990</td>
<td>0.048</td>
<td>17.35</td>
<td>0.10</td>
<td>6.40</td>
<td>-0.41</td>
</tr>
<tr>
<td>1991–1996</td>
<td>0.032</td>
<td>13.10</td>
<td>0.07</td>
<td>1.76</td>
<td>0.61</td>
</tr>
<tr>
<td>Average 1961–1996</td>
<td>0.058</td>
<td>12.25</td>
<td>0.18</td>
<td>7.17</td>
<td>1.63</td>
</tr>
</tbody>
</table>

Source: Eurostat and INEA data sets.
relationship between the two variables is testified to by the correlation coefficient of 0.72. The nominal rate of interest in the agricultural sector for investment in equipment and structures increased from 7.1% in the first decade to the highest value, 14.6%, during the period 1971–1990. In the last 20 years the interest rate level has decreased following the general interest rates trend in the economy. Note that agricultural credit in Italy is highly subsidized so that, during the period of analysis, the values for the nominal interest rate in Table 1 have to be reduced by approximately 35–40% in order to represent the nominal effective interest rate on investment in agricultural equipment and structures. In this case, we can estimate an average real interest rate for the full period of 1.8 percentage points, where the nominal interest has been deflated by using the average annual rate for the agricultural value added deflator. Finally, from Table 1 we can see that the real land prices have grown during the period of analysis at an annual average rate of 1.6%. A negative value emerges in the third decade. This period is affected by the negative performance of the years 1982–1986, when land prices decreased at an average rate of 7.7%. The worst year was 1982, with a rate of −16%. As will be explained in the empirical analysis, we have identified periods where real land prices were decreasing with periods where financial constraints may bind. During such periods firms may well run into problems with creditworthiness as lower farmland values could mean lower values for collateral.

To compute (13.1), we must estimate the commutation matrix $A$ from a vector auto-regression. Five variables are introduced in $Y$. The first variable is a proxy of the ex-post discount factor $\hat{\beta}$. Linearizing our expression $\hat{\beta}_t = (1 - \omega_t)(1 - \delta)/[1 + (1 - \mu_t)\tau_t - \tau_t^2]$ when $\omega_t = 0$ we obtain

$$\hat{\beta}_t^1 \approx 1 - (1 - \mu_t)\tau_t + \hat{P}_{At}/P_{At} - \delta$$

(15.1)

and when $\omega_t > 0$, the discount factor can be written as

$$\hat{\beta}_t^2 \approx \hat{\beta}_t^1 - \omega_t$$

(15.2)

where $\mu_t$ is the average income tax rate in the period $t$, $\tau_t$ is the nominal rate of interest on debt in the same period, $\hat{P}_{At}/P_{At}$ is the rate of agricultural price inflation and finally $\delta$ is the physical depreciation rate for which we use an average value of 0.11. The second variable in the VAR specification is the marginal profit given by the ratio of net, from income taxes, operating surplus to nominal capital stock at time $t - 1$. Its values have been presented previously in Table 1. We then insert the square of the rate of investment in order to take the effect of the marginal adjustment costs $C_K$ on marginal profits. The fourth variable is given by the real price of land price as proxy for collateralizable assets. We will discuss later the importance of this variable to locate years were financial credit constraints may bind. Finally, in the VAR matrix has been inserted the real agricultural value-added deflator, deflated by the GNP deflator. As is well known from the literature on the term structure of interest rates, price dynamics help to predict real interest rate, and thus may help to predict the discount factor $\hat{\beta}$.

We investigate for the presence of stochastic trends for all the variables used, i.e., we test for the null hypothesis of unit roots. We use the augmented Dickey–Fuller tests (ADF) and the Phillips–Perron tests (PP) with and without a deterministic trend in the process. Whereas both ADF and PP tests do not reject the hypothesis of unit roots for the log of the real agricultural value-added deflator, for the other variables we have different results.
with some tests, mainly ADF, which do no reject the null hypothesis and PP tests that rejects the null. Given these mixed responses, we decide to follow the Abel and Blanchard (1986) approach and exponentially detrend all variables before estimating the VARs. The VAR order has been selected using the mean square error criterion. We compute three statistics given by Akaike’s information criterion, the Hannan–Quinn criterion, and finally the Schwarz criterion. The first two criteria give as result a VAR of order 2 whereas the Schwarz information criterion gives a VAR of order 1. We use both VAR specifications in estimating \( q_t \), but as we will see the differences are very small. Finally, the characteristic polynomial of VAR(1) as well as VAR(2) process, given by \( \det(I_{Kp} - Az) \), has no roots in and on the complex unit circle, i.e. the process is stable.

As we have seen, \( q_t \) can be also influenced by the presence of financial constraints on the use of external finance by farmers. There are two problems in this case. The first problem is connected to identifying the periods where farmers are affected by credit constraints and, second, once such periods have been identified, how to adjust \( q_t \). Land is one of the main assets that is used as security for agricultural loans. Our hypothesis is that a sudden decline in the relative price of land may signify a lower value for collateral and thus lower access to credit markets and investment in the agricultural sector. Theoretical as well as empirical models on the importance of land as collateral for farmers have been presented in Kiyotaki and Moore (1997) and Kasa (1998). Both papers hold that a farmer cannot take out a loan for more than the expected value of his current land holdings. Stamm (1995) showed that in the United States the availability of credit to the farm sector has been sharply curtailed at times of decreasing land prices. Hubbard and Kashyap (1992) used the ratio of farm equity to farm capital to identify periods where creditworthiness was especially low or high but, at the same time, attributed to land prices high relevance as signal for the presence of firms financial constraints. We do not have data on equity so that we concentrate our attention on a period where the relative land prices declined sharply. During the period 1960–1996, we identify only one period when the decline of the relative prices of land were extremely severe. This period coincided with the years 1982–1986 where the relative prices of land declined by an annual average of 7.7%, against an average total increase over the preceding six years of 13% and an average annual rise for the total period of analysis of 1.6%. If credit constraints are binding, an increase in current profits may directly increase internal investment funds. We do not find sign of a rise in profits during these periods. The annual average growth rate for the operating surplus variable was 1.27% for the full period of analysis whereas in the period 1982–1986 it was equal to only 0.9 percentage points. The impression that the years 1982–1986 were particularly “busts” may be confirmed by looking at the annual average growth rate of investments. During this period the investment growth rate was negative and equal to \(-1\%\), against an average rise during the period 1960–1996 of approximately 2 percentage points.

We conclude that, during “busts” periods, the \( \beta_2^2 \) discount factor instead of \( \beta_1^2 \) will hold and thus we have to find a method to correct the discount factor for the presence of creditworthiness. Standard regression analysis suggests that when there are changes in slopes or intercepts at different times intervention models may be useful. An intervention model

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4 We are aware that this method may induce, as a result, spurious cyclicality (Nelson & Kang, 1981), but at the same time it permits us to compare our results with other research.

5 For a survey on the use of these tests in a vector autoregression environment, see Lütkepohl (1991).

6 A second period can be identified in the initial years 1960–1962, when relative land prices declined at the annual average rate of 7.8%. Unfortunately these years have been lost by using a VAR estimation method.
can be described as one where a stationary data generation process is valid only for a certain period and another process generates the data over a second period. We follow the same method by using VAR intervention models, Lütkepohl (1991). Our hypothesis is that, due to the increase in creditworthiness, a different data generation process was running for \( q_t \) during the 1982–1986 period, and thus from (12.1) and (12.2), we have to estimate a second set of parameters for the commutation matrix \( A \). As is usual when using intervention models, before estimating the \( A \) matrix by VAR intervention methods, we must test the null hypothesis that the parameters are time invariant during the period 1982–1986. Under the null, tests have respectively asymptotic \( \chi^2(45) \) for VAR(1) and \( \chi^2(70) \) for VAR(2) distributions\(^7\) and are equal to 104.1 and 113.6, respectively. Both tests are significant at the 1% level, and we conclude that during the period 1982–1986 the parameters are not time invariant. It is interesting to note that when intervention VAR is used for the years 1982–1986, we obtain an average value for \( q_t \) of \(-0.28\) whereas, as expected, a higher value, \(0.22\), is shown when we use unrestricted VAR estimates and, as sample of data, the full period. In conclusion, our estimate for \( q_t \) have been calculated using VAR intervention methods for the period 1982–1986 and the unrestricted VAR methods for the years 1960–1981 and 1987–1996.

Before estimating \( q_t \), we investigate the question of delivery lags. We compute different estimates for the expected value of \( q_t \) permitting for delivery periods from one to three years. The best results were obtained for a value of two, so we infer that investment expenditures at time \( t \) would depend on investment orders from time \( t - 2 \) to \( t \).

In Table 2 we give the estimated values for the standard deviation estimates of \( q_t \), \( L(\hat{\beta}_i) \) and \( L(M_i) \)\(^8\) for both VAR(1) and VAR(2) processes.

One main result emerges from Table 2. By contrast with Abel and Blanchard (1986), where much of the cyclical variability of the estimated marginal cost of investment was attributed to cyclical variability in \( L(\hat{\beta}_t) \), in our case the variability must be attributed to both components with a small prevalence of the marginal profit component. This result remains valid for the VAR(1) as well as for the VAR(2) specification. Thus, during the period 1960–1996, movement in \( q_t \) must be attributed more to variation in the marginal profits component and less to movement in the cost of capital. This finding could be related to the agricultural credit policy, which was triggered to maintain a flat real interest rate for investment in the agricultural sector during the period of analysis.

\(^7\)The test is described in Lütkepohl (1991, pp. 402–405). Under the null hypothesis of stationary models against one in which all parameters are allowed to vary, the test is distributed as a \( \chi^2 \) distribution with \([s - 1)K(K(p + 1/2) + 3/2)] \) degrees of freedom, where \( s \) is the number of regime periods, \( K \) is the number of variables, and \( p \) is the VAR order. In our case \( s = 2, K = 5, p = 1 \) or 2. Thus we have 45 degrees of freedom in the case of VAR(1) and 70 degrees of freedom for the VAR(2) specification.

\(^8\)See Appendix B in Abel and Blanchard (1986) for a method to derive standard deviations of \( L(\hat{\beta}_i) \) and \( L(M_i) \).
We use our measure of the marginal present value of profits \( q_t = E[q_t | \Omega_{t-2}] \) to compute the marginal Tobin’s Q,\(^9\) where the shadow price of capital has been calculated conditional on the information set \( \Omega_{t-2} \) in order to take account of a delivery lag of two periods. As previously defined, marginal-Q is given by the ratio of \( q_t \) to the replacement cost of capital \( p_t' \). The optimal rate of investment is clearly an increasing function of marginal-Q. Thus, we run the following regression to analyze the empirical relationship between exponentially detrended rate of investment and marginal-Q

\[
\frac{I_t}{K_{t-1}} = \delta_1 + \delta_2 \frac{q_t}{p_t'} + \delta_3 Z_t + \epsilon_t, \tag{16}
\]

where \( \frac{I_t}{K_{t-1}} \) is the rate of investment, \( \frac{q_t}{p_t'} \) is Tobin’s marginal Q, \( p_t' \) is the real investment deflator,\(^10,11\) \( Z_t \) is a vector of variables that can influence the rate of investment other than marginal-Q, \( \epsilon_t \) is an error term with zero mean and finite variance, and \( \delta_1, \delta_2, \delta_3 \) are parameters that must be estimated. Naturally equation (16) must not be interpreted as a structural equation because we are only analyzing the relationship between detrended values. In Table 3 we report the results when the estimated marginal Q from the VAR(2) model is used.\(^12\)

The first column in the table presents the OLS regression when only marginal Tobin Q has been included. The estimate for marginal-Q has a positive effect on the rate of investment and is significant at the 99% confidence level for a two-sided test. We find a value of 0.038, which is quite similar to Abel and Blanchard’s (1986) results where an average value ranging between 0.01 and 0.03 has been estimated. In the last six rows of the table, we introduce standard statistics given by the coefficient of determination \( R^2 \), the Lagrange multiplier test on the null hypothesis of zero serial order correlation, the Jarque–Bera test on the null hypothesis of normal residuals, the Arch(1) test on the null hypothesis of homoskedasticity, and finally the Reset test on the null hypothesis of correct specification. Looking at the statistics, we note that more than 65% of the variance is explained by the model and the error distribution does not show signs of serial correlation, heteroskedasticity and non-normality. Finally, the Reset test rejects the hypothesis of mis-specification of the model. We choose to consider the real land prices values, the real value-added deflator, and the net operating surplus/capital ratio as others determinants of the rate of investment. To avoid simultaneity problems, we include only lagged values of these variables. Following Abel and Blanchard’s (1986) approach, we also introduce a lagged value of marginal-Q. Columns (2)–(5) report the results. Marginal-Q is always positively and significantly related to the rate of investment. We do not note relevant changes of the \( \hat{\delta}_2 \) estimate, except for the regression where the real value-added deflator has been inserted, but in this case as well as for the other regressions where additional variables have been inserted, the reported estimates are not significant at the

---

\(^9\) We checked also for the relevance of \( q_t \) expectation of conditional on the information set at time \( t - 1 \) and \( t - 3 \). The results, not reported for brevity, show that both the expectations are negatively related with the rate of investment and not significant at the 95% confidence level for a two-sided test.

\(^10\) Note that we have also exponentially detrended the real investment deflator in order to have a comparable measure with the detrended rate of investment.

\(^11\) We do not have data for the investment tax credit \( k \) and the depreciation allowance \( z \). We assume that these effects are picked up by \( \hat{\delta}_2 \) estimate.

\(^12\) We obtain worst results when the shadow price of capital is estimated from a VAR(1) specification.
usual 95% confidence level. Note that, contrary to Abel and Blanchard’s (1986) results, regression (2) shows that the lagged value of \( q_t \) has a negative and insignificant coefficient. Finally, for all regressions the \( R^2 \) still reports that more than 65% of the variance is explained by the model and, as before, regressions do not show signs of serial correlation, heteroskedasticity, non-normality, or misspecification. Though not reported, we also estimate equation (16) by using the instrumental variables method, where instruments were given by lag values of dependents as well as independent variables included in the regression. We do not report the results because are similar with these presented in Table 3.

In conclusion, the results indicate that our marginal-Q measure may be seen as a “sufficient statistic” (Hendry, 1995) in the sense that it can well characterize relationship (16) in a parsimonious way within the general theoretical framework of an optimal capital investment decision process in the presence of adjustment costs and financial constraints.

**5. CONCLUDING REMARKS**

Recent research on investment decision process stresses the importance of financial constraints in capital market in determining the rate of investment. In the first part of the paper we review the literature on the investment decision process and we show that when credit constraints hold, the expected marginal stream of profit per unit of installed capital can be correspondingly reduced.

In the second part of the paper we present a methodology, largely derived from Abel and Blanchard (1986), to estimate the expected present discounted value of the stream of marginal profits attributable to a unit of capital and, from this, the marginal Tobin’s Q. Using VAR intervention methods we are able to correct both estimates for the presence of

**TABLE 3.** Regressions of \( I/K \) (detrended)

<table>
<thead>
<tr>
<th>Variable</th>
<th>(1)</th>
<th>(2)</th>
<th>(3)</th>
<th>(4)</th>
<th>(5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>(-0.0018)</td>
<td>(-0.0003)</td>
<td>(-0.0017)</td>
<td>(0.0030)</td>
<td>(-0.0142)</td>
</tr>
<tr>
<td>Marginal-Q</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Marginal-Q, lag 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real land prices, lag 1</td>
<td>(-0.0061)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Real value-added deflator, lag 1</td>
<td></td>
<td></td>
<td></td>
<td>(-0.6358)</td>
<td></td>
</tr>
<tr>
<td>Marginal Profit, lag 1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>(0.0604)</td>
</tr>
<tr>
<td>Number of observations</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>( R^2 )</td>
<td>0.67</td>
<td>0.70</td>
<td>0.69</td>
<td>0.67</td>
<td></td>
</tr>
<tr>
<td>( F ) test</td>
<td>66.00</td>
<td>32.71</td>
<td>37.66</td>
<td>36.27</td>
<td>32.07</td>
</tr>
<tr>
<td>LM(2) test</td>
<td>1.435</td>
<td>1.349</td>
<td>1.213</td>
<td>1.054</td>
<td>1.453</td>
</tr>
<tr>
<td>Jarque–Bera test</td>
<td>1.571</td>
<td>1.534</td>
<td>0.991</td>
<td>1.033</td>
<td>1.615</td>
</tr>
<tr>
<td>Arch(1) test</td>
<td>1.187</td>
<td>0.495</td>
<td>3.245</td>
<td>0.490</td>
<td>1.075</td>
</tr>
<tr>
<td>Reset test</td>
<td>2.243</td>
<td>2.467</td>
<td>3.091</td>
<td>2.738</td>
<td>2.154</td>
</tr>
</tbody>
</table>

*Source:* author’s calculation using Eurostat and INEA data sets. In parentheses \( t \) statistics.
financial constraints. Using data for the agricultural sector in Italy during the period 1960–1996, we show that much of the cyclical movements of the rate of investment is explained by our marginal Tobin’s Q measure. This may be seen as a sufficient statistic in the sense that it characterizes the relationship between the rate of investment and the expected marginal steam of profit in a parsimonious way within the general theoretical framework of the optimal capital investment decision making process in the presence of adjustment costs and financial constraints.

ACKNOWLEDGMENT

This study was supported by a grant from the MURST (Italy). The author thanks the Journal reviewers for helpful suggestions.

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