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Rural Market Imperfections and the Farm Size–Productivity Relationship: Evidence from Pakistan

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Summary. — The subject of this article is the relationships between farm size and productivity and between farm size and profitability in the developing countries. The recent controversies over the inverse size–output relationship are reviewed, and a framework is provided that explains the inverse relationship based on plausible assumptions about imperfections in the markets for labor, land, credit and risk. From this framework, a set of testable hypotheses are derived. The hypotheses are tested on recent farm-level panel data from Pakistan. A strong inverse relationship between farm size and yield is present in the sample, even when household fixed effects are used to account for unobserved heterogeneity. Moreover, the suggested market imperfections framework is consistent with the data. © 1998 Elsevier Science Ltd. All rights reserved

Key words — Pakistan, South Asia, agriculture, inverse relationship, market imperfections, land reform

1. THE INVERSE RELATIONSHIP

Interest in the relationship between farm size and output per acre dates back to the early days of development economics (Bauer, 1946; Sen, 1962). Through the 1960s and 1970s a substantial body of empirical work accumulated on what became known as the Inverse Relationship (IR), the majority of which supports the hypothesis that small farmers produce more per unit of land than large farmers. Because of its wide-reaching implications, the inverse relationship between farm size and output is one of the most important and hotly discussed *stylized facts* of rural development. The inverse relationship constitutes a core argument for redistributive land reform, as it implies that land reforms which lead to a more equal size distribution of holdings, by improving both efficiency and equity, will promote rural growth and poverty alleviation (Eckstein *et al.*, 1978; Lipton, 1993; Singh, 1990). For example, the early land reforms in Japan, South Korea and Taiwan were no doubt important factors behind the economic transformation of those countries, creating the agricultural surplus, growing consumer demand and political stability needed to sustain rapid industrialization.

The IR hypothesis is not only central to the analysis of agrarian structure and land reform, it also has important implications for natural resource management and migration. Labor-extensive farming on big holdings generates a class of marginalized landless laborers unable to obtain land or employment in the fertile agricultural areas. As a consequence, this excess labor is driven to cultivate ill-suited tracts in forests, uplands, steep hill-slopes and arid lands (Repetto and Holmes, 1983). This kind of agricultural expansion has devastating human and ecological consequences. Farmers earn a poor living from such marginal lands, which tend to be unproductive, ecologically fragile, prone to erosion, located far from markets and lacking basic infrastructure. The ecological consequences — deforestation, loss of wildlife habitat, soil erosion and so forth — can be very damaging and sometimes irreversible. Rather than blaming the smallholders for their unsustainable practices, however, an argument can be made that the root cause is embedded in the tenure

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relations and the distribution of land in the "sending" areas (Dorner and Thiesenhusen, 1992). A similar argument concerns rural–urban migration, often caused by institutional "push factors" related to the distribution of land in the rural areas (Mohtadi, 1990). In sum, the inverse relationship, if true, is closely related to problems of agricultural stagnation, natural resource degradation, political instability, migration and poverty.

Therefore, the hypothesis of an inverse relationship has important implications for policy makers and academics concerned with agricultural development. Nevertheless, the many studies on the topic carried out over the last 30 years have not yet led to a consensus about the alleged inverse relationship, nor to a satisfactory understanding of the factors causing it. Thus, it has often been suggested that the Green Revolution has diminished or even reversed the IR. In addition, the validity of the empirical underpinnings has been questioned, with critics arguing that the inverse relationship is a spurious result caused by bias due to the omission of land quality in the regressions (Bhalla and Roy, 1988; Benjamin, 1995). Another issue is that much of the empirical IR literature has not paid sufficient attention to the factors shaping the size–output relationship. Asymmetrical labor costs between large and small farms resulting in differential intensity of labor and fixed factor utilization is an often cited explanation for the IR. Imperfect labor markets, however, cannot alone account for a systematic size–output relationship — it remains to be construed why operational holdings fail to adjust through land rental or sales to endowments of fixed factors, including family labor. Hence, the size–output relationship has to be explained in terms of a multiplicity of market failures. The present study seeks to do this by providing a simple and consistent framework to account for the size–output and size–profit relationships based on a small set of plausible assumptions about imperfections in the markets for labor, land, credit and risk. Subsequently, this framework is tested using IFPRI's five-year survey of rural Pakistani households. Fixed household effects are used to control for unobserved heterogeneity (such as soil fertility), avoiding some of the methodological shortcomings of previous work.

This article is organized as follows. The subject of the following section is the "classic" approach to testing the IR and the methodological critique raised against that approach for omitting land quality. The data set is introduced in Section 3, followed by a set of simple regressions establishing the inverse relationship in Section 4. Explanations of the IR are discussed in Section 5, where the market-imperfections framework is set out. From this framework a number of empirical hypotheses are derived, and a regression model to test them is outlined in Section 6. In contrast to previous work, the model controls separately for size of owned holding, size of operated holding, number of family workers and risk. The empirical results from testing the market imperfections framework are presented in Section 7. Conclusions and policy implications appear in Section 8.

2. CONTROVERSIES OVER THE INVERSE RELATIONSHIP

The classic IR studies were based on ordinary least squares (OLS) regressions of simple models such as

$$\log(y) = \alpha + \beta \log(OP) + \varepsilon \qquad (1)$$

where the value of output, y, is regressed on net operated farm size OP. An inverse relationship requires β to be less than unity if y is total output and β to be negative if y is output per acre. Many studies, employing different versions of equation (1), find a significant inverse relationship. These include Berry and Cline (1979) for Brazil, Colombia, Philippines, Pakistan, India and Malaysia; Cornia (1985) for 15 different countries; Rao and Chotigeat (1981) for South India; Carter (1984) for Haryana in North India; Kutcher and Scandizzo (1981) for North-East Brazil; Bhalla (1979) and Bharadwaj (1974) for India and the 20-odd studies surveyed by Sen (1975). Thus, during the 1970s the inverse size–output relationship came to gain status of a well-established stylized fact. In recent years, however, the IR hypothesis has been questioned. There are two major arguments against the validity of the IR. The first is that the failure to control for unobserved land quality and other farm heterogeneity in regressions based on (1) could lead to biased results. The second argument is that the Green Revolution may have diminished or reversed the inverse relationship.

The first argument against an inverse relationship is that if land quality is negatively related to the size of the farm, then the omission of land quality in regression (1) would cause a downward bias in the estimate of β, giving rise to spurious conclusions with regard to the presence of an inverse relationship. Since it has in fact been suggested that a systematic correlation between land quality and farm size is possible (Sen, 1966; Sen, 1975), it appears crucial to account for land quality in order to obtain unbiased estimates of β. Unfortunately, most data sets do not include direct observations of land quality. Hence, indirect methods have to be applied. Two recent studies have done this relying on geographical disaggregation and instrumental variables, respectively.

The first study is due to Bhalla and Roy (1988), who estimate an expanded version of (1) based on nationwide Indian data. A significant negative size–output relationship is established in 16 out of 17 Indian states; yet, when the regressions are run on more disaggregated geographical units, the importance of the IR appears to diminish — a significant negative coefficient on land is found in only 51 out of 176 districts. The authors draw the conclusion that the more disaggregated the level of pooling, and thus the better unobserved soil fertility is accounted for, the less important is the IR phenomenon. The reason why geographical disaggregation can control for unobserved variables (including soil fertility) is that the smaller the geographical unit, the more reasonable is it to assume that soil is homogenous.

Bhalla and Roy's approach is not without methodological problems, though. First, the disaggregated district-level regressions have much smaller sample sizes, and even if an inverse relationship were indeed present in all the sampled districts, one would expect more rejections of the IR simply because disaggregation entails a large loss of degrees of freedom. Second, regional disaggregation controls only for between-district heterogeneity, while within-district heterogeneity remains unaccounted for. Third, it cannot be neglected that many village-level studies based on much more disaggregated and hence homogenous samples than any of Bhalla and Roy's regressions find a significant IR (e.g. Berry and Cline, 1979, pp. 80–86) for Pakistani Punjab). Indeed, it seems hard to control satisfactorily for unobserved land quality when analyzing national or regional data. Already Sen (1975) argues for the advantage of using village samples, where unobserved heterogeneity due to climate, soil type, environmental factors, infrastructure and market access is either reduced or eliminated, leaving only within-village heterogeneity. This is also the approach pursued by Carter (1984), who, using village fixed effects to control for intervillage differences in soil fertility, establishes a significant inverse relationship for farms in Haryana, India. The present article takes this idea one step further, by controlling for household fixed factors in a panel data setting.

Benjamin (1995) takes a different approach to omitted variable bias in an analysis of Javanese rice farmers. While OLS regressions reveal an inverse relationship between operational holding and output, this relationship disappears altogether in a two-stage procedure, where instruments are used to predict farm size (or more precisely: area harvested) in the first-stage and output is regressed on predicted (rather than actual) farm size in the second stage. This finding suggests that the unobserved variable, i.e. soil fertility, is correlated with farm size, and hence that OLS regressions of the size–output relationship suffer from omitted variable bias. There appear to be some problems, however, with the excluded instruments used by Benjamin in his first stage regressions. The instruments used to predict harvested area in the first-stage regressions (population density, presence of a city, number of males and females of age 10–15) appear not to account very well for the variation in harvested area, yielding R^2 of 0.12–0.14, so the validity of the instruments is an open question. Furthermore, with an average farm size of 0.71 ha the farms in his study are very small, with most farms below 2 ha. In a sample of very small and relatively homogenous farms relying mostly on family labor, it is to be expected that the inverse relationship is weaker than in more heterogenous agrarian communities as the *supervision constraint* will be less binding.

The second argument against the validity of the IR concerns the impact of the Green Revolution on the size–output relationship. The Green Revolution brought about greater reliance on purchased inputs and capital goods which supposedly are easier available to large farmers with better access to savings and credit. Based on Indian district-level data from 1970–71, Deolalikar (1981) finds that in districts using large quantities of fertilizer (a proxy for advanced technology), the big farms are the most productive, while in less-developed districts, the small farms are more productive. This corresponds partly to the findings of Bhalla (1979), also based on all-India data, who reports that although an inverse relationship was clearly present it had declined somewhat from 1968–69 to 1971–72, as the Green Revolution proceeded. Likewise, Berry and Cline (1979) note that while in India and Pakistan the IR seemed to diminish (but not disappear) during the late 1960s and early 1970s, productivity differentials remained equally strong in Brazil and Colombia, presumably because the Green Revolution had more impact in Asia. On the other hand, other studies from the same period find strong evidence in favor of the inverse relationship (for example, Carter, 1984). In any case, the picture which emerged in the early days of the Green Revolution may not be representative of the present situation, where more recent evidence, in fact, suggest that the Green Revolution technology is neutral to scale. The perception that big farms benefited disproportionately from the Green Revolution may have been caused by initial faster adoption of Green Revolution technology by large farmers, but once the benefits of the new technologies had been proven to them, the smaller farmers adopted them to the same extent (Hazell and Ramasamy, 1991). In any case, whether the inverse relationship post-dates the Green Revolution remains an important empirical question that can be settled only with up-to-date data sets.

3. DATA

The data in this study are from the Pakistan Rural Household Survey, carried out by the International Food Policy Research Institute (IFPRI) over 14 rounds, covering the five years from 1986–87 to 1990–91. The original sample includes 930 rural households from 52 villages in the districts of Attock and Faisalabad in Punjab, Badin in the Province of Sind and Dir in the North-West Frontier Province. The sample selection procedure was not entirely random, as described by Alderman and Garcia (1993). Three of the districts were chosen purposely as the least developed within their province, while one (Faisalabad) was chosen to represent a more prosperous case. Within each district, villages and households were selected by stratified random sampling.

The mean owned holding is around nine acres (2.47 acres = 1 ha), but the distribution of land is highly skewed with 39.4% of the sampled households owning no land at all. When only the group of landowners is considered, the smallest 25% own a modest 2.5% of all land, while the biggest 25% of landowners hold 71.5%. Land rental markets are quite active and lead to a more equal distribution of operated farm sizes compared to the ownership distribution. In fact, 40% of all land is operated under sharecropping contracts, while 8% of the land is operated under fixed rent tenancy. Agricultural labor markets are active. On average, in a given year 35% of farms in the sample are labor self-sufficient; 42% of farms hire, but do not sell, farm labor; 11% of farms sell, and do not hire, labor; while 12% both buy and sell labor. Even small farmers (less than five acres) use hired labor to some extent.

All data used in this article are on a yearly basis. Thus, the two annual cropping seasons, *kharif* (monsoon crop) and *rabi* (winter crop) have been aggregated, giving up to five observations for each household. The land variables *OP* (operated holding size) and *OW* (owned land) are the mean of the holdings over the year. When constructing *OP* and *OW*, adjustment is made for irrigation by weighting rainfed land at 50% of irrigated land. This corresponds to the difference in land value between irrigated and rainfed land in those areas that have both types of land.[1]

The panel nature of the data is exploited by including two-way *fixed effects*, that is, a constant term for each household and for each year. As mentioned, the household fixed effects control for unobserved farm heterogeneity (e.g. ability), for locational factors, and for differences in land quality on that (core) part of the farm which is constant over the sample period. Hence, in the fixed effects regressions, only time-variant (from year to year) differences in land quality and other unobserved variables remain unaccounted for. The models are estimated with period effects to account for latent year-to-year variation, for example in weather. In order to allow for inclusion of some time-invariant regressors, complementary random effects specifications were also estimated. The samples used for regressions were determined, after excluding a small numbers of outliers, by retaining all farming households with valid observations on all the regressors in the estimated model. As a consequence, the sample size varies between regressions, and the panel is unbalanced in that for each household, the sample contains from one to five years of observations.

4. A SIMPLE TEST

In this section the estimation results from a set of simple regressions of output as a function of farm size are presented. The purpose of this analysis is to maintain comparability with earlier IR studies and to address the issues raised in Section 2. Estimation was done on the full sample as well as for each district and for each village separately, using the following specification:

$$\frac{y}{OP} = \alpha + \beta \ln(OP) + D_i + D_t + \varepsilon \qquad (2)$$

In equation (2), y is farm value-added constructed as the value of crop and livestock production less all cash inputs including land rented in but excluding family labor. OP is operated holding size, and D_i and D_t are fixed household and year effects, respectively.

Results are presented in Table 1. Value-added per acre is found to decrease strongly, and highly significantly, with farm size. This holds equally true for the full sample, and when separate regressions are estimated for each of the four districts. The estimated elasticities of value-added per unit of land with respect to operated farm size are large and range from −0.79 in irrigated Badin to −1.46 in rainfed Attock. It is interesting that a significant inverse relationship also exists in irrigated Faisalabad, the most developed district, which is of more or less the same magnitude as in the other, relatively poorer, districts. This suggests that conclusions about the size–output relationship do not depend on whether the area under study is irrigated and relatively commercialized (as in Faisalabad), or whether it is rainfed and more subsistence oriented (as in Attock). Hence, the conclusions appear robust to IFPRI's sampling of relatively less developed districts.

Equation (2) was also estimated at the village level, in order to allow the slope of the size–output relationship to vary between villages. Estimation was carried out separately for each village with more than 20 valid observations. Results are summarized in compact form in Table 2. A significant inverse relationship is

Table 1. *Simple district-specific regressions of farm value-added*[a]

	Fixed-effect regressions of farm value-added per operated acre				
Province:	Punjab		Sind	NWFP	Full sample
District:	Faisalabad	Attock	Badin	Dir	
Comment:	(irrigated, wealthy)	(rainfed, poor)	(irrigated)	(partly irrigated)	
ln(OP)	−5133	−3775	−1535	−11524	−5786
	(8.95)*	(10.9)*	(9.74)*	(5.76)*	(10.5)*
Constant	12708	7185	5240	16723	12986
	(13.1)*	(16.3)*	(15.3)*	(11.8)*	(15.4)*
R^2	0.56	0.85	0.56	0.49	0.53
N	485	610	1013	634	2742
Elasticity w.r.t. OP	−1.22	−1.46	−0.79	−1.15	−1.33

[a]Absolute value of t-statistics in parentheses. *Significant at 99% level.

Table 2. *Summary of village-specific regressions*[a]

	Results of fixed-effect regressions of value-added per operated acre		
	Number of villages where coefficient on land is		
	Significant[b]	Not significant	Sum
Estimated elasticity			
Less than −2	3	–	3
−1 to −2	11	1	12
−0.5 to −1	14	4	18
0 to −0.5	1	5	6
Larger than 0	–	3	3
Sum	29	13	42
Mean sample size	72	47	64

[a]The table summarizes the results of individual regressions of equation (2) for 42 villages.
[b]Based on the 95% confidence level.

found in 29 out of 42 villages, that is, 69% of villages (based on 95% two-tailed level of significance). The estimated elasticities at the village level are roughly comparable to those for the districts and for the full sample. Thus, in 30 out of 42 villages the estimated elasticity of value-added with respect to operated size lies within the -0.5 to -2 range. The estimated β parameter is positive in three of the villages, but in none of these cases is it close to being significant. On average, the villages where the size–output relationship is insignificant have smaller sample sizes, which goes some way towards explaining why the relationship is not significant. In conclusion, the results strongly support the existence of an inverse relationship post-dating the Green Revolution, even when differences in time-invariant soil quality and other unobserved variables is controlled for through fixed effects and geographical disaggregation. The remaining part of this paper is devoted to understanding and testing the factors causing the observed differences in yield.

5. MARKET IMPERFECTIONS AND THE INVERSE RELATIONSHIP

In this section, the factors shaping the size–output relationship are discussed. In a neoclassical world with constant returns to scale and well-functioning markets, all variable inputs and fixed factors would be applied in equal proportions across farms. Hence, no systematic yield differences would be observed. Therefore, explanations accounting for the systematic size–output relationship reside in either

— economies of scale,
— differences in efficiency between large and small farmers,
— asymmetrical market imperfections (the subject of this paper),

or some combination hereof.[2]

First, a number of studies have found near-constant technical returns to scale in farming operations (Berry and Cline, 1979), making it unlikely that the inverse relationship is caused by decreasing returns to scale. In contrast, it has been speculated that lumpy inputs such as large capital goods may render the very smallest farms nonviable. Likewise, increasing returns to scale in processing, marketing and input delivery might be passed on to large farms as lower input and higher output prices (Binswanger and Elgin, 1990). Second, the efficiency approach studies the efficiency of farmers' input decisions. An interesting example is the study by Ali and Flinn (1989), who, using a stochastic frontier production function, find a considerable degree of profit inefficiency (the sum of technical and allocative efficiency) among Pakistani rice producers. Different socioeconomic and institutional factors are significant in explaining this inefficiency, while farm size, interestingly, is not. Third, many studies of the size–output relationship assume constant returns to scale in farming technology and rational behavior of farmers, and instead depart from the neoclassical assumptions by focusing on asymmetrical market imperfections, causing different transaction costs and effective prices on farms with differential endowments, thereby generating the observed differences in inputs and yields. This is also the approach adopted in this paper. Thus, in the remaining part of this section a survey is presented of some of the major theoretical contributions that model the size–output relationship based on asymmetrical market imperfections.

The first account of the size–output relationship is Sen's (1966, 1975) theory of *agricultural dualism*, where the "traditional" small-scale peasant sector is assumed to be endowed with plentiful family labor with low or zero opportunity cost, while facing a severe constraint on credit. The large-scale "capitalist" sector, on the other hand, relies on more costly hired labor but has better access to capital. As a consequence, the peasant sector will apply more labor per acre than the capitalists. This can explain declining *productivity* (in terms of output per acre), but increasing *profitability* (when the cost of family labor is imputed based on market wages) as the farm size increases.

A theory of labor market imperfections, however, is not sufficient to account for a systematic size–output relationship, a fact which, although noted by Sen (1966), has been largely overlooked in the empirical literature. Only if farm size for some reason is sticky will the differential labor costs lead to less intensive labor use and smaller yield on big farms. Thus, it has to be explained why farmers adjust labor intensity per acre (and hence yield) rather than modifying farm size to available labor through land rental or sales markets. In other words, given the large observed systematic productivity differentials, why does the market mechanism fail to ensure that large farms are sold or rented to landless and small peasants? The explanation, as will be seen below, either lies in imperfections and asymmetries in access to credit, which prevent financing of land transactions, or in the land markets themselves. Therefore, a multiplicity of market failures have to be invoked in order to account for systematic yield differences.

In the following, a selected set of formal microeconomic models of the inverse relationship are discussed, paying particular attention to the cause of each market failure and the way it has been modeled. All the surveyed papers employ the framework of static optimization, where a representative farm household maximizes either farm income or expected utility subject to a production function with constant returns to scale and some additional constraints. These constraints capture the various market failures and generate a solution where yield is correlated with farm size. The various contributions differ in the particular combination of markets assumed to be imperfect, as well as in the way the imperfection is modeled. Hence, the subject of the following is the modeling of labor, land, credit and risk market imperfections in economic models of the inverse relationship.

(a) *Labor market imperfections*

Sen (1966) models the labor market imperfection in the dualistic tradition of modern sector wages that exceed marginal product in peasant farming, or $w^{\text{modern}} > w^{\text{peasant}}$. Later theories, nested in the imperfect information paradigm, observe that where small farms rely mainly on family workers, who are residual claimants and supposedly well-motivated,[3] larger farms recruit wage labor either permanently or seasonally. Because of moral hazard problems, hired laborers do not exercise as much care, effort and judgement as family members, and therefore require continuous supervision. This means that time and effort of family members has to be spent on supervision and monitoring, thereby raising the effective cost of hired labor above the market wage. In addition, there are search and hiring costs associated with outside laborers, they do not share in the risk in the way family workers do, and family labor, unlike hired labor, often provide non-marketed fixed factors such as bullocks and managerial ability. Eswaran and Kotwal (1986) and Kevane (1996) model this as a fixed cost of supervision per hired laborer, $C_s = C_s(L^{\text{in}})$, where C_s is supervision cost ($C_s' > 0$) and L^{in} is the number of hired laborers. Feder (1985) and Carter and Wiebe (1990) employ a more flexible specification where effort of hired labor, e, is a function of the intensity of supervision (the number of family workers relative to the operated holding): $e = e(H/OP)$, $e' > 0$ and $e'' < 0$, where H is family labor and OP is size of the operated holding. Effective labor input in their models thus becomes

$$L^{eff} = H\bar{e} + L^{in} e\left(\frac{H}{OP}\right),$$

where $\bar{e}$ is the effort of household members. Whichever way it is modeled, it is clear that, above some threshold level, the *supervision constraint* on output is more binding the larger the operated holding relative to the number of family workers. This will be tested in Section 7.

Labor market imperfections may also arise for reasons other than moral hazard problems with respect to hired workers. Thus, labor markets may not exist for some or all types of labor, or may only exist in certain seasons. In Pakistan, this is true especially for women and children. The opportunity cost of employing such *captive* household members on the family farm is not the wage rate but the marginal utility of leisure. This relates to the discussion of whether farm household production can be modeled as separable or non-separable (Sadoulet and de Janvry, 1995). Household models are separable if the opportunity cost of hired labor (wage rate plus search, hiring and monitoring costs) equals the opportunity cost of using family workers, i.e. their wage in off-farm employment minus search and travel costs. Under separability, farm labor demand is independent of household labor supply decisions. Non-separability, in contrast, arises when the cost of hiring farm workers differs from the wage rate for family members in off-farm employment, whether due to supervision costs, missing markets or some other imperfection. Although a formal discussion of separability lies outside the scope of this paper, a few comments are in order. First, it is possible that separability applies to some farms and not to others. Thus, Sadoulet, de Janvry and Benjamin (1998) have shown, for a sample of Mexican farmers, that separability holds for labor-selling and labor-buying households, while it is rejected for the labor self-sufficient farm households. Second, because of the seasonality of agrarian labor markets it is also possible that separability holds in some seasons, but not in others. Because of its global nature, the framework proposed in this paper to test for a supervision constraint causing an inverse relationship obscures the issue of separability somewhat by not distinguishing between different types of households and between seasons.

(b) *Land market imperfections*

The hypothesis of a *"land tenure constraint"* is the dual assumption of sticky *operational* holding (due to imperfect land rental markets) and inflexible *owned* holding (due to sales market imperfections). Rental markets for land are subject to various imperfections caused by the uncertainty created by ambiguous and inexpedient land reform legislation, by Marshallian inefficiency and by other transaction costs (Skoufias, 1995). Many countries, particularly in South Asia, have enacted restrictions on land rental contracts, so-called "land to the tiller" legislation. Although these laws remain poorly enforced, they nevertheless make long-term lease contracts in land a risky venture for the landowner, because if the laws were to be enforced, the land could be allotted to the tenants. Thus, the real or perceived risk from land reform may seriously curtail land rental markets, especially for long-term lease (Hayami and Otsuka, 1993; Shaban, 1987). Thus, in the model by Kevane (1996), apart from normal rent, renting out land is associated with a cost due to the probability of property loss, the value of which is a function of net area rented out:

$$C_z = C_z(OW - OP),\ C_Z' > 0$$

where OW and OP denote owned and operated land, respectively.

In addition, land rental contracts are vulnerable to well-known agency problems including Marshallian inefficiency. Under *share* contracts, the rent is specified as a fixed proportion of the harvest, giving tenants incentive to supply less input than an owner–cultivator and to underreport output. This decreases the rent received by the landlord. *Fixed rent* contracts, in contrast, are incentive compatible as regards the input of variable factors, but place the entire yield and price risk on the tenant, and an implicit risk premium will therefore be deducted from the rent. If rent is paid before harvest, shortage of liquidity might prevent credit constrained farmers from renting land in, as in the models of Feder (1985) and Eswaran and Kotwal (1986). If instead rent is paid after harvest, the landowner faces uncertainty as to whether the agreed rent will be paid. This is the situation in the model due to Wiens (1977), where $E(r^{out}) < r^{in}$ i.e. the expected return from renting out land is less than the certain cost of renting in land. Summing up, the expected return to land leased out is less than the return to land under self-cultivation with sufficient fixed factors, imposing a limit on the extent to which land rental markets equalize the proportion of fixed factors to operated land.

Why farmers fail to adjust the size of the *owned* holding to their endowment of family labor must also be explained. Land sales markets are subject to various imperfections. First, markets for land may be thin or non-existent. In some parts of the world, for example, sales to outsiders are restricted. Second, formal credit tends to favor larger and more influential farmers, while small farmers are rarely able to mobilize savings or credit to finance land purchases. In fact, most land transactions are distress sales motivated by subsistence needs rather than by the wish to adjust farm size to optimal scale. Therefore, differential access to credit combined with distress sales may, over time, reinforce an unequal and inefficient distribution of land as the bigger farmers acquire land from productive poor farmers in temporary distress (Carter and Wiebe, 1990). Third, government intervention in input, output and land markets are rarely neutral to scale. Interventions tend to benefit the large holdings and are in practice often the result of lobbying, repression or coercion by the landed elites, eager to preserve the economic and political power associated with landownership (Carter and Barham, 1996; Binswanger, Deininger and Feder, 1995). Fourth, it should not be overlooked that land is more than an asset used in agricultural production. Land is often used for savings, as an inflation hedge, it is the place of the ancestral home, an important source of power and prestige and serves as collateral for credit (Platteau, 1992). Zimmerman and Carter (1996) have shown in a dynamic stochastic programming framework that, in the absence of other credit and insurance mechanisms, poor farmers forced to self-insure will value land less than the wealthy because land is relatively illiquid and therefore not as useful an insurance substitute as other assets. Hence, land is not a normal asset: The savings, insurance, inflation, prestige and collateral values of land inflate the price of land above the expected returns from farming. This means that even if credit for land purchases was available at market interest rates, non-farm income would be needed to service the debt, as the returns from agricultural operations on the purchased land would be insufficient (Binswanger and Deininger, 1997). Moreover, many of the mentioned valuation factors asymmetrically disadvantage poor farmers. The implication is that the actual distribution of land is likely to deviate substantially from the distribution that would maximize agricultural output or efficiency (at shadow prices). In fact, over time land may be accumulated by rich people as a store of wealth.

Hence, imperfections and interventions in land rental and sales markets constrain the ability of farmers to efficiently match owned and operated farm size to their endowment of family labor and other fixed assets. A supervision constraint on labor in conjunction with imperfect land markets can therefore account for the inverse relationship.[4]

(c) *Credit market imperfections*

Because of the risk and asymmetrical information inherent in agriculture, formal financial institutions ration the amount of credit supplied to the farm sector, giving rise to a *liquidity* or *credit constraint* (Carter, 1988). Financial institutions routinely require collateral in the form of land or other fixed assets as a condition for offering loans (Binswanger and Rosenzweig, 1986). They may also charge fixed fees or operate minimum loan sizes, which prevent smallholders from obtaining the modest loans they need. Farmers with access to liquidity are able to purchase cash inputs, can finance land improvements, can invest in machinery and may hire labor. In addition, in the absence of insurance markets, reliable access to credit allow farmers to invest in more risky but higher yielding crop and asset portfolios.

Feder (1985) models credit to be a function of the amount of land owned, i.e. $B = B(OW), B' > 0$. Eswaran and Kotwal (1986) and Kevane (1996) have credit fixed exogenously outside the model (although they say credit depends on owned holding). The resulting lack of liquidity during the planting and growing seasons limit the ability of farmers to rent in labor and land and to purchase cash inputs. Note that where the supervision constraint works on *operated* land, the credit constraint concerns *owned* land, since land rented in cannot be collateralized. Thus, in a regression of yield or profits, a positive estimated parameter on amount of owned land is evidence of a credit constraint, while a negative parameter on amount of land operated indicates a supervision constraint (Binswanger and Rosenzweig, 1986).

(d) *Risk*

If credit is rationed and other consumption smoothing opportunities are limited, it is important to incorporate risk aversion into the analysis of farm behavior. Wiens (1977) and Kevane (1996) have done this by assuming that farmers maximize expected utility (rather than income) in a stochastic production environment. The famous paper by Eswaran and Kotwal (1986) also has stochastic production, but the effect of that is neutralized by assuming risk-neutral agents. The empirical importance of risk has recently been demonstrated by Rosenzweig and Binswanger (1993), who show, using Indian data, that although poor farmers are more profitable than wealthy farmers, their relative advantage diminishes as the riskiness of weather increases. The reason is that wealth and access to post-harvest credit constitute buffers against risk which allow the larger farmers to invest in more risky crop and asset portfolios with higher expected yields. Thus, poor farmers' *ex-ante* adjustment to risk — or risk management — may result in lower average output.[5]

There is a potentially important caveat to the above statement. In a recent paper, Barrett (1996) has shown that risk-averse farmers who are net buyers of food may react to food price risk by increasing their labor input to food production. Farmers who are net-sellers of food, however, react as posited above by decreasing labor input to food production when subject to price risk. Given that net sales of food is highly correlated with farm size, the differential response to risk by food-deficit and food-surplus households may help account for the inverse relationship. Empirically, it is not always straightforward to decide whether farm households are in food-deficit or in food-surplus. Thus, households may be net-sellers of some food items and net-buyers of others. In the IFPRI Pakistan data set, if the food position of farm households is measured as the difference between farm value-added and current food expenditures, it is found that on an annual basis, 62% of sample farm households are net-buyers of food.[6] Hence, the effect of risk on productivity is *a priori* ambiguous and may depend on household endowments.

(e) *Relevance for Pakistan*

The market failures discussed above are not merely of theoretical interest, but play important roles in Pakistani agriculture, as documented by Faruqee (1995a,b). Fundamental issues faced by policy-makers include slow agricultural growth, rising unemployment and the financial cost to the government of agricultural subsidies. In Pakistan, agricultural output grew by 3.2% annually during 1970–91, barely exceeding population growth. Land markets are distorted by the exemption from tax (until recently) of agricultural income and property, making agriculture a tax shelter for absentee landlords. In addition, ownership of land is highly valued as a traditional source of status and political influence, and urban families are reluctant to part with their landed property. As a result, land distribution in Pakistan is highly unequal. Land rental markets, although very active, are affected by insecurity of property loss created by land-to-the-tiller legislation enacted in the 1970s.

There are also a number of other policy distortions with differential impact on farms of different sizes. These include subsidies for mechanization and subsidized credit directed to the large farms and the rural elite, while collateral requirements exclude the small farmers. Many of the loans used to finance tractors are subsequently defaulted, but, ironically, the land put up for collateral is never foreclosed by the financial institutions. Extension is inadequate and biased toward large farmers. The predictable outcome is promotion of self-cultivation by medium and large farmers, resulting in low cropping intensities, one of the reasons for the disappointing performance of agriculture and the employment problems (Faruqee, 1995a,b). For these reasons, Pakistan offers an interesting and important case for testing the market imperfections framework.

6. REGRESSION MODEL

The framework outlined in the preceding section is general in nature and does not necessarily predict an inverse relationship in all cases. Imperfect credit and risk markets entail relative advantages for the large farmers, that is, effects opposite of the supervision constraint. This means that the framework of labor, land, credit and risk market imperfections can be used to explain size–output and size–profit curves of all possible shapes, depending on the relative magnitude of the supervision constraint *vis-à-vis* the credit and risk constraints for different farm sizes. Hence, the framework is capable of encompassing all previous studies, irrespective of the functional relationships established. The generality of the framework, however, does not mean that it is impossible to discriminate between this and competing theories. To the contrary, a number of testable predictions, which make falsification possible, can be derived from the market imperfections framework. These hypotheses are:

(a) There is an overall inverse relation between operational farm size and productivity and efficiency per unit of land.

(b) Farmers operate under a supervision constraint with respect to hired labor, which is more binding the larger the operated holding relative to the family work force.

(c) Land sales and rental markets are imperfect, giving rise to a land tenure constraint. The return from land leased out is less than from self-cultivation with sufficient family labor and hence, at the margin, the possibility for efficiently adjusting owned and operated farm size to the endowment of family labor and other fixed factors is limited.

(d) Farmers are subject to a credit constraint, which can be relaxed through ownership of land and other fixed assets.

In order to empirically investigate these hypotheses, a parsimonious model is formulated, which permits a simultaneous test of all the above hypotheses. This approach contrasts to most other work in this area, which typically has analyzed one of the above hypotheses in isolation, for example by estimating equation (1) to test for an inverse relationship, by testing for credit constraints (Sial and Carter, 1996) or by testing for separability of family and hired labor (Benjamin, 1992). The advantage of the proposed simultaneous test is that it allows drawing inferences about the size–output relationship as well as the underlying market failures causing it. The model is[7]:

$$\frac{y}{OP} = f(OP, OW, H, R, Z), \tag{3}$$

where y represents different input and output variables (see below), OP denotes the size of the operated holding, OW is amount of owned land, H is the number of (adult equivalent) family workers, R is risk, and Z is a vector of other exogenous variables influencing farm productivity such as exogenous land quality, farmer education etc.

The expected signs of the regression parameters in (3) are: $f'_{OP} < 0$, because for given family size and size of owned holding, more operated land makes the supervision constraint and other labor market imperfections bind harder[8]; $f'_{OW} > 0$, because for given family size and operational holding, a larger owned holding relaxes the credit constraint[9]; $f'_{H} > 0$; because additional family workers relax the supervision constraint; and f'_{R}, indeterminate, because farmers' choice of crop mix under risk may result in lower output, while risk-averse food-deficit households may increase their labor input.

Equation (3) is a multiple correlation. Land rental decisions, inherent in the difference between *OP* and *OW*, two of the right-hand side variables, cannot be considered exogenous. Hence, the results should not be interpreted as in a reduced-form model, where the regression parameters represent the complete marginal effect of the exogenous on the endogenous. Instead, the estimated parameters represent partial correlation coefficients that show the impact of the right-hand side variables for given levels of all the other regressors. As such, this model is ideal for a simultaneous test of the hypotheses above. As in all regression analysis, however, there is a potential for biased estimates if omitted, yet important, variables are correlated with one or more of the regressors. This is the potential problem of omitted variable bias discussed in Section 2. At the household level, such excluded variables are for example land quality, farming skills, experience and preferential access to inputs. At the village level, candidates for omitted variables are infrastructure and asymmetrical prices. These — potentially very important — variables are unobserved in most data sets. They may reasonably be assumed, however, to be time-invariant. This means that the omitted variables can be modeled as household-specific constant terms, or dummies. In practice, this amounts to assuming that unobserved variables such as the fertility of a given plot of land, the household's farming skills, preferential access to credit, market access etc are constant over the sample period. The consequence is that the omitted variables will be differenced out by the fixed effects procedure adopted for estimation. In fact, fixed effects is the recommended estimation procedure for dealing with latent, time-invariant regressors, which in that case yields consistent and unbiased estimates (Hsiao, 1986).

Another issue concerns the choice of output variable to analyze (y in equation (3)). Focusing on farm yields for testing the IR hypothesis, as has been done in much of the previous IR literature, is not entirely satisfactory, since yield is a very partial measure of productivity. Land is not the only scarce resource, and for researchers and policy makers concerned with overall resource efficiency (or total factor productivity), the relationship between agricultural *profitability* (at social or market prices) and the scale of operations is more relevant. Calculating farm profitability, however, requires imputing the value of family labor, whose opportunity cost of time is very difficult to estimate; as a consequence, profit measures may contain biases, depending on whether the opportunity cost of time for family labor is over- or underestimated. For these reasons, three different output variables are analyzed in this paper: farm value-added (crop and livestock output less all cash inputs), return to owned land (farm value-added plus rental payment received for land rented out) and crop profits (the value of crop production less cash inputs and family labor). In addition, two input variables are included in the analysis: labor and credit.

7. EMPIRICAL RESULTS

The market imperfections framework was tested by estimating relationship (3) with five different output and input measures. In Table 3, the means of the dependent variables are presented by farm size category. Foreshadowing later results, it can be seen that the measures of production (per acre value-added and return) decrease with operated farm size, while the opposite is true for profits. A third-degree polynomial form for *OP* was chosen in order to have a flexible functional form, encompassing a variety of non-monotonous relationships. In order to avoid collinearity problems, the ratio of owned to operated land, *OW/OP*, is included to control for owned farm size (instead of *OW*), following van Zyl, Binswanger and Thirtle (1995).

Table 3. *Means of endogenous variables by farm size*

Farm size *(acres)*	Value-added[a] *OP*	Return[a] *OW*	Crop profits[a] *OP*	Labor[b] *OP*	Credit[a] *OP*	Proportion of farms in sample (%)
Less than 5	5395	6314	−507	78	5954	52
5–12.5	1994	4735	−235	47	2258	33
12.5–25	1773	4709	381	34	1501	12
Above 25	1689	3903	971	19	1830	3
All farms	3721	5586	−256	59	3997	100

[a]In rupees.
[b]In man-days.

(a) *Analysis of value-added*

The results from the extended regression of value-added are presented in Table 4.[10] In the fixed effect (FE) regression, OP, OP^2 and OP^3 are all highly significant in explaining farm value-added. The parameter estimates imply a U-shaped relationship between value-added per acre and operated holding size. This is depicted in Figure 1, which was constructed by fitting a third-degree polynomial least-square line through the predicted values from the fixed-effect regressions. The results entail a distinct inverse relationship for the vast majority of farms which are smaller than 16 acres,[11] that is, 90% of all farms and 65% of all operated land. Given that owned holding and family size is controlled for, the downward-sloping part of the curve is consistent with a supervision constraint. Possible explanations for the upward-sloping part of the value-added curve in Figure 1 are discussed below. However, it should be kept in mind that the upward-sloping section of the curve represents a tiny fraction of the sample. Thus, estimation of a functional relationship for the largest of farms is much more sensitive to outliers and statistical uncertainty than for farms smaller than 25 acres, where the bulk of observations are located. In any case, an important policy conclusion of this paper is that land redistribution in favor of small and average-sized farms can substantially increase the productivity of Pakistani agriculture. The ratio of owned to operated holding has a positive and highly significant impact on production, underpinning the productivity effects of property rights to land. Thus, for a given operated size, 10% expansion of the owned holding will lead to 1.2% increase in value-added. This is consistent with the hypothesized collateral effect. Family size, as measured by the number of adult equivalent household members, also has a positive and highly significant influence on farm value-added, suggesting that family and hired labor are imperfect substitutes. The implied elasticity indicates that, at the mean, a 10% increase in the number of family workers is associated with 3.4% higher yield.

The relationship was also estimated with a random effects (REM) procedure, which, unlike fixed effects, does not control for unobserved time-invariant variables such as soil heterogeneity. To the extent such unobserved variables are correlated with the included regressors

Table 4. *Regression results for value-added, profits and labor*[a]

	Farm value-added per operated acre		Crop profits per operated acre	Labor input per operated acre	
	FE	REM	FE	FE	REM
Operated land, OP	−493	−565	325	−10.4	−7.20
	(6.79)**	(17.9)**	(6.12)**	(7.62)**	(10.9)**
OP^2	12.7	14.7	−9.6	0.251	0.170
	(5.23)**	(13.6)**	(5.73)**	(5.54)**	(6.94)**
OP^3	−0.080	−0.093	0.069	−0.0016	−0.0011
	(4.24)**	(10.9)**	(5.21)**	(4.70)**	(5.45)**
Ratio of owned to operated land,	355	301	84	0.894	−0.321
OW/OP	(7.57)**	(14.3)**	(2.14)*	(1.18)	(0.66)
Adult equivalents, H	304	211	352	7.97	4.74
	(4.12)**	(5.6)**	(2.50)*	(2.63)*	(5.58)**
CV of income, R	–	−1597	–	–	−10.5
		(2.23)*			(1.45)
Highest education	–	372	–	–	−2.27
		(3.41)**			(1.96)
Constant	4419	5101	–	80.9	88.7
	(9.48)**	(7.64)**		(5.26)**	(6.43)**
R^2	0.68	0.18	0.61	0.65	0.13
N	2708	2708	1715	1604	1576
Hausman chi-square (5 d.f.)	15.7**	–	28.7**	18.5**	–
Breusch–Pagan chi-square (2 d.f.)	–	535**	–	–	692**
Elasticity w.r.t. OP	−0.72	−0.80	–	−0.91	−0.61

[a]Absolute values of t-statistics in parentheses.
*Significant at 95% level.
**Significant at 99% level.

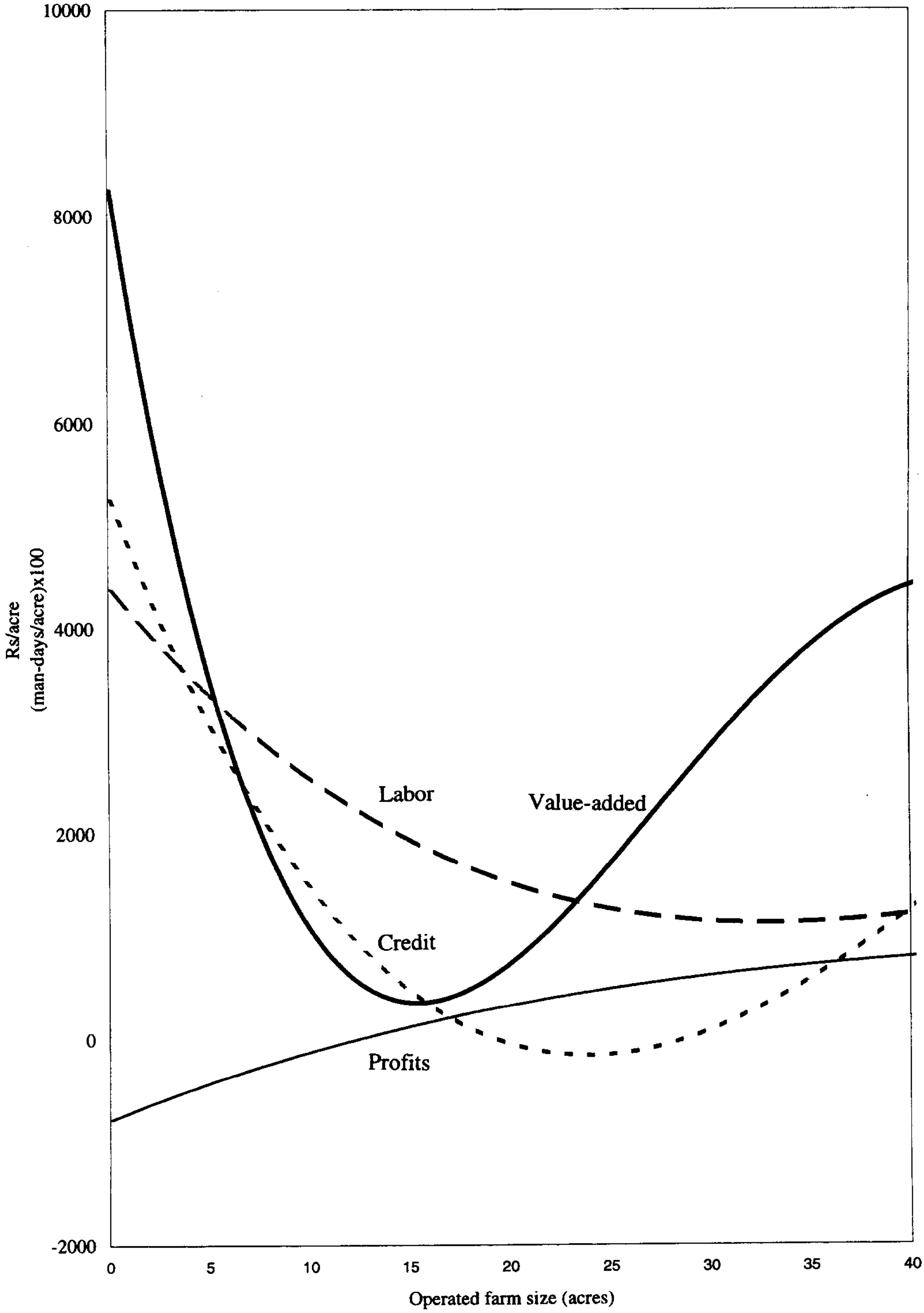

Figure 1. *Per acre value-added, profit, labor input and credit as a function of operated holding size (based on predicted values from the fixed effect regressions).*

random effects will lead to biased results (Mundlak, 1978). As a matter of fact, the significant Hausman test statistic (for the model without risk and education) suggests a correlation between the household-specific effects and the regressors, arguing in favor of the fixed effects. Although results of the random effects regressions therefore have to be interpreted with caution, they yield interesting insights since additional variables can be included in the REM models. These variables — risk and education — are time-invariant, and have to be excluded from the fixed effect specifications as they are orthogonal to the household dummies. The results in Table 4 show that compared to fixed effects the REM model yields fairly similar, and again highly significant coefficients for operated land, owned land and family size, inspiring confidence in the results. The elasticity of value-added with respect to operated size, taken at the mean and accounting for *OW/OP*, is -0.72 and -0.80 using fixed and random effects, respectively. These values are comparable to the elasticities estimated in the simple regressions of value-added on ln(*OP*) in Table 1 and Table 2. Hence, a 10% reduction in the size of the mean farm would raise its yields by 7–8%. Risk is measured as the Coefficient of Variation (CV) of per capita real income over all five years.[12] Risk is found to have a marked negative impact on production, significant at the 97% confidence level. This is consistent with the hypothesis that, due to imperfect insurance markets, farmers' *ex-ante* risk management results in less profitable cropping and investment patterns. Thus, at the mean, an increase in the variation of household income of one CV reduces per acre value-added by 43%. In elasticity terms, this corresponds to 2.1% reduction in output every time income risk increases by 10%. Education, measured as the highest level of schooling achieved by any member of the household, is found to have a fairly large and highly significant positive impact on value-added. The highly significant Breusch–Pagan test statistic suggests that, compared to OLS without household-specific effects, REM is to be preferred.

(b) *Analysis of return to land*

The next output variable to be analyzed is return to land per acre of owned holding. Return is defined as farm value-added plus rental income from leasing out land. The purpose of analyzing return to owned land is to investigate how the profitability of land use varies with ownership size. That is, which farm size category is able to put its land to the most profitable use, whether through own farming or leasing out. Return to land is analyzed with a flexible functional form in *owned* holding size, while controlling for the level of operational holding. The sample size for this regression is smaller since pure tenants, who do not own any land, are excluded.

The results, reproduced in Table 5, indicate a highly significant U-shaped relationship between per acre return to land and owned holding size. Hence, for given operated holding and family size, the profitability of land declines markedly as owned holding increases up to about 27 acres (4.5 times the mean, 14 times the median). For the largest 3% of farms, return to land increases with farm size. Thus, it can be concluded that small farmers, on average, are able to secure a higher return (gross of own labor) to the land they own compared to medium and large farmers. Return per unit of owned land is found to increase significantly with operated size. This is as expected since a larger operated holding allows a higher total production, while leaving the owned holding unchanged. The number of family workers has a large positive and highly significant coefficient, supporting the hypothesized supervision constraint. Estimating return to land with random, instead of fixed effects, gives strikingly similar results with respect to owned land, operated land and family size. In addition, income risk, as measured by the CV of per capita real income, has a very large and significant negative influence on per acre return to land, supporting the hypothesis of lacking insurance opportunities. The level of education is not significant in this regression.

(c) *Profits*

The last output measure to be analyzed is crop profit. The purpose of using profits is to approximate total factor productivity, albeit at market rather than shadow prices. This way, the size–*efficiency* relationship may be estimated. Crop profits are constructed as the value of crop production less cash inputs (including rented land) and less family labor valued at the mean market wage. Livestock profits had to be excluded due to the difficulty of interpreting herding labor data. Because of paucity of labor data, only the first three years are included in the sample for this regression. As can be seen from Table 3 and Figure 1, calculated mean profits for small and average-sized farms are negative.

Table 5. *Regression of return to land*[a]

	Return to owned land per acre owned	
	FE	REM
OP	164	167
	(2.72)**	(5.65)**
OW	−899	−972
	(3.62)**	(9.60)**
OW^2	17.4	19.2
	(2.32)*	(6.35)**
OW^3	−0.0926	−0.107
	(1.84)	(4.99)**
Adult equivalents	1269	1207
	(6.07)**	(10.2)**
CV of income	–	−5266
		(2.79)**
Highest education	–	536
		(1.87)
Constant	3787	5712
	(2.61)**	(3.11)**
R^2	0.64	0.13
N	1829	1829
Hausman chi-square (5 d.f.)	12.2*	–
Breusch–Pagan chi-square (2 d.f.)	–	294**
Elasticity w.r.t. *OW*	−1.27	−1.39

[a]Absolute values of *t*-statistics in parentheses.
*Significant at 95% level.
**Significant at 99% level.

These "losses" are, of course, fictitious, and illustrate the problem of imputing to family labor the market wage, instead of the unobserved shadow wage or opportunity cost of time (Sen, 1966).

Results are given in Table 4. Interestingly, crop profits per operated acre exhibit a highly significant monotonous increase with respect to operated farm size. The increasing size–profit relationship, although relatively flat, is in striking contrast to the U-shaped relationship estimated for value-added and return to land.[13] The difference between the production and the profit curves is, as will be seen shortly, caused by much more intense labor input on smaller farms, which reduce calculated profits. Caution is warranted, however, when interpreting the size–profit relationship. The efficiency of small farms is likely to be understated insofar as the market wage overstates the shadow wage of family labor. Hence, from this analysis it is difficult to draw conclusions about the size–efficiency relationship at social prices. In line with previous findings, owned holding size and family labor force contribute positively and significant (at the 96 and 98% level, respectively) to crop profits.[14]

(d) *Input of labor*

In order to investigate the causes of the size–output and size–profit relationships, complementary analyses of size–input relationships were undertaken for inputs of labor and credit. Looking first at total labor input (sum of family and hired) per operated acre, the regression results show a significant decrease in labor use as farm size increases up to about 30 acres. For the 2.5% of farms above 30 acres, the intensity of labor use appears to increase again slightly (see Table 4 and Figure 1). Labor use does not respond significantly to the ratio of owned to operated farm size. This is hardly surprising given that owned holding is included to control for credit access, which is probably of limited importance for labor input on that majority of farms where household members provide the main source of labor input. Family size, instead, is a highly significant determinant of labor input. The elasticity of per acre labor input with respect to the number of adult equivalents is 0.61 (holding other factors constant), indicating the crucial role of family labor in farming. A qualitatively similar picture emerges in the random effects specification of labor input, where operated holding and family size are again significant. The absolute size of the parameters, however, decreases somewhat in the REM model, and the ratio of owned to operated land changes sign, but remains insignificant. The estimates indicate that, at the mean, a 10% decrease in operated holding leads to 6.1–9.1% increase in labor input. The strength of the estimated inverse relationship for labor is therefore commensurate with the inverse relationship for value-added. Risk does not appear a significant determinant of labor input. The highest education of any person in the household is found to have a small negative impact on labor use, which is almost significant at the 95% level.

(e) *Credit use*

Finally, the determinants of credit use were investigated. The endogenous variable is the sum of all credit obtained during the previous year, including formal and informal, short term and long term. Table 6 shows the distribution of credit on purpose of loan, type of lender i.e. formal (bank, cooperative) and informal (moneylender, shopkeeper, trader, friend etc) and type of collateral. It is striking that a large share, 80%, of all credit in the sample is given without explicit collateral requirement. Nevertheless, when looking at credit for production purposes, and especially for capital equipment, collateralized loans are important. This is because credit for farm capital, being long-term, mostly comes from institutional lenders who are much more likely to demand collateral than informal lenders specializing in consumption loans. Thus, the importance of collateral, mostly in the form of land, should not be underestimated. Not only is collateral often required to achieve attractive institutional loans, which are cheaper and have a longer maturity than informal loans. Even in cases where explicit collateral is not requested, lenders may use endowments of land and other assets to screen potential borrowers, in the sense that wealthy people are judged more creditworthy than others.

The results of an econometric analysis of the determinants of credit use are presented in Table 7. The analysis does not seek to separate demand from supply, nor to explicitly test for rationing.[15] Instead, the purpose of this regression is to analyze credit use within the market imperfections framework developed in Section 5 and Section 6. It can be seen that, in line with expectations and previous results, credit use responds positively and significant to owned holding size. But, the amount of credit obtained per unit of cultivated land displays a significant U-shaped relationship with respect to *operated* size, decreasing up to 25 acres and increasing hereafter (plotted in Figure 1). Hence, for the majority of farms below 25 acres, the larger the operated farm (for given owned holding and family size), the less credit is obtained per acre. At the mean, an increase in *operated* holding of one acre is associated with a fall in per acre credit of 7.3%, while a one acre increase in *owned* holding entails a 1.2% increase in per acre credit. The finding that per acre credit declines with operated size for the majority of farms does not contradict the notion of a credit constraint for small farmers, insofar as the amount of credit obtained may still be less than desired (at given interest rate). In any case, the mix between institutional and informal credit, which carry very different interest rates, differs between small and large farms.

The size–labor and size–credit curves in Figure 1 illustrate how the systematic output differentials are caused by differential input intensity across the farm size range. The much higher labor input on small farms explain their superior output combined with low or negative imputed profits. It is interesting how the

Table 6. *Credit use by source, type of collateral and purpose*

	Percentage value of all loans						
	Formal sector loans — type of collateral			Informal sector loans — type of collateral			All loans
	Land	Other	Nothing	Land	Other	Nothing	
Purpose of loan							
Farm machinery	10.5	0.8	5.7	–	0.1	1.8	18.9
Other farm purposes	3.3	0.4	4.1	–	1.6	7.3	16.7
Non-farm purposes	1.7	0.3	1.7	0.3	1.0	59.4	64.4
All purposes	15.5	1.5	11.5	0.3	2.7	68.5	100

Table 7. *Regression of credit use*[a]

	Credit use per operated acre	
	FE	REM
OP	−267	−308
	(3.95)**	(10.2)**
OP^2	1.88	2.46
	(2.39)*	(6.31)**
OW/OP	357	334
	(4.39)**	(8.81)**
Adult men	397	546
	(1.15)	(3.70)**
Adult women	−4.54	17.4
	(0.013)	(0.11)
CV of income	–	178
		(0.19)
Highest education	–	476
		(3.17)**
Constant	4474	3105
	(4.24)**	(2.73)**
R^2	0.65	0.12
N	2200	2200
Hausman chi-square (5 d.f.)	11.1*	–
Breusch–Pagan chi-square (2 d.f.)	–	362**
Elasticity w.r.t. *OP*	−0.53	−0.58

[a]Absolute values of *t*-statistics in parentheses.
*Significant at 95% level.
**Significant at 99% level.

U-shaped farm size–credit curve mimics that of value-added. A causal relationship, though, between credit and value-added cannot be established without further analysis. Hence, it is conceivable both that more credit causes higher productivity, or that higher cropping intensity by small farmers makes them demand more credit. In addition, the higher per acre production on farms of 50 acres, as compared to farms of 25 acres, is related to higher input intensity, perhaps caused by preferential access to credit by the largest handful of farms.

A different measure of family size was employed for the credit regression, since it is the number of creditworthy individuals, rather than the family labor force, which is of analytical interest in this case. The number of adult family members of each sex (above the age of 18) was entered separately in order to test for differential treatment of men and women. Although both variables are insignificant in the fixed effects specification, it is interesting to note that the parameter for adult men has a large positive value, while it is close to nil for women. In the random effects version, the same picture emerges, with the exception that here the number of adult men is highly significant. This suggests that Pakistani lenders are reluctant to advance loans to women. The sign of risk is ambiguous *a priori*, since, on the one hand, higher income risk leads to larger demand for credit in order to smooth consumption, while, on the other hand, risky environments can scare away lenders concerned about repayment. As it turns out, the coefficient of risk is positive but insignificant. The level of education is associated with a significant and fairly large amount of additional credit.

8. CONCLUSIONS AND POLICY IMPLICATIONS

The inverse relationship between farm size and productivity is an important stylized fact of rural development, which has far-reaching implications for development policy and academic research. The present study has sought to review and clarify the controversy over the inverse relationship and to present novel empirical work based on Pakistani farm data. Three lines of criticism have been raised in the literature against the IR hypothesis, (a) that the empirical evidence is flawed due to omitted variable bias,

(b) that the relationship may no longer hold after the Green Revolution, and (c) that a consistent explanation for the inverse relationship is missing.

With respect to the first criticism, this article has presented strong evidence to support the presence of an inverse size–output relationship even when soil and other heterogeneity is controlled for through a fixed-effects procedure. With regard to the second point of critique, it was found that small farms are still significantly more productive than big farms, also in irrigated and relatively developed areas of Pakistan. With respect to the third point, a parsimonious framework based on a set of reasonable hypotheses about labor, land, credit and insurance market failures was set up to account for systematic size–output and size–profit relationships. The approach, which controls explicitly for operated land, owned land, family size and time-invariant unobserved heterogeneity using panel data, is novel in the IR literature.

The study suggests that the market imperfections framework conforms well with the data. Thus, the evidence is consistent with the presence of a supervision constraint with regard to labor, where outside workers are imperfect substitutes for family labor. Data also support the hypothesis of a credit constraint. Indeed, credit use is positively related to ownership of land, even when operated holding is controlled for, consistent with the hypothesis of an important collateral value of owned land. This implies that the size of the owned holding is a significant determinant of per acre productivity, after controlling for operational holding and other factors.

Summing up, for these data there is no indication that the Green Revolution has reversed the size–output relation, or that the IR should be an artifact of omitted variable bias. The results imply that land redistribution in favor of small owner–operators could enhance agricultural production as well as improve equity, although it is unclear what effect such reform would have on the social efficiency of resource allocation. The policy implications, however, extend well beyond redistributive land reform, which is highly difficult politically. Instead, market-based reforms are urgently called for, which enhance the flexibility of land markets to adjust the size distribution of farms. Policy reforms called for to this end are (a) removal of subsidies and other policies with differential impact on small and large farms, (b) improved access to credit for small farmers (at market rates), (c) improved access to training and extension for small farmers, and (d) removal of restrictions which limit or cause insecurity in land tenure contracts. Such improvements in rural markets, by capitalizing on the superior productivity of small farmers, would lead to increases in efficiency, productivity, employment and equity, even in the absence of state-sponsored land redistribution.

NOTES

1. The dominant mode of providing irrigation is through canals (96% of all irrigation in the sample). Canal irrigation is an example of a land improvement which is exogenous to the individual farmer, and hence its inclusion does not bias the estimates (which would be the case if endogenous types of land improvements were included on the right-hand side).

2. Barrett (1996) shows that differential response to risk also may cause an inverse relationship. See the discussion in Section 6(d).

3. Although Kevane (1996) points out that there can be moral hazard problems associated with family labor as well.

4. None of the surveyed theoretical papers have explicitly modeled the land sales market; instead, owned holding is taken as given.

5. By risk *management* is meant *ex-ante* adjustment to risk (e.g., through cropping and investment patterns), whereas *ex-post* adjustments to realized production or income shocks is referred to as risk *coping*.

6. This finding is evidence of the importance of non-farm income for rural households in Pakistan, as documented by Alderman and Garcia (1993).

7. This is an extended version of the model originally proposed by Binswanger and Rosenzweig (1986) and by Binswanger, Deininger and Feder (1995).

8. An anonymous referee of this journal suggests $f'_{OP} \leq 0$, since the supervision constraint may be non-binding for small farmers that do not hire any labor. This would correspond to an initial flat segment on the size–output relationship. Even very small farmers, however, may occasionally hire labor, for example due to harvest labor shortages, illness, temporary migration etc. Furthermore, if there is captive labor without off-farm employment opportunities, labor input will be strictly decreasing in operated farm size even for farms that do not hire any labor. Ultimately, this is an empirical question that can only be settled using sufficiently flexible functional forms in the size–labor and size–output regressions: Section 7

shows that these relationships are indeed decreasing over most of the range, including the small farms.

9. In a similar way, one could argue that $f'_{OW} \geq 0$, since over certain ranges an increase in owned land may have no effect on the shadow price of liquidity.

10. Year and fixed effects are not reported.

11. All data on farm size are adjusted for irrigation by scaling rainfed area by a factor of 0.5.

12. This is conceptually quite different from the risk measure adopted by Rosenzweig and Binswanger (1993), which is the CV of the monsoon starting date.

13. A U-shaped size–output relationship combined with monotonously increasing profits is also found by Carter and Wiebe (1990) for a sample of Kenyan farmers. Benjamin (1995) finds a stronger IR for labor and output than for profits in his Java data set.

14. The random effects specification is not presented because of a very low R^2. Interpretations are not qualitatively different.

15. This has been done by Broca (1995) using the same data set as in this paper. Broca also finds that formal lenders are willing to lend more to large landowners.

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