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THE HUMAN FACTOR IN ARGENTINE AGRICULTURE

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Resumen

El objetivo de este trabajo es identificar los determinantes de la reducción de uso del factor trabajo en el sector agropecuario argentino. El trabajo focaliza atención en el período 2002-2018, período comprendido entre los dos últimos Censos Nacionales Agropecuarios con resultados confiables (el CAN 2008 quedó incompleto). El trabajo pasa revista a las tendencias en cuanto a uso de trabajo y tamaño de empresa en Argentina, y presenta tres posibles hipótesis que explican los cambios observados: (a) sustitución de trabajo por capital, (b) cambio tecnológico ahorrador de mano de obra (labranza reducida y siembra directa) y (c) cambio en el tamaño de empresa y en el tipo de capital (maquinarias) utilizadas.

El trabajo también discute posibles vínculos entre productividad por unidad de superficie, tipo de maquinarias y tamaño de empresa.

Abstract

The objective of this paper is to identify determinants of the reductions in the use of labor observed in Argentine agriculture. The paper focuses on the 2002-2018 period, using data from the last two publications of the *Censo Nacional Agropecuario* (the census undertaken in 2008 is incomplete). The paper summarizes trends of labor use and firm size in Argentina, and presents three possible hypothesis accounting for observed changes: (a) capital-labor substitution, (b) labor-saving technical change (reduced and no-tillage) and (c) changes in farm size and the types of capital (machines) used.

The paper also discuses possible linkages between output per unit of land, types of machinery used and farm size.

JEL Codes: Q1, D2

The human factor in Argentine agriculture

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I. Introduction

Since the early 1960's Argentine agriculture experienced considerable growth, contrasting with the relatively poor performance of the previous decades. Output growth resulted from a steady stream of new technologies. These included new wheat varieties, sunflower hybrids, the introduction of the soybean crop in the 1960's and early 1970's, increased us of fertilizer (1980s) and rapid adoption of no-till production methods (1990's). This latter technology resulted in reduction in the cost of production and improved soil management. It also triggered a substantial shift of land from livestock to crop production, in particular in land previously considered "marginal" for crops.

The Argentine agricultural sector is highly heterogeneous, including both "extensive" crops such as cereals and oilseeds, and "intensive" fruit and vegetable production. More than three quarters of output is accounted for by cereal, oilseed, beef, dairy and poultry production. Heterogeneity in outputs and in production conditions results in a wide variety of input combinations being used: labor share in total costs range from less than 10 percent in cereal and oilseed crops, to more than 50 percent in fruits and vegetables.

The objective of this paper is to identify forces affecting labor use in the Argentine agricultural sector. While several studies have outlined general input and output trends of the Argentine agricultural sector., the "human factor" has received less attention. This is somewhat surprising, given that ultimately output is forthcoming only as a result of human intervention. Human adjustment to changing conditions results in the well accepted "stylized fact" that

[1] Arguments presented here are my own and do not necessarily correspond to those of the university of CEMA.

economic development is accompanied by a reduction in the labor force employed in agriculture. This change is a result of substitution of other inputs for labor in the production process, as well as "technological change" that allows increased output to be produced with the same input levels.

Reduction in labor use in agriculture occurs simultaneously with changes in the types of labor employed. Shifts in the demand for skills resulting from new technologies increase returns to managerial skills and thus the quantity supplied of both managerial as well as operator know-how. Evidence of the impact of human capital in agriculture is abundant (see e.g. Evenson, 1988; for Argentina Gallacher, 2010, Gallacher, 2012 and Gallacher and Lema, 2018).

In the case of Argentina, data limitations restrict "what can be learned" in relation to the labor input in agriculture.[2] With this caveat, the following are some of the relevant issues related to the "human factor" that merit attention:

1. To what extent is the agricultural sector becoming less "labor dependent": i.e. are production processes tending towards lower ratios between labor and other inputs.
2. How does the marginal productivity of the labor input compare to the relevant factor price: is disequilibrium the norm, suggesting continued labor out-migration?
3. What changes are occurring in the types of labor inputs used: is increasing human capital evident?
4. What complementary relations exist between the on-farm labor input, and the supply off-farm know-how (public extension services, private advisors).
5. How responsive is the ratio between labor and other inputs to relative price changes: i.e. can we get a grip on the relevant elasticity of substitution? How is the elasticity of substitution affected by characteristics of the technology used in production?

Items (1) – (5) include an ambitious research agenda, and are included here only as a "road map" of issues that merit attention. This paper will focus on items (1) and (2). Items (3) - (5) merit separate analysis, and in the case of (5) substantial data-gathering efforts if econometric estimation is to be attempted.

[2] The term "labor" is used here somewhat loosely, including both "workers" and managers/entrepreneurs. Unless otherwise stated, "labor" and "human factor" will be thus used interchangeably to refer to various inputs of human effort.

II. Labor Use Trends

Falling share of agriculture in economy-wide employment is a well-established fact for most countries. World Bank data (World Development Indicators [WDI]) shows for the Latin America and Caribbean region a decline in the share of agricultural over total labor from 20.8 in 1995 to 13.7 percent in 2019. For the OECD countries relevant data are respectively 8.5 and 4.8 percent, while for the U.S., an advanced economy with an export-oriented agricultural sector the reduction was from 1.7 percent in 1995 to less 1.4 percent in 2019. Figures for Canada and Australia show in general a similar pattern to that found in the U.S. Middle and low-income economies show much higher labor employment shares, but these are also characterized by a declining trend.

Unfortunately, data in the WDI data for Argentina are not trustworthy, as for recent years they report labor shares well below 0.1 percent, an unreasonable figure given observed trends in other countries.[3] The wide range of existing estimates is highlighted comparing WDI data mentioned above (less than 0.1 percent employment), with for example that reported by a private think-tank according to which jobs in the primary agricultural sector are some 9.5 percent of total jobs in the country. (Pisani Claro and Mazo, 2019).[4]

A first (and crude) approximation to labor use **trends** (as opposed to absolute values) in agriculture can be obtained looking into evolution of population residing in rural areas. If ("a big if") the ratio of ag employment to rural area population remains fairly constant over time, rural population trends can suggest – if not absolute labor employment – at least ag employment trends. As shown in Figure 1, in Argentina rural as a fraction of total population decreased continuously over time, from approximately 30 percent in the late 1950's, to 8.2 percent in 2019. In the period analyzed, fall in rural population seems to have slowed down significantly from a fall of 7-8 percentage points per decade in the 1950's, to less than 1.5 percentage points in the last decade of the series. For 2018, the rural/total population ratio was 8.2 percent.[5]

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[3] Labor surveys are done in metropolitan areas, thus excluding rural residents.

[4] The FADA report estimates employment by using data on "sector-specific jobs" produced by a government agency. A ratio of "jobs/workers" of 1.09 is used to extrapolate from jobs to workers.

[5] According to INDEC, "Urban" population refers to population residing in rural areas or towns of more than 2.000 inhabitants. "Rural" population is the difference between total and urban population.

The national employment figure for 2018 was 18.8 million. Assuming identical labor force participation in rural and urban areas, this would result in some 1.54 million workers residing in rural areas (18.8 x 0.082 = 1.54 million). Taking his figure as a starting point, estimation of workers engaged in **primary production** requires estimates on:

1. Workers in non-rural areas engaged in primary ag production
2. Decomposition of the 1.54 million workers residing in rural areas into:
    i. Primary ag production
    ii. Workers not engaged in primary ag production. This includes both ag- as well as non-ag related activities.

The above only suggests data needs involved in estimating labor input in the primary agricultural sector, but allows no progress to be made in obtaining relevant figures. However, it suggests possible shifts in occupational patterns through time. In particular:

1. Informal evidence suggests increasing access to vehicles by farm workers during the last decades. This results in a larger portion of the agricultural labor force reporting residence in areas classified as "urban" (> 2.000 inhabitants). These workers commute weekly or for longer periods to sites where work is undertaken. Increased mobility of workers results in closer integration of ag- and non ag- labor markets, possibly tightening labor supply (and increasing wages) at the farm level. [6]

2. Allocation of labor among: (i) ag-primary production, (ii) ag-related, but not primary production, and (iii) non-ag activities depends on a host of factors. If the elasticity of substitution between labor and capital substitution is higher in (i) than in (ii) or (iii), labor should migrate accordingly. But ease of substitution is not the only factor: increased local demand for non-ag as compared to ag (export + domestic) output plays an additional role.[7]

[6] Ag workers residing in towns and commuting to work are in closer contact with information flows related to job opportunities and demands for know-how in the non-ag sector.
[7] Of course, labor mobility is not restricted to "local" areas (rural and non-rural) but includes the possibility of substantial geographical re-location.

3. In relation to the last point, during the last decade municipal employment increased 40 percent (Susmel, 2020), resulting additional competition for labor with ag-related activities. This factor is particularly important in areas where labor-intensive activities take place, and could account for part of the reduction in labor allocated to agriculture.

Census data do not report labor hours used in agriculture but “permanent labor” (family + non-family). Estimation of labor use is further complicated by the fact than a considerable portion of crop area receives labor services in the form of custom work by contractors not classified as “farmers”. Thus, these services should be added to the existing on farm labor services (see Appendix for calculations)

Table 1 shows an estimate of labor use changes between the 2002 and 2018 censuses. This estimate was derived by adding reported farm permanent labor to an estimate of person-years of labor provided by contractors. Labor is measured by headcount and not the more appropriate labor-hours metric. Available evidence thus points to a 42 % country-wide reduction in labor input, ranging from 30 % in the *pradera pampeana* to 55 % in the non-pampean area. These averages mask considerable disparities in fall in labor-use, from a minimum of 26 % in Buenos Aires to over 70 % in Tucumán.

III. Explaining the reduction in the use of the labor input

Estimates presented above are crude: “permanent” labor as reported in the census hides the fact that the degree of utilization of this labor may have changed through time. As an example, the 42 % country wide reduction in reported labor (most of which is “permanent” labor) may over-estimate the actual reduction in *labor services* if remaining laborers each supplied in 2018 more labor hours than that supplied per worker in 2002. [8] The point here is that disequilibrium may result under-utilization of labor stocks. Adjustment takes then place reducing labor stocks with a resulting increase in labor flows resulting from existing stocks. “Measured” reduction in labor

[8] Allocation of time to off-farm work is an important issue to be addressed in future work. Preliminary analysis of this issue, however, suggest relatively modest changes in the proportion of producers reporting off-farm work. No information exists for off-farm work for family or hired labor.

use may then over-estimate actual reduction. Despite these caveats, the evidence points out that a significant reduction in labor has taken place during the last decade and a half. Despite these caveats, the evidence points out that a substantial reduction in labor has taken place during the last decade and a half.

Three possible hypotheses may explain reductions in labor use observed during the last decade and a half in Argentine agriculture:

1. H1: Capital (in particular, farm machinery) has substituted for labor inputs.

2. H2: Technical change: widespread adoption of reduced tillage systems allowed for reductions in the labor input due to the considerably lower requirements per unit of cropland of reduced as compared to conventional tillage systems.

3. H3: Economies of size: reduction in labor requirement per unit of output resulting from increased farm size and a resulting increase in labor-use efficiency (increased specialization, reduced inefficiencies due to "lumpiness")

H1: Input Substitution

Available data render econometric estimation of the elasticity of substitution between capital and labor of dubious value. As an alternative, a first approximation may be obtained by comparing changes in capital and labor (2002-2018) in order to detect the extent to which reductions in the labor input are correlated with increases in the use of capital.

In addition to changes in labor already commented, **Table 1** reports changes in an index of the capital (see Appendix for calculations). Increase in the capital input was 6.3 percent for the country as a whole, 9.6 percent for the *pradera pampeana* and 12.9 percent for the four provinces of the non-pampean areas considered here. Capital use in provinces excluded from the table decreased 9.1 percent, accounting for the lower country-wide increase in capital as compared with the provinces included here.

Attempt is now made to obtain a first approximation of substitution possibilities between these inputs. Column (5) of the table reports the ratio between percent change in the labor and the capital inputs. Strictly speaking, this is not a measure of elasticity of substitution as not only input, but output level changes occurred in the 2002-2018 period. However, if the assumption is made that increases in output are a result mostly of technical pure change, plus changes in inputs other than labor and capital, results of column (5) of the table may be interpreted as approximation to substitution possibilities between the pairs of inputs considered. Under these assumptions, results indicate that for most provinces, a 1 percent increase in the capital inputs allows reductions in the use of labor ranging between 3.2 percent *pradera pampeana*, and 4.2 percent in the non-pampean region. Country-wide value for $\Delta L/\Delta K$ is 6.2 percent, higher than the previous two regions. This result is caused by the reduction in capital input observed between 2002 and 2018 in the provinces not included in the table. This reduction results in a fall in country-wide ΔK and thus an increase in overall $\Delta L/\Delta K$.

Results presented here suggest two possibilities. The first is the conventional capital-labor substitution, in the sense of work done by machines replacing work done by humans. If this is the case, increasing capital use will allow reductions of labor from three to four times as large (percentage-wise). Highly elastic substitution possibilities among these inputs appear to be present, in particular in the non-pampean areas.

A second possibility is that the reduction in the use of labor is not necessarily (or even primarily) a result of increasing use of capital. Labor may have re-allocated from farm to non-farm work as a result of improved opportunities in the non-farm sector, coupled with under-utilization in the current (farm) activities. The decrease in the labor input observed in the 2002-2018 period may thus be a decrease more in *stocks* of labor present at the farm level, than in the *flows* of labor effectively supplied. If this is the case, substitution possibilities reported in Table 1 over-estimate “real” possibilities for input substitution.

To put the previous figures into perspective, the Cobb-Douglas production function – widely used in agricultural economics research - results in an elasticity of 1. This of course is not an estimated value, but is a consequence the functional form itself. Results presented here therefore suggest that the Cobb-Douglas technology results in lower substitution possibilities than those apparently existing in Argentine agriculture.

Empirical estimates of capital-labor substitution (Wei, 2013) show values for the elasticity of substitution ranging from 1 to 7 for Brazil and from 2 to 3.5 for the U.S. These cases are of interest, as agriculture in both countries shares similarities with that found in Argentina. Substitution values reported in Table 1 appear therefore "reasonable", at least as compared with those reported in Wei's paper.

Summarizing H1, evidence suggest high substitution possibilities between capital and labor inputs. These may account for part of the decrease observed in the use of labor. However, labor reductions can also be a result of other factors: sub-utilization of labor is one of these, and labor-saving technical change and scale/size relationships the other. In this case, results reported in Table 1 over-estimate substitution possibilities.

H2 and H3 presented below present alternative explanations for the observed shifts in in the demand for labor.

H2: Labor-saving technical change

For the period analyzed here, the adoption of reduced and zero-tillage was a significant labor-saving technological change affecting Argentine agriculture. Adoption of this technology increased from less than 5 percent of planted acreage in the 1990's, to 55 percent in 2002 and 90 percent in 2018 (Nocelli Pac, 2018). Extensive use of this technology was possible by the introduction of herbicide resistant seeds, in particular in the soybean and corn crops.

The "net" effect of reduced tillage systems can be expressed as the sum of a "substitution" effect resulting from lower labor requirement per unit of area of reduced as compared to conventional tillage, plus an "expansion effect" that results from changes in crop area induced by the reduced tillage technology.

The substitution effect ΔL^S represents the impact of reduced tillage as of t = 2002. It is calculated as the difference between labor requirements that would result if only conventional tillage were employed and labor requirements given the shares of conventional and reduced tillage existing in 2002. In turn, the expansion effect ΔL^E is the difference between the extra labor resulting from expansion in the crop area and the reduction in labor resulting from a fall in livestock numbers, fall presumably caused be re-allocation of land from livestock to crop production.

Table 2 shows total crop area, and area under conventional and reduced tillage systems in the two time periods considered here. Estimates are presented on labor-hours per unit of land for both systems. As shown, reduced tillage results in about half the number of hours per hectare (soil preparation, planting, weed and pest control, excluding harvesting).

As relates to the substitution effect ΔL^S, adoption of reduced tillage (55% of planted area) allowed a reduction in the labor (as compared to the conventional tillage scenario) of some 19.000 workers, or some 2.4 % of the *reported* (permanent workers + contract work) ag labor force for that year (784.000). In turn, the expansion effect ΔL^E results in an increase of 20.000 workers from additional crop area, minus 26.000 from reduction in animal stocks during the period. The net figure for $\Delta L^S + \Delta L^E$ is 25.000 less workers in 2018 as compared to 2002. This figure represents 3.2 percent of existing ag labor force in 2002, and 7.4 percent of the reduction (337.100 workers) in ag labor force occurring from 2002 to 2018.

In conclusion, observed reductions of labor use between 2002 and 2018 cannot be explained by the adoption of reduced tillage systems. Even allowing for errors in the technical coefficients used in calculations (many of them crude estimates), it is highly unlikely that reduced tillage systems per-se are responsible for the large falls in reported labor in the primary agricultural sector.

H3: Scale/size relationships

Increasing returns resulting from consolidation of resources from a larger to a smaller number of farms can account for increasing output from a given stock of resources. However, it cannot explain decreasing use of farm labor: the “scale” concept refers to equi-proportional changes in input (including labor) use. Economies of scale would result in a reduction in the number of farm units, but not in outflow of resources (labor in particular) from the agricultural to other sector of the economy. If this is the case, the possible impact of farm size on labor use requires attention be focused on input proportions and not pure “scale” effects.

In the 1988-2002 period farm numbers in Argentina fell by 1.7 percent per year (Table 3). Reduction in farm numbers increasing slightly to 1.8 percent between 2002 and 2018. Reduction in numbers was somewhat higher in “non-pampean” that in the “pampean” region. As a result of these changes, in the 2002-2018 period farm size (measured in area per farm) increased some 35 – 40 %. Increased farm size results from optimizing decisions, in particular reductions in costs with resulting improved perspectives for profit and further firm growth. While a host of factors may result in a negative relation between firm size and average costs, an important one to be considered are savings associated with higher capacity machines.

Increased farm size may facilitate (and in turn be the result of) changes in the types of capital used, and in particular, in the ratio between the capital and the labor input. Moreover, different types of capital may allow an increase in the K/L ratio without a corresponding increase in the amount of K. Instead K/L may increase due only (or mostly) a reduction in L.

Let farm machinery K^A be twice as large and costing double as machinery K^B. If a farm substitutes one unit of K^A for two units of K^B, total capital remains unchanged. However, "labor use" under K^A may be half as that required by $2K^B$ if K^A "requires" only one worker, the same labor requirement of each of 2 units of K^B it replaces. Formally:

$$\textbf{(1)}\ Q^B = 2\min[L, K^B] = Q^A = \min[L, K^A] \quad \text{where } K^A = 2K^B$$

The issue here is thus not capital/labor substitution, but differences in the organization of production. The trend towards larger machinery may be catalogued as "technical change" if machinery is not only larger, but incorporates features not found in smaller versions. A good example of this is reduced tillage planters, sprayers as well as computerized monitoring systems that are only cost-effective in high-output agricultural machines such as tractors and combines.

Figure 2 shows for the 2002-2018 period the percentage of total tractor and combine horsepower stock accounted for by largest two categories of each of these two types of machines (see Appendix for details). Results indicate that "large" tractors accounted for 43 percent of total HP in 2002, increasing to 60 percent in 2018. In the case of combines, "large" units accounted for 30 percent of the total in 2002 and 62 percent in 2018.

Higher capacity machines thus allow reductions in labor costs without an increase in the capital-labor ratio. However, larger farms are better able to spread out costs associated with this equipment. In summary: in contrast with the inconclusive evidence resulting from both hypothesis H1 and H2, hypothesis H3 appears to reasonably explain observed reductions in labor use that have occurred in Argentine agriculture.

IV. K/L ratios as function of agronomic practices and crop yields

Economic theory suggests that input proportions are a function of input relative prices and substitution rates among inputs. As suggested by the discussion presented above, not only the "amounts" of capital but the specific forms this capital takes may affect cost-minimizing input combinations. The last decades have witnessed a virtual revolution as relates agricultural machinery. Improvements have not only occurred in basic design (e.g. reduced tillage planters allowing higher planting speed, improved precision, fertilizer placement) but also in the introduction of real-time monitoring of crop conditions, soil fertility and other aspects. These technologies are not scale neutral, but involve fixed costs both as relates to hardware, software (where applicable) as well as technological know-how on the part of the farmer.

The case of modern harvesters illustrates some of the issues involved. A steady trend towards higher output machines has been evident: in the early 1970's engines of harvesters produced by major manufacturers averaged some 140-150 HP. In the following decades, these increased linearly averaging 400 HP in 2010 (Méndez, Velez and Scaramuzza, 2014). Larger combines allow increased throughput and reduced labor costs. However, the question may be asked on what limits exist on size. In relation to this, technical limits exist on both the "practical" width of cutting platforms as well as on the speed at which the machine can travel over ground. Given these limitations, harvest tonnage depends on yield per unit of area. Cost-efficiency of larger machines increases not only as function of harvested area, but also of crop yield.

Differences in yields are expected to vary according to both technical (TE) as well as allocative (AE) efficiency at the farm level. TE will increase yields as a result of higher output levels per unit of input. But an upward shift in the production function (increased TE) will generally increase input marginal productivity as shifts will generally result also in changes in the slope as well as in output for every input level. Higher input marginal productivity will therefore result. This will trigger higher input levels and thus and additional yields independent of those resulting only from increasing TE. The result is improved conditions for better quality and higher-capacity machines, larger farm size and reduced labor for a given amount of capital.

The implications of the above are the following. First, labor-savings may be achieved by the use of "larger" capital inputs (tractors, combines, planters, forage equipment) as these allow a given capital stock to be combined with a reduced level of labor services. Second, cost-efficiency of larger machines increases with farm size: if the farmer contracts machinery services instead of purchasing equipment, coordination costs are reduced – at least up to a point - when a given contractors supplies services to a smaller number of clients. Of course, if the farmer purchases instead of renting equipment, the case for a larger farm unit is even stronger.

Lastly, interactions exist between farm-level productivity and choice of machinery size: higher yields reduce average operating costs of higher output harvesters. Similarly – and given all else equal – more frequent or higher-volume fertilizer or pesticide applications, or the need for more timely production practices increase optimum machinery size, and thus indirectly, farm size as well. "Technical change" interpreted as increased volume from a given stock of resources is thus an additional factor pushing machinery size upwards and, as a spinoff of these changes, reducing the demand for labor services.

V. Final comments

Agricultural modernization results in significant changes in input types, input proportions, production technology and farm organization. Evidence presented here indicates that the elasticity of substitution between capital and labor inputs is high (although in line with some finding for example in Brazil and the U.S.). However; it probably does not account for all of the significant reductions observed for labor input. A topic that deserves further attention is the possible impact - in the period analyzed here - of changes in relative prices between capital and labor (***r***/***w***). A-priori, it would seem that even if real wages showed some increase, prices for major capital inputs such as farm machinery could have been affected by credit constraints resulting from limited access of Argentina to international capital markets. Analysis of this issue is a significant challenge, in particular as no official statistics exist for wages of agricultural workers.

Labor-saving allowed by reduced tillage is a possible determinant of shifts in the demand for labor. However, in the case analyzed here reduced tillage, while saving on labor on a per-hectare basis, has its effect dampened due to increase in crop area that his technology allows.

Moreover, even abstracting from this issue, per-hectare labor savings alone cannot account form the large reduction in labor input observed in the Argentine agricultural sector. Other factors are probably operative.

Increased capacity of agricultural machinery seems to be the most important variable explaining falling demand for labor. In Argentina, total capital – at least as measured by a “horsepower index” appears to have experienced relatively modest increases – in particular as compared to decreases in the use of labor (increases where 6.3 percent country-wide, 9.6 percent in the “pradera pampeana”, ad 12.9 percent in the non-pampean provinces). Evidence is then not on the increase in “conventional” (i.e. horsepower index) of capital, but on the types of capital employed: the share that machines of larger capacity represent of total capital stock has increased significantly during the last decade and a half. As argued above, larger machines allow labor savings as – at least in some size ranges – as labor input per machine does not change proportionally with the output capacity of the machine.

It should be emphasized that larger machines (in particular newer ones) incorporate features not present in the same degree in ones of smaller size. “Technical change” in capital inputs is therefore an additional factor that adds to the “conventional” labor saving resulting from machine size per se.

This paper argues that linkages exist between production per unit of land and optimal machinery size: higher yields increase the cost efficiency of higher output machines (in particular, harvesters, but probably also planters and other pieces of equipment). A causal chain then exists linking better management with higher yields, and thus larger machine size. Larger machines, in turn act as a catalyst for increase in farm size.

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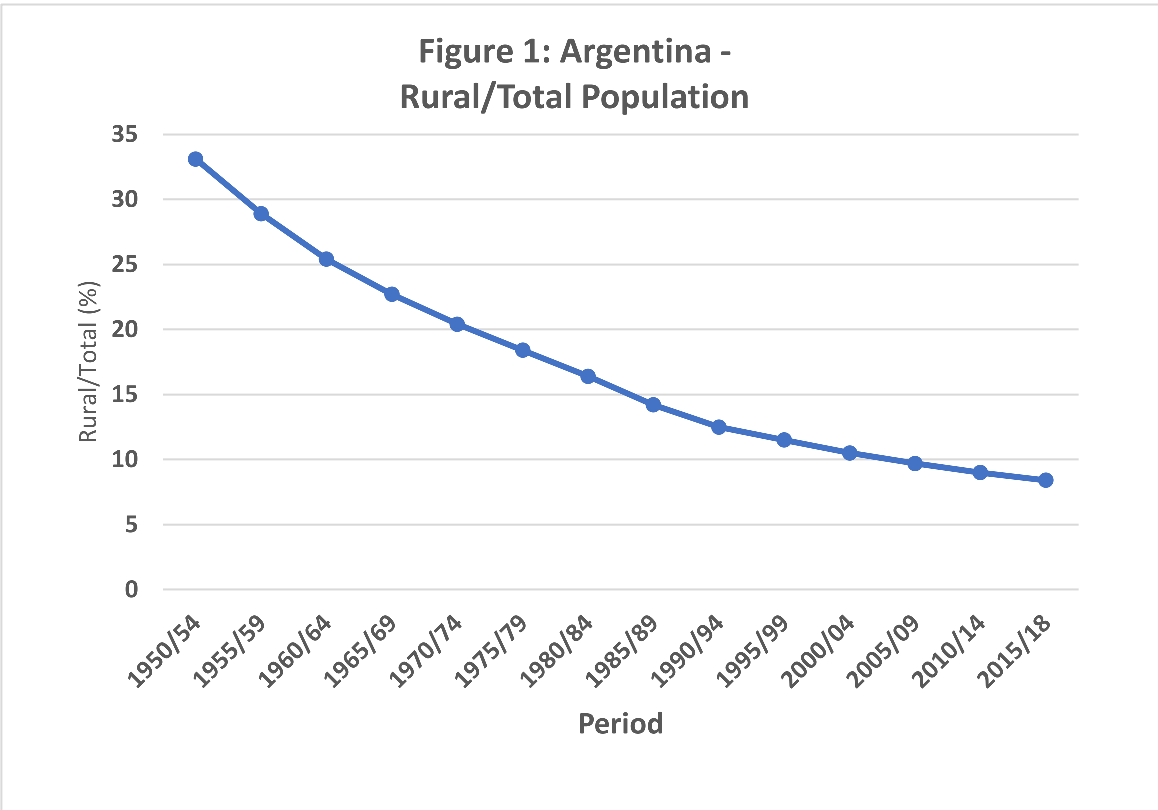

Source: FAOSTAT

Table 1: Labor Input in Argentine Agriculture

(total and selected provinces)

	L			K	
	2002	2018	% Δ L	% Δ K	% Δ L/% Δ
	(1)	(2)	(3)	(4)	(5)
Total	795	458	-42.4	6.3	-6.7
"Pradera Pampeana" Provinces:					
Buenos Aires	125	93	-25.6	5.7	-4.5
Cordoba	68	49	-27.9	19.8	-1.4
Entre Rios	45	26	-42.2	12.6	-3.4
Santa Fe	64	41	-35.9	2.1	-17.1
La Pampa	16	11	-31.3	20.6	-1.5
Selected "Zona Extra-Pampeana" provinces:					
Chaco	38	17	-55.3	10.1	-5.5
Salta	29	17	-41.4	11.2	-3.7
Santiago del Estero	55	25	-54.5	70.2	-0.8
Tucuman	25	7	-72.0	-19.1	3.8
Total "Pradera Pampeana"	320	223	-30.3	9.6	-3.2
Total Selected "Zona Extra-Pampeana" provinces:	148	67	-54.7	12.9	-4.2

Source: INDEC - Censo Nacional Agropecuario 2002 and 2018

Table 2 : Changes in labor use resulting from Reduced Tillage

		2002	2018
Planted area	**million hectares**	25.0	35.0
Share Conventional Tillage	**%**	0.45	0.10
Share Reduced Tillage	**%**	0.55	0.90
Area Conventional tillage	**million hectares**	0.1	0.0
Area Reduced Tillage	**million hectares**	0.1	0.3
Labor requirement Conventional Tillage	**Hrs/ha**	3.5	3.5
Labor Requirement Reduced Tillage	**Hrs/ha**	2.0	2.0
(A) Substitution Effect	**Person-years**		-19000
(B) Expansion Effect (1) **(additional labor from additional crop area)**	**Person-years**		20000
(C) Expansion effect (2) **(reduced labor from reduced livestock)**	**Person-years**		-26000
Net Effect = (A) + (B) + (C)	**Person-years**		-25000

Sources:
Planted Area Ministerio de Agricultura
Technical coefficients: own calculations based on trade publications

Table 3: Farm Numbers, Selected Provinces

	1988	2002	2018	1988/ 2002	2002/ 2018	1988/ 2018
	farm numbers			Δ/yr (%)		
Total	421,221	333,533	250,881	-1.7	-1.8	-1.7
Pradera Pampeana (1)	189,000	134,000	98,000	-2.4	-1.9	-2.2
Selected "Zona Extra-Pampeana" provinces (2)	68,000	58,000	40,000	-1.1	-2.3	-1.8

(1): Provinces of Buenos Aires, Cordoba, Entre Rios, La Pampa and Santa Fe

(2) Provinces of Chaco, Salta, Santiago del Estero and Tucuman

Source: CNA 1988, 2002 and 2018

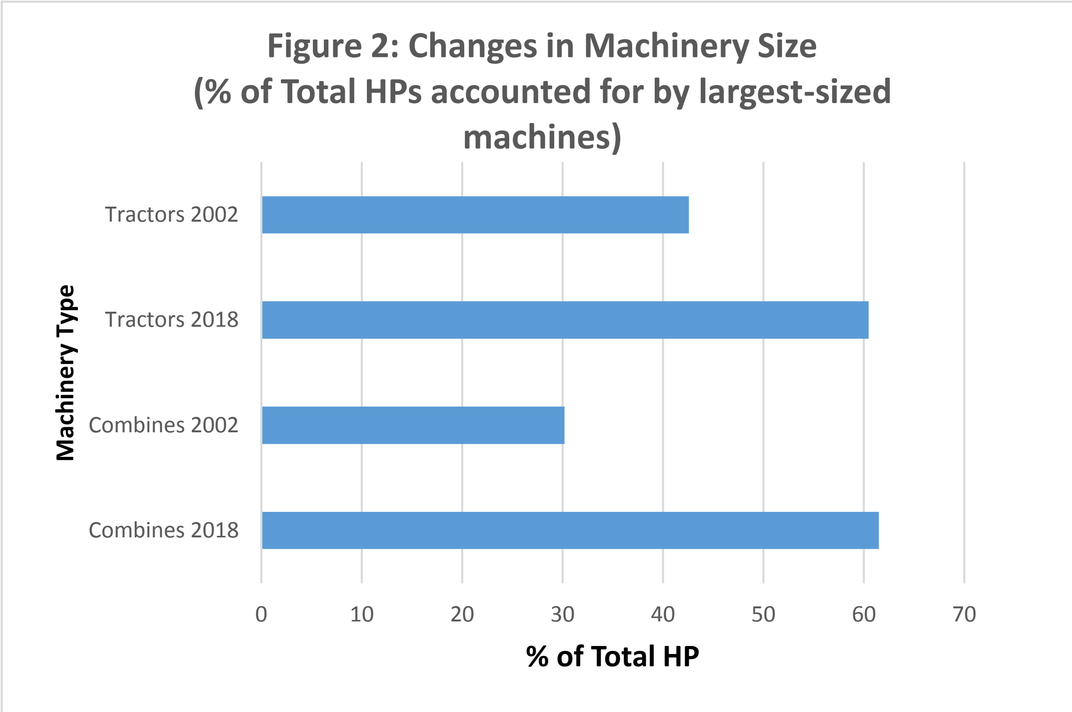
Figure 2: Changes in Machinery Size
(% of Total HPs accounted for by largest-sized machines)
Machinery Type
Tractors 2002
Tractors 2018
Combines 2002
Combines 2018
0
10
20
30
40
50
60
70
% of Total HP

Appendix: Data and Calculations

Labor Input

Data source is the *Censo Nacional Agropecuario* (CNA) 2002 and 2018. Census data does not report approximate labor flows (e.g days worked by family and hired laborers per year), but stocks of "permanent" labor. This measure is not a good estimate of actual labor supplied due to: (a) varying degree of labor utilization, (b) does not include seasonal labor (of particular importance in labor-intensive activities such as fruits and vegetables) and (c) does not include labor supplied by custom contractors. The approach used here was to add to permanent labor figures an estimate of labor supplied by contractors:

(1) $L^{T} = L^{CNA} + L^{Co}$

Where:

L^{T} = Total labor input (persons/year)
L^{CNA} = Labor input (persons/year) reported in CAN
L^{Co} = Estimate of labor from contracted services

And:

(2) $L^{Co} = A^{C} \times t_1 + A^{C} \times S^{H} \times t_2$

Where:

A^{Co} = total land area (hectares) receiving contract work
t_1 = estimate of labor hours of labor used in contract work (excl harvest)
S^{H} = share of contracted hectares receiving harvesting services
t_2 = estimate of labor hours of labor used in contract work (harvest)

Coefficients used were t1 = 2hrs/ha, t2 = 0.25 hrs/ha. SH was obtained from the CNA. Identical procedure was used for the 2002 and 2018 censuses.

Capital Input

The capital input was derived by a (weighted) sum of tractor plus combine (harvester) horse-power. The following correction was used for age (vintage) of tractors and combines: $0.80^{(t-1)}$ where:

Machine age	**t**
<5	1
5 – 9	2
10 – 14	3
>15 and +	4

The above hyperbolic decay function was used in order to capture advances in "quality" (sensors, GPS, automatization). After adjustment for vintage, total capital was then calculated as the weighted sum of tractor and combine horsepower:

(3) K^T = Adjusted Tractor Horsepower x (1/0.40) + Adjusted Combine Horsepower x (1/0.25).

The weights hopefully approximate the approximate "expansion" of machinery horsepower to total capital associated with each machinery: i.e. total cost of a combine + ancillary equipment used for harvest is 4 times the cost of the combine's engine.

Impact of reduced tillage on labor use

As mentioned, the adoption of reduced tillage results in changes in labor requirements. As mentioned in the text, a "substitution" and an "expansion" effect are present:

Substitution Effect:

(4) $\Delta L^{S} = A_{t0}[L^{C} – (S_{t0}^{C} L^{C} + S_{t0}^{RT} LR^{T})]$

Expansion Effect:

(5) $\Delta L^{E} = [A_{t1} - A_{t0}][(S_{t1}^{C} L^{C} + S_{t1}^{RT} LR^{T})] - [LU_{t1} - LU_{t0}] L^{L}$

Total Effect:

(6) $\Delta L^{T} = \Delta L^{S} + \Delta L^{E}$

Where:

Δ Labor = change in labor use resulting from reduced tillage

$A_{t = t0}$ = Crop area at t = t0

$A_{t = t1}$ = Crop area at t = t1

L^{C} = labor per unit of land conventional tillage

L^{RT} = labor per unit of land reduced tillage

L^{L} = labor per unit livestock unit (LU)

Crop area in 2002 and 2018 were obtained from Ministerio de Agroindustria. L^{C}, L^{RT} and L^{L} from trade publications and personal communication by farm advisors:

L^{C} (hrs/ha) = 3.5

L^{RT} (hrs/ha) = 2.0

L^{L} (hrs/ha) = 1/250 = 0.004

Labor-hours were transformed to "person-years" assuming 1760 potential working hours per year per person, of which 60 % are transformed into actual labor input flows: 1760 x 0.60 = 1056 hrs/year per person. The assumption of 60 % "efficiency" of labor use was based on lost days due to weather, travel, overhead and other factors.

Estimation of reduced labor due to reduction in livestock numbers (L^L) was done by dividing reduction in animal stocks ("Livestock Units", LU) by an estimate of LU per unit of labor input (250 person-years per LU).

Data for LU was taken from the CNA:

Animal stocks (millions):

	Beef	**Sheep**	**Pigs**	**Total LU**
2002	48.5	12.6	2.18	40.7
2018	40.4	8.8	3.10	34.3
Change	- 8.1	- 4.0	1.4	6.4

Source: CNA 2002 and 2018

Total "Livestock Units" (LU) equivalents was calculated as 0.80 x Beef + 0.10 Sheep + 0.30 x Pigs [9]. Change in labor use was calculated dividing the change in LU by 250, an estimate of LU/person-year.

[9] See https://ec.europa.eu/eurostat/statistics-explained/index.php/Glossary:Livestock_unit_(LSU)