DETERMINANTS FOR THE ADOPTION OF SOYBEAN DIRECT PLANTING TECHNOLOGY IN GOIÁS, BRAZIL

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Abstract

The objective of this paper is to identify the factors that determine the adoption of direct soybean planting technology in the state of Goiás, Brazil. The methodology used to ascertain those factors is based in the Maximum Likelihood estimate of the "logit" model. It is verified that the variables "training," "profitability," "area," "productivity," "capital stock," and "investment" determine the adoption of the technology of direct-planting, with the "training" and "profitability" variables having the greatest affect.

Key Words: Soybean, technological change, technology adoption, direct-planting, Goiás.

1. Introduction

The development of agriculture has been based on increased production using mechanical and biochemical technologies unfettered

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by environmental concern. The planting technology used in the 1970s and 1980s, known as the conventional planting system, was characterized by soil cultivation using, on average, from nine to twelve mechanical operations over the crop cycle.

Continual mechanized cultivation causes soil erosion, as the ground is left unprotected by vegetal cover in the rainy season when planting begins. This erosion causes rivers to become shallower and the ecology is put into disequilibrium. To avoid these environmental problems, the substitution of sustainable farming techniques for conventional cultivation processes is recommended. Sustainable farming helps to minimize soil loss, reduce production costs, and maximize crop yields, while reducing the use of chemical fertilizers and preserving water and energy resources.

Among the farming techniques considered sustainable, the most relevant are terraced cultivation, crop rotation, minimized tillage, organic fertilization, integrated pest and disease management, and direct-planting.

Direct-planting was introduced in Brazil at the end of the 1980s. In the Brazilian state of Goiás, it is believed to have been first employed in 1988. This new technology, based on the absence of soil tillage and the presence of a permanent vegetative soil cover, is an attempt to keep land exploitation in balance with nature. Using direct-planting, there are four to six mechanical operations during each crop cycle (herbicide application, fertilizer application, planting, pesticide application, and harvest) and no soil tillage. This system reduces interference with the physical and biological structure of the soil, and because the soil is always covered by organic material, erosion is diminished.

According to EMBRAPA (2000), the use of direct-planting techniques in the Brazilian Cerrado, where soils and pasture have been degraded due to erosion, reduced soil loss 7.3 times and water loss 3.2 times when compared with traditional cultivation methods.

The object of our research is to identify the factors that determine the adoption of direct-planting technology by soybeans producers in Goiás.

2. Agriculture Modernization

Agricultural modernization is an attempt to overcome reduced crop profitability caused by product prices falling at a greater rate than input prices. The ratio of soybean producer prices received to prices paid between 1986 and 1999 decreased by 2.53% (Getúlio Vargas Foundation, 2000), demonstrating the unfavorable situation faced by soy farmers.

Alves (1980) concluded that increases in Brazilian agricultural productivity are due to the use of advanced technologies, such as improved seeds, more efficient pesticides, new inputs, machinery, and a separate group of non-technological factors that include rural extension services, change in agrarian structure, education, agricultural credit availability, farmer's stock of capital, and the market's pricing structure.

Teixeira (1991) determined that one important factor among the variables that favor the adoption of new agricultural techniques is the farmer's level of personal capitalization. The producer tends to invest in modern technology when monetary capital is readily available.

The process of agricultural modernization is discussed thoroughly in economic literature, occupying the attention of many outstanding researchers: Schultz (1965), who developed the Modern Input and Urban-industrial Impact models; De Janvry (1978), who developed a model in which the process of technological generation is dynamic, interactive, and linked with the socioeconomic and political/ bureaucratic structure; Hayami and Huttan (1988), who developed the Induced Innovation model; and, Solow (1993), who tried to explain neutral technological change though embodied technology. Hicks, according to Binswanger (1978), treated technological change as biased or non-neutral, originating from changes in factor prices that lead to the use of the most abundant or least expensive factors.

3. Characteristics of Soybean Production in Goiás

Conventional planting is employed by 38.4% of Goiás' soybean producers, while direct-planting is employed by 61.6% of these producers. Average farm size in the state is 626.82 hectares, varying from 24.2 to 2,500 hectares; average soybean farm size is 591.26 hectares, varying from 18 to 4,490 hectares; and 63.2% of the soybean land is family owned and operated as opposed to leased. Table 1, columns (1), (3), and (5) correspond to the areas planted using conventional techniques; and columns (2), (4), and (6) correspond to the areas cultivated using direct-planting techniques.

Table 1 – Areas planted with soy by farming techniques employed, State of Goiás, 1999.

Size (ha)	Farm Area		Rented area		Total area with Soybean	
	Conventional (1)	Direct (2)	Conventional (3)	Direct (4)	Conventional (5)	Direct (6)
1 - 100	45.2%	14.1%	43.8%	19.1%	41.7%	7.8%
101 - 500	42.8%	40.6%	43.8%	42.6%	47.9%	46.7%
501 - 1000	7.2%	14.1%	12.4%	27.7%	8.3%	20.8%
1001 - above	4.8%	31.2%	0.00%	10.6%	2.1%	24.7%

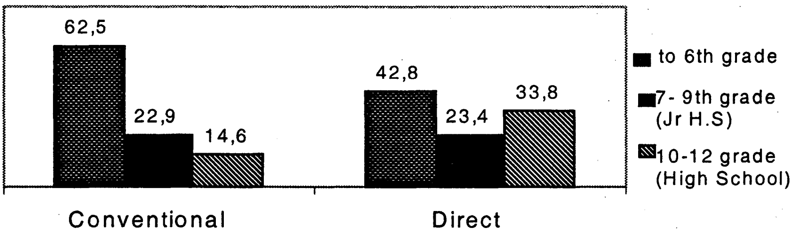
Source: Research Data.

Obs.: Farm Area is the total land area in hectares that the producer possesses. The Total Area with Soybean is the percent of the total cultivated soy area that is cultivated using each type of faming technique by each farm size group.

It can be verified that as farm area, rented area, and total area planted with soybean increases, the area cultivated using conventional planting methods decreases and the area cultivated using direct-planting techniques increases. The decision as to which technique to use is always taken by the farmer, even when there are hired managers on the farm.

There are hired managers on 6.3% of the conventionally planted properties and on 27.3% of the properties using direct-planting. In the conventional planting system, the hired managers don't have any technical education, but in the system of direct-planting, 9% have a high school level agricultural education, 9% are agronomists, and 6% have a business school degree.

Manager's basic educational level related to farming technique in use (%) is showed in Figure 1.



Source: Data of the research.

Figure 1 - Education of the producers in %, in agreement with the planting type, for the soybean crop, State of Goiás, 1999.

It is verified that the producers who use direct-planting techniques have a lower median age yet more years of experience in soy cultivation than managers who use conventional planting techniques.

4. Methodology

The data used in this work are primary, obtained through a structured survey applied to soybean producers in the Southwestern region of Goiás in the second semester of 1999. The sample is composed by 127 soybean farms defined by simple random sampling criteria from population information found in the Systematic Survey of Agricultural Production (IBGE, 1999).

From an understanding of the theories presented in Section 2, it was possible to define some of the more important variables for our study of the adoption of direct-planting technology. To verify the influence of the variables studied on the probability of adoption of direct-planting, the model was specified such that the dependent variable admits the discreet values of zero and one. Binary answer models identify the probability that an individual with certain group of attributes will make a specific decision in response to a given event (Amemiya, 1981).

The logit model uses the logistics accumulated distribution function, given by

$$L\,(X_i^{'}\,\beta) = \frac{1}{1+e^{-Xi\beta}}, \qquad (1)$$

where *L* represents the function cumulative logistics; *X'i* is the vector of independent variables; β is the vector of parameters; and *e* represents the base of the natural logarithm.

In the decision making process as to which planting system to use, conventional planting or direct, it is admitted that the producer evaluates the advantages and disadvantages of the adoption of a particular system. As the parameters of that decision are not observable for each farm *i*, a latent or non observed variable, y^*, can be estimated

$$Y^*_i = \beta^{'}\,X_i + u_i\,, \qquad (2)$$

where Y^*i is the dependent variable, $i = 1,..., n$; β is the parameter; X_i is the group of explanatory variables; and u_i is the random error.

The observed adoption pattern can be described by the binary variable Y, such that $y_i = 1$ if the producer adopts the system of direct-planting, and $y_i = 0$ if he doesn't and the system of conventional planting is used. The observed values of y are related to the estimated values y^*:

$y_i = 1$, if $y_i^* > 0$; and, $y_i = 0$, if $y_i^*. \leq 0$;
$$\text{Prob}\ (y_i = 1) = \text{Prob}\ (y_i^* > 0) = \text{Prob}\ (u > -\beta' X_i) = L\ (\beta' X_i). \qquad (3)$$

The model is estimated by the Maximum Likelihood Method. The probability of adoption of the system of direct-planting (a) and the probability of non-adoption of direct-planting (b) are computed in the following manner:

$$\text{(a)}\ \ P_i = \frac{1}{1+\ell^{-Xi\beta}}; \qquad \text{e,} \qquad \text{(b)}\ \ 1 - P_i = \frac{\ell^{-X_i\beta}}{1+\ell^{-X_i\beta}}, \qquad (4)$$

where *Pi* is the probability of adoption of direct-planting; 1 - *Pi* corresponds to the probability of non-adoption of direct-planting; x_i describes the explanatory variables of the model; and β is the estimated coefficient for each explanatory variable.

The following variables are considered in the model: a) a dependent variable (CD), which is a binary variable with value zero for conventional planting and one for direct-planting; b) independent variables: (ESCO) - years of producer education; (TREIN) - binary training variable with value zero for those whose didn't receive training and one for those who are trained; (ASSI) – number of visits by a technician [farm adviser] to a farm over the agricultural year; (AREA) - total hectares planted in soybean; (PROD) - soybean crop yield, a measure of the number of 60kg bags produced/hectare; (RENT) – a binary prices variable with value zero for price received considered low by the farmer and one for price received considered to be medium or high; (INVEST) - number of machines bought in the last four years, independent of acquisition costs; (CREDI) - binary credit variable taking zero value for those who did not borrow investment capital and one for those who borrowed investment capital; and (KPRÓPRIO) - the proportion of personal capital used to pay for operational expenses in relation to the amount of credit obtained for the same purposes.

In the logit model, the coefficients of the explanatory variables don't reflect the marginal effect of those variables. The marginal effect is the rate of change in the probability of adoption given a one unit variation in the independent variable.

The marginal effect of variable X_i on the dependent variable is expressed below:

$$\frac{\partial P_i}{\partial X_i} = \beta_i \frac{1}{1+\ell^{-Xi\beta}} \frac{\ell^{-Xi\beta}}{1+\ell^{-Xi\beta}}, \tag{5}$$

where $P_i = \dfrac{1}{1+\ell^{-Xi\beta}}$ e $(1 - P_i) = \dfrac{\ell^{-X_i\beta}}{1+\ell^{-X_i\beta}}$.

It is observed that the marginal effect of each explanatory variable on the probability of adoption is not constant but depends on the effect of the value each variable takes.

5. Results

In this section, the results from the logit model estimations are presented, followed by a detailed interpretation of the decisive variables (variables that affect the probability of the adoption of direct-planting technology to the greatest degree).

Table 2 presents the estimated coefficients for the variables that determine the probability of adoption of direct-planting technology and their respective statistical significance.

The adjusted model identified six statistically significant variables: training (TREIN - zero value for the un-trained and 1 for the trained), area cultivated with soybeans (AREA), productivity measured in 60kgbag/ha (PROD), profitability (RENT - zero for price received considered low and 1 for price received considered medium to high), investment in machines and equipment (INVEST), and the ratio of farmers using their own capital to pay for operational expenses as opposed to using credit (KPRÓPRIO). The variables that were not statistically significant are education (ESCO - years of education of the producer), technical support (ASSI - number of technical visits received), and loans from FINAME/FCO for capital investment (CREDI - zero for those that don't use credit and 1 for those who use credit).

Table 2 – *logit* model coefficients for the factors determining the adoption of direct soybean planting technology, state of Goiás, 1999

Variable	Coefficients	Standard error	t-student	Prob.
C	-5.468364	1.809563	-3.021925	0.0025
ESCO	0.021693	0.064741	0.335069	0.7376
TREIN	0.925972	0.475718	1.946473	0.0516
ASSI	0.050797	0.064956	0.782015	0.4342
AREA	0.002434	0.000898	2.711037	0.0067
PROD	0.076816	0.041661	1.843821	0.0652
RENT	0.860390	0.467189	1.841632	0.0655
INVEST	-0.094380	0.055625	-1.696716	0.0898
CREDI	0.171654	0.535321	0.320656	0.7485
KPROPRIO	1.598068	0.949526	1.683016	0.0924
Obs. with dep = 0		48		
Obs. with dep = 1		77		
LR stat.		2.63E-07		

Source: Data of the research.
Note: C = constant; ESCO = education of the producer; TREIN = training; ASSI = technical support; AREA = area exploited with soybean; PROD = productivity (60kgbag/ha); RENT = profitability; INVEST = investment; CREDI = Capital investment loan; and KPRÓPRIO = ratio of personal capital to credit for the payment of operational expenses.

The variables TREIN, AREA, PROD, RENT, INVEST, and KPRÓPRIO presented results that were compatible with those expected, the signs were coherent, and the coefficients were statistically different from zero.

In the adjustment of the equation, the obtained index of verisimilitude ratio was 0.71, which indicates that 71% of the variations observed in the probability of adoption of the direct-planting system are explained by the independent variables.

In the logit model, the coefficients of the explanatory (continuous) variables do not reflect the marginal effect of these variables on the probability of direct-planting adoption. The general average values of these explanatory variables presented in Table 3, column (1), are used to determine the marginal effect of each of these variables on the probability of direct-planting's adoption, as demonstrated in equations (1) through (5). In the case of the binary variables, TREIN and RENT, the values zero or one were used rather than average values.

Table 3 presents the average values of the variables that determine the probability of the adoption of a particular planting technology. The test for difference of averages for the variable ESCO was not significant at 5% probability. In other words, the averages can be considered the same in both planting systems, indicating that the two groups that make up the variable come from the same population; therefore, the variable doesn't affect the probability of a particular planting technology's adoption.

Table 3 - Average values of the variables that determine the adoption of a particular planting technology in the state of Goiás, 1999

Variable	General average (1)	Average Conventional Planting (2)	Average Direct Planting (3)
ESCO	10.51	10.21a	11.29a
ASSI	7.47	6.71a	7.95a
AREA	591.26	254.68b	801.08b
PROD	44.16	41.45b	45.85b
INVEST	5.70	4.33b	6.54b
KPROPRIO	0.23	0.16b	0.27b

Source: Research data.

Note: 1) Statistically significant for the averages at 5% (a=not significant, b=significant); 2) ESCO = education of the producer; ASSI = technical support; AREA = area cultivated with soybean; PROD = productivity (60kgbags/ha); INVEST = investment; KPRÓPRIO = ratio of use of own capital to use of credit to pay operational expenses.

In general, it is verified that all variables present higher average values for direct-planting than for the conventional cultivation, especially the cultivated area variable (AREA). The producers that use direct-planting technology possess larger properties and a have a greater capacity to pay operational expenses than do producers that use conventional planting systems.

The producer education variable, ESCO, presented an average value of 10.5 years, (column (1), Table 3). The producer using conventional planting techniques had an average of 10.2 years of education while the one using direct-planting techniques had an average of 11.3 years of education.

5.1. Marginal effects of the factors determining the adoption of direct-planting

Table 4 presents the values for the marginal effects of the continuous variables. In the first alternative, column 1.a, the binary variables admit value zero for training (T=0) and profitability (R=0); in other words, the producer is untrained and considers his profitability to be low. The average variable marginal effect values and the implication of those values are as follows: the marginal effect of variable AREA is 0.0006: for each hectare added, the probability of adoption of direct-planting rises by 0.06%; The marginal effect of variable PROD is 0.0190: a productivity increase of one 60kg bag per hectare elevates the probability of adoption of direct-planting by 1.90%; The marginal effect of variable INVEST is -0.0234: for each investment by the producer to acquire a machine or other equipment, the probability of adoption of direct-planting is reduced by 2.34%; The variable investment (INVEST) presented a negative sign, demonstrating that an increase in capital equipment increases the chances that the producer will continue using the conventional, machine intensive planting system.

In conventional planting, a tractor cultivates 40.5 hectares, while in the direct-planting a tractor cultivates 214.9 hectares. A tractor cultivates 5.3 times more area under the direct-planting system than under the conventional planting system, which may explain the negative marginal effect presented by the INVEST variable.

Table 4 - Marginal effects of the continuous variables obtained from the *logit* model, in agreement with the values of the binary variables, State of Goiás, 1999

Alternative	1.a	2.a	3.a	4.a
	Marginal effect			
Variable	T=0 R=0	T=1 R=0	T=0 R=1	T=1 R=1
AREA	0.0006	0.0005	0.0005	0.0003
PROD	0.0190	0.0168	0.0172	0.0107
INVEST	-0.0234	-0.0207	-0.0212	-0.0133
KPRÓPRIO	0.3957	0.3505	0.3582	0.2246

Source: Data of the research.
Note: the) T is variable binary training; R is variable binary profitability; AREA is soybean area; PROD is productivity (60kgbag/ha); INVEST is investment; and KPRÓPRIO is the ratio of personal capital to credit used to pay for operational expenses.; b) in the first alternative, T=0 and R=0, training absence and low farm profitability; in the second alternative, T=1 and R=0, training presence and low profitability; in the third, T=0 and R=1, training absence and profitability is medium to high; in the fourth, T=1 and R=1, training presence and profitability is medium or high.

Table 4 shows that variable KPRÓPRIO, the capacity of the producer to pay operational expenses with his own capital as opposed to borrowed capital, has the most influence of all variables presented on the decision to adopt direct-planting technology. This variable has its greatest marginal effect, 0.3957, when farmer training and assumed profitability are low, Table 5, alternative 1.a (T=R=0). In this alternative, an increase in the farmer's ability to use his own capital to pay operational expenses can increase the probability of adoption of direct-planting by 39.57%.

Comparing this alternative with alternative 2.a (T=1, R=0), it is verified that the marginal effect of the variable KPRÓPRIO is reduced, although it continues to be the most influential factor on the direct-planting decision. It is observed that though profit is considered low, the producer still is willing to finance the adoption of new technologies should his capitalization increase. This implies that the higher the level of producer self-capitalization, the more risk tolerant the producer becomes, which would result in the expressive marginal effect of the capitalization variable (KPRÓPRIO).

It is verified that the marginal effect of KPRÓPRIO in the absence of producer training and medium to high profitability (Table 4 col. 3a) is practically the same as in alternative 2.a and only slightly reduced from alternative 1.a. However, the marginal effect of KPRÓPRIO is reduced considerably if the producer is both trained and considers his farm to be of medium to highly profitability (Table 4, alt. 4.a). Still, in all combinations of training and farm profitability levels, KPRÓPRIO has the by far the greatest affect on the producers' technology adoption decision.

The marginal effects of the discreet variables TREIN and RENT cannot be identified and analyzed in the same way as the continuous variables AREA, PROD, INVEST, and KPRÓPRIO. The marginal effects of the variables TREIN and RENT are determined by the increase in the probability of adoption of direct-planting under various training and profitability alternatives (Table 5 and Figure 2).

Table 5 - Marginal effects of the discreet variables for the logit model, in agreement with the values of the binary variables, state of Goiás, 1999

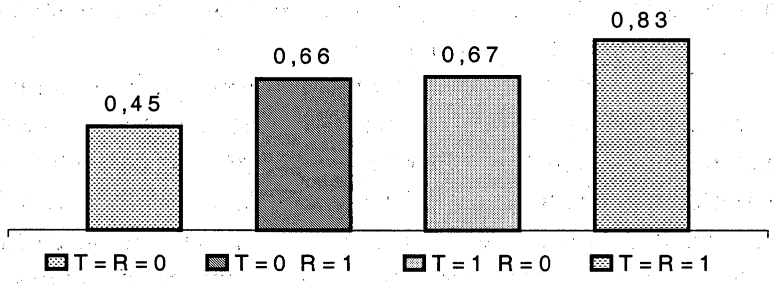
Alternatives: marginal effect of the variable X_i		Adoption probability	Value of the marginal effect
1.a) X_i = TREIN (T), considering R = 0	T=0 R=0 T=1 R=0	0.4514 0.6751	0.2237
2.a) X_i = RENT (R), considering T = 0	T=0 R=0 T=0 R=1	0.4514 0.6605	0.2091
3.a) X_i = TREIN (T) AND RENT (R)	T=0 R=0 T=1 R=1	0.4514 0.8308	0.3794
4.a) X_i = TREIN (T), considering R = 1	T=0 R=1 T=1 R=1	0.6605 0.8308	0.1703
5.a) X_i = RENT (R), considering T = 1	T=1 R=0 T=1 R=1	0.6751 0.8308	0.1557

Source: Data of the research.

A trained producer (T=1) operating a low profitability activity (R=0) is on average 22.37% more likely to adopt direct-planting than an untrained producer (Table 5, row 1.a, col. 4). This was calculated by subtraction of the "adoption probability" with low profitability and the absence of training from the "adoption probability" in the presence of training and while maintaining low profitability.

Figure 2 shows the effect of different levels of producer training and farm profitability on the probability of adoption of the direct-planting technology.

Figure 2 - Effects of the variables training and profitability on the probability of adoption of the direct-planting for different T and R, in the soybean crop, Goiás, 1999



Source: Research data.

Table 5 and Figure 2 show that when the variables area (AREA), productivity (PROD), investment (INVEST), and KPRÓPRIO interact they can exercise significantly more influence on the adoption of the direct-planting than when acting separately. When there is no producer training and profitability is perceived as low (T=R=0), it is observed that the four variables can combine to increase the probability of adoption of direct-planting by 45.14%. In the presence of training (T=1) and high profitability (R=1), the four variables can combine to increase the probability of adoption by 83.08% (Table 5, Fig. 2).

The variables KPRÓPRIO, TREIN and RENT should be more thoroughly examined because they present marginal effects with expressive values and may have similar importance in the adoption of other agricultural technologies.

The results presented in this paper are corroborated in Nicholls' (1973) report in which it is observed that adequately self-capitalized producers have a greater propensity for the adoption of new techniques than producers with marginal financial resources or those dependent on the extension of credit. The less capitalized farmers are more risk averse, leading them to continue using older, traditional farming techniques. Risk aversion can be reduced by increasing farmer capitalization. This rational can be used to explain the relatively greater marginal effect of the capitalization variable (KPRÓPRIO) on a producer's decision to employ what may be considered an innovative cultivation system: direct-planting.

Paiva (1983) verified that when the producers have technical knowledge and enough financial resources, they are more inclined to adopt modern production technologies. The profitability of the crop also influences the adoption of relevant technologies, as an unfavorable relationship between costs for the new factors and the agricultural product's price, the norm, generally constrains the introduction of the new technique and discourages the adoption of new technologies.

6. Conclusions

Long-run sustainable development of the agricultural sector requires natural resource preservation necessitating the selection of low environmental impact agricultural technologies to improve productivity and profitability.

The objective of this paper is to identify the factors that increase the probability of the adoption of direct-planting, an environmentally friendly farming technology. Our results show that the levels of self-capitalization, producer training, farm profitability and productivity, investment, and area under cultivation are the main factors affecting the producer's decision to adopt this technology.

It is observed that the more trained the producer is, the more likely he is to implement new technologies that seek to rationalize the use of natural resources. It is therefore important that existing institutions continue to sponsor courses promoting sustainable technology. Institutions such as the National Service of Rural Learning (SENAR), farmers associations, rural unions, and cooperatives make possible a continued advance in the use of agricultural techniques that are considered sustainable.

The chances of a new technology's adoption are greatly improved if the trained producer enjoys financial and economic conditions compatible with the maintenance of a technologically modern productive structure. The need for producer capitalization is unquestionable; it allows him to continue investing in processes that generate increasing productivity.

The Brazilian government's role in the support of economically and environmentally rational technological improvement is to definite appropriate policies to improve producer profitability and make possible producer capitalization. One way for the government to accomplish this would be through the implementation of agriculture policies that reduce interest rates and taxes to enhance the competitiveness of local products. The government should also complete trade agreements with the various economic blocks to reduce external protectionism, thereby significantly improving the income of Brazilian producers.

The probability of the adoption of rational agricultural technologies would also be indirectly improved by the development of tools to finance agriculture and stabilize agricultural prices, such as the Rural Producer Bill (CPR), the creation of efficient commodity futures and options markets, the support of public investment in infrastructure, and improved access to market information and social services.

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