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The Impact of Human Capital on Firm-Level Input Use: Argentine Agriculture[1]

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This paper attempts to understand the linkages between human capital and input choice in agricultural firms. The hypothesis to be tested is that better educated managers choose different input combinations than managers with a lower educational level. In particular, the hypothesis is that the ratio between non-land and land input increases as education increases. Non-land inputs include fertilizers, machinery services, herbicides, animal stocks and others. An increase in the non-land/land input ratio results in increased output (and costs) per unit of land. Given the fixity of land at the aggregate level, the non-land/land input ratio is an important determinant of total sector output.

Este trabajo tiene como objetivo entender los vínculos que existen entre capital humano y uso de insumos en empresas agropecuarias. La hipótesis a ser sometida a prueba es que los productores con mayor nivel de educación eligen combinaciones de insumos distintas que las elegidas por aquellos que cuentan con un nivel de educación mas bajo. En particular, que el ratio entre insumos de capital y el insumo tierra aumenta a medida que la educación de los productores aumenta. Los insumos de capital incluyen fertilizantes, servicios de maquinaria, herbicidas, capital biológico (animales) y otros. Un aumento en el ratio entre insumos de capital por unidad de recurso tierra resulta en mayor producto (y costos) por unidad de tierra. Dado que a nivel agregado la tierra es un insumo fijo, el ratio entre capital y tierra es un importante determinante de la producción total lograda. El nivel educativo de los productores, al impactar sobre la intensidad de uso de la tierra, resulta entonces un importante determinante del nivel total de producción logrado.

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[1] Views and opinions are of the author and not necessarily of the University of CEMA

The Impact of Human Capital on Firm-Level Input Use:
Argentine Agriculture

Human capital has long been recognized as an important factor in the efficiency of agricultural firms. Schultz´s pioneering paper (Schultz, 1961) opened up a research agenda that resulted in valuable insights related to the linkages between formal schooling, on the one hand, and different measures of economic efficiency, on the other (see, e.g. Welch, 1970; Huffman, 1974; Fane, 1975; Huffman, 1977; Welch, 1978; Petzel, 1978). The impacts of improved education are numerous, and include optimum level of input use (Huffman, 1974 and 1977), output choice (Petzel, 1978), firm size (Welch, 1978), off-farm income (Huffman, 1980) as well as other dimensions of agricultural firm efficiency.

Agricultural production takes place in many different types of production units. Firm differences include size, output mix, production technology as well as general organization (e.g. land tenure, degree of "vertical integration" and other aspects). Variation in the demand for decision-making skills is to be expected in different types of production units: availability of new technologies, changing prices, possibilities for multiple-output production as well as increased optimal scale of production all result in increased complexity of the management task. In this kind of scenario, managerial "quality" (presumably a function of formal schooling) should be expected to reduce mis-allocation of resources.

This paper attempts to understand the linkages between human capital and input choice in agricultural firms. The hypothesis to be tested is that better educated managers choose different input combinations than managers with a lower educational level. In particular, the ratio between non-land and land input increases as education increases. Non-land inputs include fertilizers, machinery services, herbicides, animal stocks and others. An increase in the non-land/land input ratio results in increased output (and costs) per unit of land. Given the fixity of land at the aggregate level, the non-land/land input ratio is an important determinant of total sector output. Higher "production intensity" results in lower marginal productivity of non-land inputs, thus increased risk of input use being higher than optimum. This is particularly true in firms subject to production variability due to uncertain in weather patterns.

Argentine Agriculture: 1970-2000

During the last decades, economic performance of the Argentine economy has been poor (see, e.g. Kasper and Streit [2000] Fig.1.1 p.12). The agricultural sector, in contrast, experienced rapid rates of technological change and output increase. Lema (2001) reports for the period 1970-1997 a 300 percent increase in output, and a 55 percent increase in Total Factor Productivity (TFP). Productivity growth has not been constant over the years; indeed there are some indications of lower TFP during the 1980´s, a period of high inflation and a "closed economy" policy environment. TFP growth has resulted from dramatic shifts in input use: corn hybrids replaced conventional varieties in the 1950´s, and new wheat, sunflower and soybeans seeds replaced older genetic materials during the 1970´s, 1980´s and 1990´s. Fertilizer and expanded despite "closed economy" periods, which resulted in very high fertilizer/grain prices for farmers. Inflation, weak or absent futures markets as well as political instability put additional strains on decision-making. Even so, production and TFP increased.

Research on the impacts of human capital on Argentine agriculture is not abundant. However, Gallacher (1999 and 2001) provides some evidence of the marginal productivity of human capital in production: estimation results (using 1988 Agricultural Census data) show a substantial return to educational inputs. Given the importance of the Argentine agricultural sector to the countries´ economy and the complex nature of decision-making in the Argentine agricultural firm additional research on the topic is warranted.

Human Capital in the Agricultural Firm: Conceptual Framework

Alchian and Demsetz (A&D) argue that "monitoring input use" is a key managerial activity (Alchain and Desmetz, 1972). Management returns are higher when this monitoring is done with greater effectiveness. Monitoring involves choosing which inputs to use, controlling shirking, detecting most favorable uses for certain inputs and providing incentives. The manager provides a "metering service" that would be costly in purely market-mediated transactions. The A&D hypothesis constitutes a useful starting point for understanding the linkages between human capital and agricultural production systems. In particular, these systems probably differ in the opportunities they offer for efficient monitoring: "simple" versus "complex" production situations may be associated with differences in the returns to increased quality and quantity of monitoring. In agricultural production systems the “monitoring” function includes a wide variety of tasks: labor has to be directed and supervised for effort, productivity of land in different enterprises has to be gauged and conditions for the use of fertilizers have to be determined.

Profit maximization requires equating input marginal productivity with relevant input prices. However, this is not the only (or the main) problem faced by the manager. An appropriate technique has to be discovered: inputs have to be used in certain ways. Higher-ability managers achieve higher profits because they discover ways in which inputs can be used more productively. This, in turn, leads to higher levels of input use.

Let V and T stand for, respectively, non-land, land inputs and management inputs. The firms´ production function is y = f(V, T,M). Cost minimization requires:

$$[1]\ RTS_{TV} = (\partial y/\partial T)/(\partial y/\partial V) = w_T/w_V$$

If all firms: (a) face identical input prices, and (b) RTS_{TV} is not a function of input M. the input ratio V/T (“intensity of production”) should be equal for all firms. However, the above may not hold. In order to explain this, consider the following. In a strictly neoclassical framework, production function y = f(V, T,M) is “known” by the decision-maker: for every input (V, T) combination some output y is forthcoming. The fact that knowledge flows freely among firms implies that the “availability” of input M is identical among all production units. However, if the assumption of identical managerial skills is dropped, input (V and T) productivity will depend on managerial skill. In relation to this, it is possible that increasing levels of M impact differently on the marginal product of non-land and land inputs: “new” (non-land) inputs result in complexity in decision-making. Their use may require skills that are in short supply. As a result the marginal productivity may be lower than what is possible. A positive interaction exists between managerial skills and the marginal productivity of non-land inputs if:

$$[2]\ \partial[(\partial y/\partial V)]/\ \partial M > 0$$

If such is the case, RTS_{TV} will differ among firms. If this is the case, firms with better managers will choose a “more intensive” (higher V/T) input ratio. To summarize, the important point is that not “one” but “many” production functions exist at any given point in time. A given firm is in (cost-minimizing) equilibrium given available knowledge. However, firms change their chosen input combinations as decision-making skills increase, and perceived input productivities shift to “potential” or “frontier” productivities. Education plays an important part here.

Education may have further impacts on input use. For example, loose evidence suggests that decision-making complexity increases with increases in V/T: as inputs (fertilizers, cattle, production expenses) per unit of land increase, output is more dependent on the vagarities of weather: given “good” conditions production will respond favorably, however if drought, hail or other hazards are present production may well be identical (or even lower) in firms using high as compared to low V/T ratios. The fact that non-land inputs require cash outlays, whereas the land inputs (for landowners) is a non-cash opportunity cost may further result in financial constraints for input use.

Education may also result changes in the relative prices of inputs, $w_T/w_{V.}$. In particular, market-purchased inputs included in V may be “cheaper” for better educated managers as a result of: (a) better access to capital markets results in lower costs of credit for the purchase of these inputs and (b) improved off-farm income prospects results in a lower “risk premium” on the use of purchased inputs. In particular, in a risk less setting optimum input use requires equating input productivity with input-output price ratio:

[3] $\partial y/\partial V = w_V/p$

However, under risk (see, e.g. Anderson, Dillon and Hardaker, 1977), input productivity will possibly be equated with the price ratio “corrected” by a risk premium factor β (>0):

[4] $\partial y/\partial V = [w_V/p]\ (1 + \beta)$

For reasons mentioned previously, β May well be a decreasing function of managerial human capital. Thus, increased use of V should result from improved levels of education.

In summary, managerial education may change both relative input productivity (RTS_{TV}) as well as (the relevant) relative input price ratio. Both changes will result in a higher V/T input ratio being chosen. Agricultural firms will thus differ in the quantities of inputs such as fertilizer, general crop expenses used per unit of land. In livestock farms, variation will be observed in the ratio between biological capital and the land input.

A further (and related) consequence relates to the demand – in firms differing in managerial human capital – of "information-type" inputs. It is advanced here that an increase in the V/T ratio will go hand-in-hand with increasing costs of input mis-allocation. Thus, managerial human capital leads to an increase in V/T ratios, where "V" includes both "conventional" inputs (fertilizers seeds, cash expenses) as well as "information-type" inputs such as soil testing, record-keeping and the use of private consulting services.

Empirical Analysis

Data analysis described below attempts to detect differences in resource use by managers differing in formal skills. The hypothesis to be tested is that increased skill levels result in increased intensity of production, "intensity" being defined here as the ratio of non-land to land inputs. The hypothesis that production intensity (V/T) is positively related to managerial skill (education) results from both the higher marginal productivity schedule of variable inputs that characterizes better managers, as well as a result of the lower total costs of inputs faced by these. In part, both of these aspects may result from the increased use of information inputs by more highly educated managers.

We focus attention o the main agricultural production region of Argentina: the *pampas*.[2] Five types of farms are analyzed: corn/soybean (C/S), wheat (W), mixed (M) cattle-fattening (CF) and cattle-breeding (CB). Impacts of managerial human capital on the use of "conventional" as well as "information" ("production function shifting) inputs is analyzed for each of these. A-priori, it is expected that a higher "decision-complexity" exists in C/S as compared to W farms, and in CF as compared to CB farms. Farms of type M – because of reduced specialization and crop-livestock interactions – also result in challenges for management. Although this paper does not address these issues in

[2] Data used here corresponds to the 1992 Agricultural Census, for the provinces of Buenos Aires, Cordoba, Santa Fé and Entre Ríos. This area the argentine *pampa* region, the most important agricultural region of the country.

depth, this taxonomy of production situations is a useful starting point for the subsequent analysis. Table 1 shows results. These can be summarized as follows:

Intensity of conventional input use: in C/S, W and M type farms a positive association clearly exists between fertilizer use and human capital (HC). Cropping intensity also increases with HC in farms of type M. Note that in C/S and W farms this measure is probably not relevant, as these two types of units have all a high (≥ 70 percent) of land allocated to crops. In livestock farms a similar (though not as strong) pattern exists: land allocated to artificial pastures (a “high cost per unit of land” feed strategy) generally increases with increases in HC. In CF farms HC is also associated with higher ratio between biological and land capital (“stocking rate”). This relation does not hold, however, in CB farms.

Intensity of Use of “knowledge” Inputs: the relation between HC and “information” inputs (“Technology Index” variable) appears even stronger than that between HC and conventional inputs discussed above. In all cases, increases in HC appear to be associated with increased demand for information and management tools. For example adoption of crop production information tools increases from 17 to 27 percent in C/S farms, and from 4 to 21 in W farms. The use of private professional consulting services (mostly agronomists) increases from 52 to 61 percent in C/S farms, and from 47 to 69 percent in farms type W. As discussed previously, it is possible the value of different types of information inputs varies between different types of production systems: for example, a higher adoption of crop production information tools appear (for each HC level) in C/S as compared to W farms. Similarly, in livestock production information use increases with HC: from 13 to 31 percent in farms CF, and 8 to 30 percent in farms CB. They are also more intensively used in CF as compared to CB farms. The use of private consulting services is also higher in CF as compared to CB farms (as expected a-priori), however in all cases increased HC results in increased demand for this input. Consulting services thus appear to *complement* rather than *substitute* for the managers HC level.

Conclusions

Management of firms is a complex endeavor. Complexity increases in situations where “new” inputs are continually being generated both by private as well as by government-funded organizations. In this context, managerial “quality” possibly results in changes in the rates at which inputs substitute for one another. Managerial quality can also impact input costs: relevant input prices are a function of the firms borrowing interest rate and the perceived “risk premium” that is required before inputs are committed to the production process. Both of these aspects may be a function of the managers´ know-how.

Results shown in this paper suggest that considerable heterogeneity exists in input use in agricultural firms. For all types of firms analyzed here, input “intensity” (the V/T ratio) generally increases as human capital increases. Furthermore, increases managerial human capital seems to be positively associated with the demand for “knowledge” type inputs of different kinds. It appears then that managerial knowledge (education) does not substitute but rather complements other types of knowledge inputs.

The Argentine agricultural sector provides an interesting case-study of decision making under risky and complex situations. The fact that important productivity increases have taken place during the last decades suggests a significant demand for decision-making skills. As in many other countries, in Argentina agricultural areas lag behind in educational levels. The impact of these lags has yet to be ascertained.

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Appendix: Data Set and Variable Definition

Data Set

Micro-data (firm level) of the 2002 Agricultural Census was used. A 10-percent sample of census observations was randomly chosen in order to speed up processing. Observations correspond to the Argentine "pampa" region, the most important agricultural area of the country (provinces of Buenos Aires, Córdoba, Santa Fé and Entre Ríos). Total census observations for these provinces is around 253.000 farms (sample approximately 25300 observations).

Variable definition

Human Capital: Human capital (HC) levels of farm managers was divided into three groups: (i) less than primary education (five or less years of schooling, HC = 1)), (ii) complete primary education and up to three years of secondary education (HC = 2) and (iii) more than three years of secondary education, and up to complete university education (HC = 3).

Crops Production – resource intensity: Two important determinants of costs per unit of land input ("input use intensity") are derived: planted crop hectares as a percentage of land area ("Crops/Total Land), and fertilized hectares as a percentage of total crop area ("Fertilizer Use"). As mentioned in Section II, crop production has been subject to a considerable higher rate of technical change than livestock production. Further, crop – as compared to livestock production - involves considerably higher cash inputs per unit of land. These cash inputs are subject to considerable production risks.

Crop Production – information/managerial inputs: The "Technology Index" variable includes "knowledge" type inputs such as soil and seed testing, "precision agriculture", new crop field tests and insect monitoring ("scouting"). The "Private Consulting" variable measures percentage of farms using these services, and is also a "knowledge" type input.

Livestock production - resource-use intensity: The ratio between livestock capital and land ("Livestock/Land") is an important measure of the intensity of land use in livestock farms. The “Technology Index” variable includes rotational grazing, supplemental feeding, use of production records and other “managerial” practices.

Table 1: Impact of Human Capital (HC) on Selected Input Ratios

	Crops/Total Land	Fertilizer Use	Technology Index	Private Consultant
Corn/Soybeans (C/S)				
HC = 1	94	37	17	53
HC = 2	94	38	20	55
HC = 3	94	46	27	61
Wheat (W)				
HC = 1	88	63	4	47
HC = 2	91	76	13	58
HC = 3	90	90	21	69
Mixed (M)				
HC = 1	23	32	4	31
HC = 2	36	40	9	47
HC = 3	38	57	14	61

	Livestock/Land		Technology Index	Private Consultant
Cattle-Fattening (CF)				
HC = 1	1.0		19	14
HC = 2	1.2		33	17
HC = 3	1.4		34	31
Cattle-Breeding (CB)				
HC = 1	1.7		9	28
HC = 2	1.5		14	45
HC = 3	1.4		30	62