NEUTRALITY OF DECOUPLED PAYMENTS IN THE PRESENCE OF CREDIT MARKET IMPERFECTIONS

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ABSTRACT

Decoupled payments have emerged as an alternative to traditional agricultural subsidies –that are coupled to production decisions–, in order to minimize the distorting impacts of domestic agricultural policy. Economic theory suggests that, when farmers face imperfections in key markets –such as that for financial services–, even lump-sum subsidies may affect agricultural output. This paper explores these issues by developing and solving a deterministic dynamic optimization model for a credit-constrained representative corn farming household in the United States. The model is parameterized using data from the USDA's ARMS database. Simulations for different levels of DP and other parameters were conducted, and three effects on agricultural output stemming from DP were found: an expanding and temporary "liquidity effect"; an expanding and permanent "credit supply effect"; and a contracting and permanent "land price effect". The magnitude and direction of the final net effect depends on several factors that require further empirical research.

1. Introduction

In a time when the issue of the impact of the developed nations' domestic agricultural support policies on international trade flows and prices has reached the top of the agenda for multilateral trade negotiations, the so-called *Green Box-type policies* emerge as a good alternative to try to disentangle the farmers' production decisions from the levels of support they receive from their governments. In the United States, these policies are usually called 'Decoupled Payments' (DP) and have been granted since 1996.

The concern about the capability of DP to affect US farmers' production decisions is related to the degree of market power that the US possess in international crop markets. The larger such market power is, the larger the extent to which changes in US domestic crop production will affect international prices, thus having an impact on the welfare of other countries, particularly developing small economies whose domestic policies cannot affect their terms of trade.

The fact that the amount of DP received by a farm does not depend on its current production level brings about a significant improvement with respect to the traditional (i.e., "coupled") agricultural support policies –which have explicit links to current production decisions–, in the sense that DP distort agricultural production less (Dewbre, Antón and Thompson, 2001; Key, Lubowski and Roberts, 2005) and make U.S. agriculture more responsive to market signals (Westcott and Young, 2004).

In the Farm Bill of 2002, DP were renewed but farmers were allowed to update the base acreage and yields upon which the payment is computed, thus creating a new potential link between this type of domestic support and the farmers' current production decisions. Although this is an issue that goes beyond the scope of this paper, such a change in the rules should not happen again, for otherwise strong expectations of future updates would clearly destroy the neutrality of DP, as suggested by Goodwin and Mishra (2005).

Although DP represent a clear step ahead in the process of making U.S. agriculture more responsive to market signals, several research efforts have documented a positive and modest impact of DP on agricultural output (Dewbre, Antón and Thompson, 2001; Adams *et al.*, 2001; Burfisher and Hopkins, 2003; Burfisher and Hopkins, 2004; Chau and de Gorter, 2005; Goodwin and Mishra, 2006). In turn, Vercammen (2003) finds that the impact of DP on the farmers' production decisions may as strong as that of coupled subsidies.

The literature has identified at least two channels through which DP would influence the farmers' production decisions. Hennessy (1998) shows that, under uncertainty, assuming that the farming households have preferences consistent with decreasing absolute risk aversion is enough for the farmers' production decisions to be affected by DP. In turn, Young and Westcott (2000), Burfisher and Hopkins (2003), Vercammen (2003), Collender and Morehart (2004), and Goodwin and Mishra (2005), point out that limitations in the farmers' access to credit create a channel for DP to have an impact on agricultural output, since DP will provide the farmers with the chance to expand their scale of production and get closer to the optimum size they could not achieve because of the credit constraints. This is supported by the fact that farmers do not usually have access to outside equity investors, thus having to rely on their own equity and on borrowed funds for investment (Collender and Morehart, 2004).

The main objective of this dissertation is to analyze the extent to which DP may influence the production decisions of a representative farming household that faces imperfections in the credit market, widely pointed out by the literature as the most important case for DP to affect the farmers' production choices, and likely to be the case for U.S. corn farmers, as it follows from the evidence presented by Collender and Morehart (2004).

Credit rationing may take place through either price –the interest rate is increasing in loan size–, or quantity –the borrower does not get as much credit as wanted even if he is willing to pay a higher interest rate. The former was chosen in this paper to avoid kinks in the formulation of the model that reduce its stability.

In turn, corn is chosen as the crop to be considered for this research. Such a choice is based on the fact that it makes a perfect case for a commodity in which the US possess market power. US corn production accounts for 27% of total world production and nearly 60% of world's exports (USDA, 2006).

This dissertation develops, parameterizes, and solves a fully non-stochastic dynamic optimization model for a representative U.S. corn farmer that is credit-constrained by being charged an interest rate that increases as the debt-to-asset ratio increases. The model is used to perform simulations for different scenarios, in order to theoretically assess whether DP may be expected to have an impact on the farmers' production decisions under credit rationing.

The model is parameterized using a sample of corn-specialized farms from the Agricultural Risk Management Survey (ARMS) database of the United States Department of Agriculture (USDA), which includes the estimation of the production technology using a Cobb-Douglas dual cost function. The steady state values for action and state variables are approximated numerically using a standard root-finding routine, while the model is solved using function approximation by collocation[1].

The results of the simulations performed suggest that, when a representative corn farming household faces an interest rate that is increasing in the debt-to-asset ratio, the reception of DP leads it to increase the farm size temporarily (i.e., along the optimal path) but not permanently. This is called the "liquidity effect" of DP.

However, the collective reaction of all corn farming households along the lines of what the representative one does, increases the demand for farmland and bids its price up, thus leading the representative corn farming household to reduce the farm size, both along the optimal path and in the long run. This is called the "land price effect" of DP. The simulation showed that a 6 percent increase in land prices produces an 11 percent contraction in the steady-state farm size.

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[1] An excellent assessment on the use of numerical approximation techniques can be found in Miranda and Fackler (2002).

In turn, the guaranteed increase in the farming household's cash flow implied by DP increases its creditworthiness with the financial system. This was found to lead the representative corn farming household to increase the farm size, both along the optimal path and in the steady-state, and is called the "credit supply effect". The simulation for a one percentage point reduction in the base interest rate produces a 5 percent increase in the long-run optimal farm size.

The balance between the three effects will depend on how far US farmers may be from their optimum scale of production, how burdensome credit constraints are, how much room for financial innovation there is and how elastic the supply of land may be. Further empirical research is needed to address these elements.

The rest of this paper is organized in four additional sections. The next section develops the dynamic optimization model. Section three discusses briefly the methodological procedures followed for the parameterization of the model, while section four presents the main results obtained from both the solution of the model and the simulations performed. Finally, the main conclusions and policy recommendations are sketched.

2. The Model

This dissertation focuses on the decisions of a representative farming household that attempts to maximize the discounted sum of present and future utility derived from the consumption of a single good –whose price is normalized to be one– over an infinite time horizon. In order to maximize the present value of the current and future stream of utility, the household must optimize consumption intertemporally, by making production and indebtedness decisions that allow its farm to produce a stream of dividends capable of financing consumption and farm expansion as well as servicing the debt. The household faces no uncertainty, as it is assumed to have perfect foresight about the future. The prices of output and of land are assumed to be time-invariant and given to the household as a parameter (i.e., the farming household is a price taker).

The financial market is assumed to suffer from information asymmetries and incentive incompatibility, which prevent lenders from having complete information about the profitability of the particular farm and to control the diligence of the farmer. To capture the consequences of this type of market failure, the model assumes that lenders classify borrowers on the basis of the expected risk associated with their class (Gonzalez-Vega, 1976; Jaffee and Stiglitz, 1990). Under an efficient classification system, riskier borrowers are charged higher interest rates. Thus, the safest borrowers are charged the prime rate and riskier borrowers are quoted a premium over the prime rate. In the model, the risk class of the farming household is determined by its debt/assets ratio (capital structure). As this ratio increases, the farming household moves to a higher-risk category and it has to pay a higher interest rate.

To allow for continuity in this functional relationship, rather than discrete classification jumps, the model assumes that there is a lender that behaves as a perfectly discriminating monopolist and, therefore, charges a "personalized" interest rate on loans to each borrowing class, depending on the borrower's capital structure (Gonzalez-Vega, 1976).

More specifically, in the model, borrowers are charged a fixed interest rate (prime rate) as long as their debt-to-asset ratio does not exceed a certain threshold, beyond which they are charged a premium over the base interest rate that is monotonically increasing on the debt-to-asset ratio. Should the household choose to hold deposits rather than debt, it will be paid a constant interest rate on its deposits equivalent to the base interest rate that borrowers are charged. There is no explicit limit on the amount of credit that a household can borrow, but a "natural" limit will emerge from the increasing cost of access to credit and diminishing marginal returns at the farm.

The interest rate function considered is of the form:

$$i(D,A) = \begin{cases} i_0 \forall \dfrac{D}{zA} \leq \theta \\ i_0 + \eta \left(\dfrac{D}{zA} - \theta \right)^2 \forall \dfrac{D}{zA} > \theta \end{cases},$$

where i_0 is the base interest rate, D is the outstanding debt, z is the price of land and A is the number of acres owned by the farming household.

The household has a structure of preferences that is characterized by decreasing absolute risk aversion (DARA): namely, the household's level of risk aversion decreases as the level of consumption increases. Since no uncertainty is present in the model, this assumption simply translates into a decreasing marginal utility of consumption, as an additional unit of consumption brings about a smaller increase in the household's well-being the larger the current level of consumption is.

Consumption possibilities are bounded by a budget constraint that reflects the sources and uses of funds. One of the sources is a payment that the household receives every period from the government and that is time-invariant and independent of current output level and farm size (DP).

The production technology of this farming household depends on land only and bears diminishing marginal returns, as the productivity of an additional acre decreases as farm size increases. There is a constant per-acre marginal cost that includes the cost of other inputs that are combined with land for production.

At the beginning of period *t*, the farming household finds itself owning *A* acres of land and holding an outstanding debt of *D* dollars. These are in fact the two state variables in this model, since the farmer has no way of affecting their current level with his actions. Instead, these actions affect the future levels of the state variables. Given the nature of the credit-rationing process considered in this model, the outstanding debt is unbounded and it can be either positive (debt) or negative (deposits). There is no limit on how big the farm can get, and the smallest possible farm size takes place when the farmer runs out of business (i.e., $A = 0$). More formally:

$$-\infty \le D \le \infty$$
$$0 \le A \le \infty$$

Contingent on the observed farm size and outstanding debt, the farming household must choose the optimum addition to its current debt (ΔD) and the optimum farm expansion (ΔA), such that it maximizes the sum of current and discounted future utility derived from consuming as much as the dividends produced by the farm allow. A negative addition to debt means that part (or all) of the debt has been repaid. The household is allowed to buy or sell land. A negative farm expansion implies that the household is selling part (or all) of its land.

Given both the unbounded nature of the level of debt and the credit-rationing mechanism considered in this model, the household can choose whatever addition to debt it wishes, regardless of whether debt is being increased or repaid. Moreover, the fact that the household can choose to hold unlimited amounts of deposits allows the addition to debt to become as negative as desired. In turn, the farm expansion is unlimited if positive, but limited by current land holdings if negative (i.e., the farming household cannot sell more land than it owns). More formally:

$$-\infty \leq \Delta D \leq \infty$$
$$-A \leq \Delta A \leq \infty$$

The size of the farm in the next period is determined by its current size and by the present expansion as chosen by the farming household. In turn, the amount of outstanding debt next period is equal to the current outstanding debt and the present addition to debt chosen by the farming household. These conditions define the transition or update rules for the state variables over time, expressed as:

$$A_{t+1} = A_t + \Delta A_t \qquad (1)$$

$$D_{t+1} = D_t + \Delta D_t \qquad (2)$$

The farming household wants to maximize its utility by consuming as much as possible. However, consumption possibilities are constrained by the amount of harvest revenue produced by the farm, the amount of money received from the government as a lump-sum transfer, the additional cash brought in by the chosen debt expansion (if positive), the operational cost of farming, the cost of the chosen farm expansion, and the cost of servicing the debt (i.e., paying interests on it). More formally, the household faces the following budget constraint:

$$f(A) + \Delta D + g = C + z\Delta A + (A + \Delta A)k + i(D, A)D \qquad (3),$$

where $f(A)$ is a function that defines the harvest revenue in terms of acreage (it is assumed that all acreage owned is cultivated), g is the lump-sum payment received from the government, C is consumption, z is the price of land, k is the per-acre constant marginal cost of production, and $i(D, A)$ is a function that defines the interest rate in terms of debt level and farm size.

If utility is defined by a concave function of consumption $u(C)$, and a subjective discount factor β is considered, the farming household's dynamic optimization problem can be defined by the following Bellman equation:

$$V(A,D)=\max_{\Delta A\geq -A,\Delta D}\left\{u(C)+\beta V(A+\Delta A;D+\Delta D)\right\} \tag{4}$$

The set of first order conditions that define the solution to the dynamic model can be obtained by putting together the Euler conditions and the optimization constraints, to form the following system of equations:

$$C=f(A)+\Delta D+g-(z+k)\Delta A-kA-i(D,A)D>0 \tag{5}$$

$$\mu_{\Delta A}=-u'(C)(z+k)+\beta\lambda_A(A+\Delta A;D+\Delta D) \tag{6}$$

$$\Delta A\geq -A\Rightarrow \mu_{\Delta A}\leq 0\,;\quad \Delta A>-A\Rightarrow \mu_{\Delta A}=0 \tag{7}$$

$$0=u'(C)+\beta\lambda_D(A+\Delta A;D+\Delta D) \tag{8}$$

$$\lambda_A(A,D)=u'(C)\left[f'(A)-k-\frac{\partial i}{\partial A}D\right]+\beta\lambda_A(A+\Delta A;D+\Delta D)-\min(0,\mu_{\Delta A}) \tag{9}$$

$$\lambda_D(A,D)=-u'(C)\left[\frac{\partial i}{\partial D}D+i(D,A)\right]+\beta\lambda_D(A+\Delta A;D+\Delta D) \tag{10}$$

2.1 Characterization of the optimal path

After some substitutions and simplifications, equations (9) and (10) can be rewritten to characterize the optimal path, as follows:

$$\mu_{\Delta A_t}=u'(C_t)\left[f'(A_t)-k-\frac{\partial i}{\partial A_t}D_t\right]+\left[\beta\lambda_{A,t+1}-\lambda_{A,t}\right] \tag{11}$$

$$\lambda_{D,t}=\beta\lambda_{D,t+1}-u'(C)\left[\frac{\partial i}{\partial D_t}D_t+i(D_t,A_t)\right] \tag{12}$$

Equation (11) implies that the increase in the household's welfare from adding an extra acre of land to the farm is equal to the sum of the increase in utility from consumption financed with the net revenue produced by the additional acre and the increase in household welfare from having a farm that is one acre larger. Such a relationship must be satisfied for any pair of two consecutive years along the optimal path.

In turn, equation (12) implies that the increase in the household's welfare from holding one dollar of debt today must be equal to the present value of holding the same dollar of debt the next period, plus the forgone utility from the consumption possibilities given up due to the financial cost of holding one dollar of debt today. Again, this relationship must be satisfied by any pair of consecutive periods along the optimal path.

2.2 Characterization of the steady state

The set of conditions that defines the solution to the model can be rewritten to create the set of conditions that define the steady state, as follows:

$$C^* = f(A^*) + \Delta D^* + g - (z+k)\Delta A^* - kA^* - i(D^*, A^*)D^* > 0 \tag{13}$$

$$\mu_{\Delta A}^* = -u'(C^*)(z+k) + \beta\lambda_A^* \tag{14}$$

$$\Delta A^* \geq -A^* \Rightarrow \mu_{\Delta A}^* \leq 0; \quad \Delta A^* > -A^* \Rightarrow \mu_{\Delta A}^* = 0 \tag{15}$$

$$0 = u'(C^*) + \beta\lambda_D^* \tag{16}$$

$$\lambda_A^* = \left[z + f'(A^*) - \frac{\partial i}{\partial A^*} D^* \right] u'(C^*) \tag{17}$$

$$\lambda_D^* = -\left[1 + i(D^*, A^*) + \frac{\partial i}{\partial D^*} D^* \right] u'(C^*) \tag{18}$$

$$A^* = A^* + \Delta A^* \tag{19}$$

$$D^* = D^* + \Delta D^* \tag{20}$$

From equations (19) and (20), it follows that, in the steady state, the optimum actions by the farming household are not to increase nor reduce the size of the farm and not to increase nor reduce its outstanding debt. In other words, $\Delta A^* = 0$ and $\Delta D^* = 0$. These results mean that, in the steady state, the household cannot increase its welfare by either changing the size of its farm or changing its indebtedness. Actually, the fact that $\Delta A^* = 0 \Rightarrow \Delta A^* > -A^* \Rightarrow \mu^*_{\Delta A} = 0$. Using these results, the steady state can be ultimately characterized by a system of two non-linear equations on two unknowns (A^* and D^*), as follows:

$$f'(A^*) = \rho(z+k) + k + \frac{\partial i}{\partial A^*} D^* \tag{21}$$

$$D^* = \frac{\rho - i(D^*, A^*)}{\frac{\partial i}{\partial D^*}} \tag{22}$$

By solving these two equations, the steady-state optimum consumption and shadow prices can be determined using equations (13), (17) and (18).

The system of equations (21) and (22) does not have a closed-form solution though, thus making necessary to rely on numerical approximation methods. Nevertheless, the lack of a closed-form solution does not prevent an analysis of the dynamics embedded in the steady state. The first feature that deserves some consideration is the fact that the government payment *g* does not affect the steady-state optimum levels of land holdings and debt, although it does affect the optimum level of consumption. The rationale for this lies in the definition of steady state itself. At the steady state, consumption must be the same period after period, and thus the interest rate looses its role as an intertemporal allocator of consumption. Thus, it does not matter that the government payment provides a stream of cash at zero financial cost, since the household will spend it in consumption, which will also remain at a constant level. The only consequence is a permanently higher level of consumption.

The fact that the optimum additions to debt and land holdings are zero in the steady state indicates that the opportunities to increase the welfare of the household through increases of either farm size or debt have been fully exhausted and thus the remaining unexploited opportunities to increase the household's welfare through consumption are those that result from taking advantage of the expansion of the household's budget constraint implied by the government payment. Thus, for two regimes with different levels of g, the steady-state debt balance and farm size will be identical.

Another feature of this steady-state is that, in light of the marginal diminishing returns on land assumed for the model, the optimum farm size decreases as either the price of land or the per-acre marginal cost of production increase, as shown by equation (21). The rationale for this can be found in that, the greater the cost of acquiring or harvesting an acre, the lower the marginal profitability of land and thus the household can be better-off by reducing its long-run land holdings.

Finally, equation (22) reveals that the steady-state optimum level of debt will be greater the higher the subjective discount rate (ρ), the lower the base interest rate charged by the lenders, or the higher the debt-to-asset ratio threshold beyond which the lenders start charging a premium on the interest rate on loans. A higher subjective discount rate means that the household is more impatient and, thus, it will be willing to borrow more. In turn, a lower base interest rate or a higher threshold debt-to-asset ratio means a lower financial cost of debt, thus increasing the marginal "profitability" of debt and inducing the household to hold a larger debt at the steady state.

3. Parameterization of the Model

The parameterization was performed using data for 2001 from the Agricultural Resource Management Survey (ARMS) database, a comprehensive set of information on a broad range of issues about agricultural resource use, costs and farm financial conditions, for a representative sample of U.S. farms.

The first round of DP took place between 1996 and 2001, while the second round has been in place since 2002. A word of caution is worth about the information contained in ARMS for the second round of DP, since the 2002 Farm Bill gave farmers the chance, although it did not force them, to update their base acreage and yields from those of 1991-1995 to those for the 1998-2001 period (Whitaker, 2006). Such a change may actually erode the lump-sum nature of DP, as farmers may develop the expectation that more updates will be allowed in the future, leading to increases in their acreage (Goodwin and Mishra, 2005). Thus, a fair evaluation of the potential impacts of DP on the farmers' production decisions should privilege the use of the ARMS data for the first round of DP.

Under the premise that the participation in the DP program increases as time goes by, year 2001 was chosen in order to assure the widest participation of farmers in the first round of DP. Besides, experts from the National Agricultural Statistics Service confirmed that 2001 can be considered as a "normal" year for the production of corn in the U.S.

Out of the 1891 observations available for 2001 in ARMS, the 218 specialized in the production of corn and for which no missing values were found in the relevant variables, were selected as the sample to be used in this research.

For most of the parameters, the values assigned were obtained from the selected sample of 218 corn farms, by drawing the values from an interval around the mean of the relevant variables, since the model is expected to resemble the environment of a representative US corn farming household.

In turn, the production technology for the representative corn farming household was estimated using a Cobb-Douglas dual cost function.[2] Also, since the model considers land to be the key input that determines the scale of production, fixed per-acre relationships were estimated for the other inputs different than land.

The set of variables chosen as the regressors in the Cobb-Douglas dual cost function are: the quantity of corn produced, the price paid per pound of fertilizer, the average hourly wage rate (includes paid and unpaid wages), the interest rate paid on loans –used here as a proxy for the cost of use of physical capital, and the rental rate of land per acre.

Although the dynamic model that will be parameterized with the results of the estimated production technology is one where it will be assumed that the farmer owns rather than rents land, the rental rate of land is used for this estimation since it reflects the true period-by-period unit cost associated to the use of land. By the same token, in the absence of an accurate measure of the period-by-period cost of the use of capital, the interest rate was chosen as a proxy. When physical capital is purchased with the farmer's own funds, the interest rate represents the opportunity cost of funds; when capital is purchased with credit, the interest rate represents the financial cost of this purchase.

The functional form of the non-linear regression equation is:

$$C_j = \left(\sum_{k=1}^{4} \gamma_k \right) \left[Q \left(\frac{p_{F_j}}{\gamma_1} \right)^{\gamma_1} \left(\frac{w_j}{\gamma_2} \right)^{\gamma_2} \left(\frac{i_j}{\gamma_3} \right)^{\gamma_3} \left(\frac{r_j}{\gamma_4} \right)^{\gamma_4} \right] \varepsilon_j ,$$

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[2] This approach was followed after considering the potential endogeneity biases associated to the estimation of a primal production function, discussed by Coelli and Cuesta (2000).

where C is cost of production, Q is output, p_F is the price of fertilizer, w is the hourly wage rate, i is the interest rate, r is the rental rate on land, and γ_k for k=1,…4, are the Cobb-Douglas primal production technology coefficients for the k-th factor of production associated to the corresponding price in the non-linear regression equation.

The estimation was performed using non-linear Ordinary Least Squares procedures in SAS and its results are summarized in Table 1. The coefficients for fertilizer, physical capital, and land are statistically significant at the 5% level, while the coefficient for labor is not statistically significant. The fit is particularly good for a cross-section, since the variation of the regressors can explain as much as 80% of the variation of the dependent variable. The coefficients that resulted statistically significant were rounded to the first decimal place for the sake of favoring the stability of the dynamic model. These coefficients are 0.3 for fertilizer, 0.4 for physical capital, and 0.1 for land.

The result of White's test for heteroscedasticity reports a chi-squared statistic that rejects the null hypothesis of homoscedastic errors. Several correcting procedures –including White's general method, the jackknife-scaled method, and the use of weighting factors– were attempted with no success, since no procedure generated a significant reduction of the White's test chi-squared statistic, which would lead to failure to reject the null hypothesis of homoscedastic errors, nor were they able to increase the statistical significance of the coefficient for labor. Instead, all of these procedures reduced the statistical significance of the already statistically significant coefficients.

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    Cobb-Douglas Dual Cost Function (INPUTS: FERTILIZER,LABOR,PHYSICAL CAPITAL,LAND)
                                The MODEL Procedure


                    Nonlinear OLS Summary of Residual Errors

                 DF       DF                                                   Adj
Equation      Model    Error         SSE         MSE    Root MSE    R-Square      R-Sq
C                 4      214    1.959E13    9.156E10      302596      0.7987    0.7959



                         Nonlinear OLS Parameter Estimates

                                       Approx                    Approx
               Parameter       Estimate     Std Err    t Value     Pr > |t|
               b1              0.340722      0.1612       2.11       0.0357
               b3              0.124327      0.0944       1.32       0.1894
               b4              0.386033      0.1231       3.14       0.0020
               b5              0.105645      0.0386       2.73       0.0068



                    Number of Observations     Statistics for System
                    Used               218    Objective      8.9884E10
                    Missing              0    Objective*N    1.9595E13



                              Heteroscedasticity Test

Equation        Test              Statistic     DF     Pr > ChiSq    Variables
C               White's Test          169.2     14         <.0001    Cross of all vars
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Table 1: Regression results for the Cobb-Douglas dual cost function

According to Greene (2002), White’s test is so general, that a failure to reject the null hypothesis may indicate one of two things: either the errors are not homoscedastic or there is a problem with the specification of the model (i.e., with the functional form of the regression equation). That the methods used to correct for the presumed heteroscedasticity did not deliver satisfactory results may well indicate that there is a problem with the functional form specified for the dual cost function. However, the opportunity to attempt a different functional form here is limited by the factors that led to choose a Cobb-Douglas dual cost function in the first place, since this is the only functional form that has a closed form solution that allows the researcher to go back and forth from the dual to the primal. This constraint prevented a change in the specification of the cost function. Besides, the results of the heteroscedasticity corrections attempted offer some grounds for not worrying much about the variances of the error terms.

In turn, the results for the estimation of the fixed per-acre linear proportions of use of inputs other than land are presented in Table 2. In both cases, the intercept was not statistically significant but the slope coefficient was. The first regression indicates that the variability of land explains as much as 80 percent of the variability in the use of fertilizer, with an average of 296 pounds of fertilizer applied per acre of farmland. In turn, the second regression reported that the variability of land explains about 65 percent of the variability in the use of physical capital, with an average of 86 dollars of physical capital used (i.e., fully consumed in the production process) per acre of farmland. In order to consider only the fraction of the physical capital that is fully consumed in the production process, the capital expenditures corresponding to depreciation, maintenance and repairs were the ones used for this estimation.

By using these estimated linear relationships along with the coefficients estimated for the production technology, the production function can be expressed as a single concave function of land, which is then raised to the power 0.8 (resulting from adding up the coefficients for fertilizer, physical capital and land). This functional form depicts diminishing marginal returns to land, and it offers the desirable characteristics of curvature and continuity needed for the dynamic model.

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     Linear Regressions of each one of the inputs as a function of Acreage


                         Dependent Variable: F_DWSCL

                            Analysis of Variance
                                  Sum of           Mean
Source                   DF      Squares         Square    F Value    Pr > F
Model                     1   2204.05239     2204.05239     908.72    <.0001
Error                   216    523.89373        2.42543
Corrected Total         217   2727.94612

             Root MSE              1.55738    R-Square     0.8080
             Dependent Mean        2.64817    Adj R-Sq     0.8071
             Coeff Var            58.80971

                             Parameter Estimates
                          Parameter       Standard
    Variable      DF       Estimate          Error    t Value    Pr > |t|
    Intercept      1       -0.16088        0.14075      -1.14      0.2543
    AHVT_DWSCL     1        2.96471        0.09835      30.15      <.0001




                       Dependent Variable: K_EXP_DWSCL

                            Analysis of Variance

                                  Sum of           Mean
Source                   DF      Squares         Square    F Value    Pr > F
Model                     1    183.50425      183.50425     418.80    <.0001
Error                   216     94.64364        0.43816
Corrected Total         217    278.14788

             Root MSE              0.66194    R-Square     0.6597
             Dependent Mean        0.83320    Adj R-Sq     0.6582
             Coeff Var            79.44570

                             Parameter Estimates
                           Parameter       Standard
    Variable       DF       Estimate          Error    t Value    Pr > |t|
    Intercept       1        0.02266        0.05982       0.38      0.7052
     AHVT_DWSCL      1        0.85545        0.04180      20.46      <.0001
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Table 2: Regression results for the linear relationships between acreage and the other inputs

At least two different explanations can be offered to support the existence of diminishing marginal returns to land in farming. On the one hand, a Ricardian explanation can be provided on the basis of the heterogeneity of land quality and the fact that land with higher fertility is used first. A second explanation reflects how coordination and monitoring costs increase as the size of the farmland being operated by the same farmer increases. Thus, it is the farmer's (limited) entrepreneurial capacity that gets saturated as farm size expands.

Finally, it is important to mention that the parameters measured in monetary terms were normalized by expressing them as a fraction of units of marginal revenue. In other words, the variables normalized were divided by the market value of the average per-acre yield of corn production for the sample, which for an average price of 2 dollars per bushel of corn and an average yield of 175 bushels per acre, resulted in 350 dollars per acre. This normalization helps to avoid scaling problems that may bring undesirable effects to the stability and convergence of the model.

4. Results

The use of numerical approximation techniques requires consideration at all times about the accuracy of the approximants. This is addressed through the computation of the approximation residual for the value function, which is depicted Figure 2. The approximation residual is not only evenly distributed around zero but also of a magnitude that is sufficiently low –always lower than 0.00004 around the origin– as to consider the approximation error negligible, thus confirming that, within the range used for the solution of the model –which happens to be 35 percent around the steady state optimal values of the state variables–, the numerical approximation can be trusted.

Once the model was solved, an optimal path for farm size was recreated over a 40-year horizon, starting from the lower bound of the state space considered for solving the model, as shown by Figure 2. The expected path for farm size over time follows a decreasing accumulation process that stabilizes around the 37th year, when the farming household achieves the steady state in farm size. The reason for this concave accumulation path can be found in the optimal solution for the shadow price of land holdings which, as shown by Figure 3, sharply decreases as land holdings increase.

The shadow price of land holdings is defined as the farming household's own valuation of owning an additional acre of farmland. Given the marginal diminishing returns on land implied by the production technology estimated for this model, an additional acre of farmland is less valuable the larger the farm is. In turn, since land is the farming household's main asset, it would be expected that an additional acre of farmland is more valuable the larger debt is, since it can contribute to reduce both the debt-to-asset ratio and the financial cost of debt. However, such a contribution is less significant at the margin, the larger the farm is.

An interesting fact that is worth to point out about the shadow price of land depicted in Figure 3, is that its value is clearly above the normalized market price for land considered in the model (5.0) for any contingent levels of land holdings and debt. An additional acre of farmland being worth for the farmer more than its market value, can be explained by the fact that the acre contributes to increase current and future consumption –through higher farming revenue–, and to reduce the financial cost of debt.

Three simulation exercises are conducted in order to assess the potential impact of DP on agricultural output. The first one solves the model and produces an expected farm size path over a 40-year horizon for different levels of DP. The second simulation exercise attempts to account for the fact that the impact of DP on the representative farmer will translate into an impact on the market for land. The third simulation accounts for the fact that DP provide the farming households with a stream of revenue that increases its creditworthiness with the financial system.

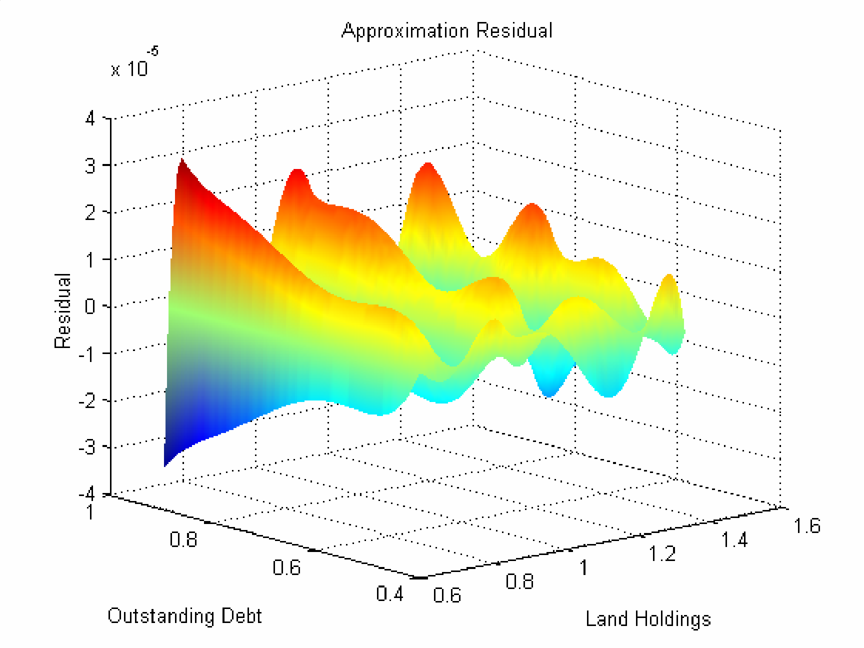

Figure 1: Approximation residual

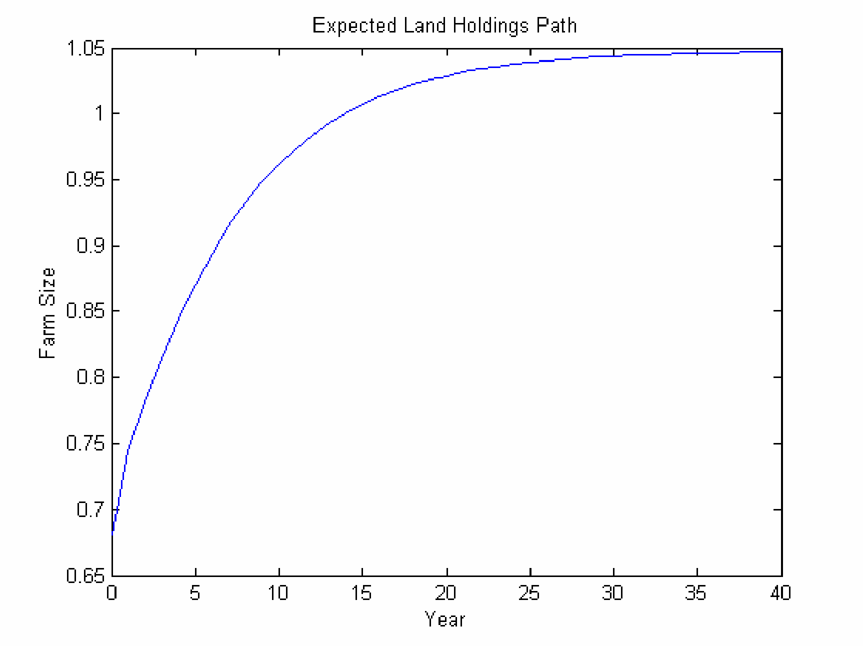

Figure 2: Expected land holdings path over a 40-year horizon

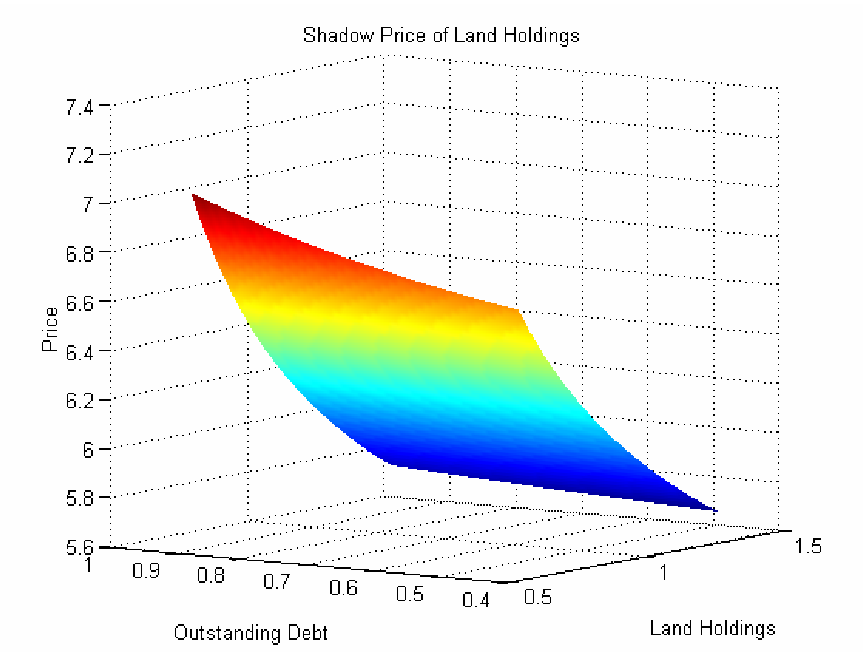

Figure 3: Shadow price of land holdings

Four different DP regimes are considered for the first simulation: total absence of DP; DP exist and are at the current level; DP are twice as big; and, DP are five times as big. While the first and third scenarios correspond to equidistant shifts of DP around their current level, the last one simply reflects the amount of money the U.S. government is currently giving to farmers through the different modalities of agricultural support available (coupled and decoupled). This does not mean that the effects observed for this last scenario would be the ones that should be expected if the entire U.S. agricultural support were given out in the form of DP only, because it does not account for the impacts on farmers' production decisions stemming from the implicit removal of all coupled subsidies. Thus, this last scenario must be taken with care, simply as an indication of what would happen if DP ever reach a level equivalent to the total agricultural support the U.S. government is able to provide nowadays.

The result for this simulation is summarized by Figure 4. The first important result is that the long-run optimum farm size is the same for the different regimes of DP considered in the simulation. Such a result stems from the update rule for the state variables and the definition of steady state itself. Since farm size is a state variable, only its future values can be affected by today's actions.

However, the transition rule defined for the state variables combined with the definition of steady state imply that in the steady state the optimum addition to land holdings and debt are both zero, regardless of the values of parameters.

This implies that the update for land holdings next period when the farmer is at the steady state, does not depend on any of the current actions, thus disentangling the steady-state farm size from the steady-state level of consumption, which is in turn the only channel through which DP may affect the steady-state optimum actions and states.

The economics underneath this result are quite simple. At the steady state, the household has fully exhausted the marginal rewards from both purchasing an additional acre of land and contracting an additional dollar of debt. This can be confirmed easily by checking that both land purchases and debt additions have interior solutions in the steady-state. However, the budget constraint faced by the household leads it to end up consuming at a level where the marginal utility of consumption is positive, again, in the steady state. Therefore, if the household receives extra cash in the form of DP, it will not devote it to purchase land or repay debt, but rather to consume more, since no further opportunities to increase welfare are available from purchasing land or repaying debt, as they effectively are from increasing consumption.

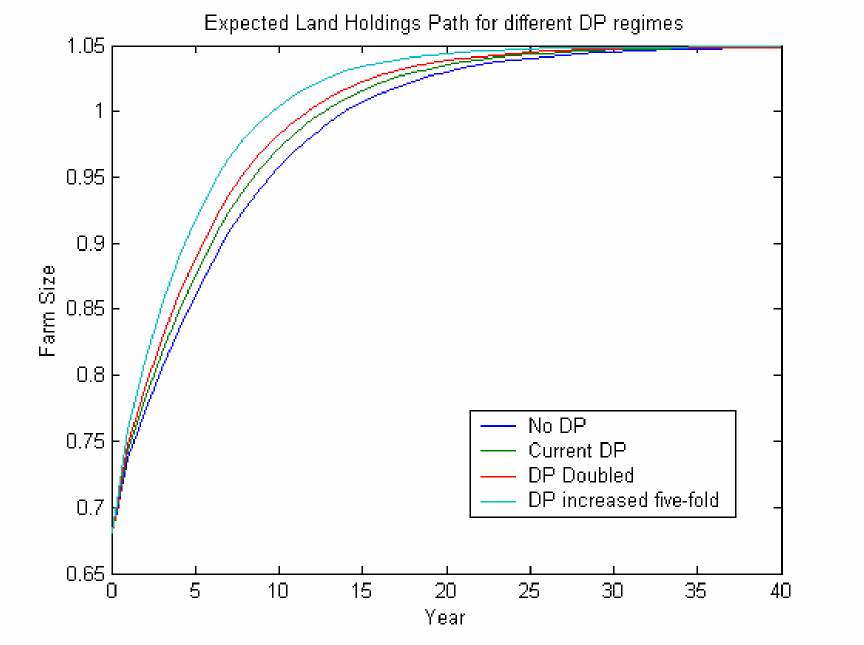

Figure 4: Expected land holdings path for different DP regimes

The second result that deserves consideration is that the optimum farm size is larger along the optimal path, the larger the DP received is. This is explained using the same elements described in the previous paragraph, by simply saying that, along the optimal path, the future level of land holdings depends on the current land purchases and, consequently, on the current consumption choice. Therefore, the budget constraint considered in this model implies that DP can have an impact on farm size, but only along the optimal path.

The combination of larger farm size along the optimal path with the same steady-state farm size for regimes with different amounts of DP, imply that the larger the DP received by the farmer the sooner it can reach the long-run optimal farm size. In other words, the DP does not affect the farm size in the long run, but instead increases the speed of adjustment towards the steady state.

The next question to ask is what are the policy implications of the effects of DP on the representative corn farming household's production choices observed from the simulation exercise described above? A larger farm size implies a larger level of output and, thus, a potentially larger supply in the international market that bids down the international price of corn. However, our results indicate that such an outcome can be expected along the optimal path but not at the steady state. This means that DP could be expected to have a positive impact on U.S. corn production and a negative impact on corn international price while the U.S. corn farmers are on the path towards the steady state, but not once they get there. Thus, the impact of DP on corn trade flows and international prices would be expected to be temporary rather than permanent, which opens a window for the discussion at the WTO to be centered around time rather than money, conditional, of course, on the real possibilities to obtain sound estimates on the time span that developed nations' farmers may need to achieve their steady state.

Nevertheless, the previous conclusion should not be taken as definitive, since DP can be expected to bring about side effects on other variables that will also influence the farmers' production decisions and that are considered in the next two simulations.

Everything said so far accounts only for the impact of DP on the production decisions of one single representative farmer, it is in the representative farmer's nature to resemble what all of the farmers will do. So, if all of the corn farmers attempt to bear larger farms along the optimal path, an excess demand will arise in the market for land and land prices will be bid up, thus making necessary to evaluate how the higher prices of land affect the farmers' production decisions (if at all).

Thus, the idea for the second simulation is to solve the model and produce the optimal intertemporal path for farm size under two different regimes: one in which the farmer receives no

DP and faces a certain price per acre of land, and another in which the farmer receives the current level of DP and faces a higher price of land. Thus, the implicit assumption is that, as explained above, when all farmers attempt to increase the farm size along the optimal path in reaction to the DP, the price of land will increase.

Goodwin, Mishra and Ortalo-Magne (2003) found that the increase in farmland prices associated to the emergence of DP ranges between 2 and 6 percent in the Northern Great Plains and Corn Belt regions. Although several research has been done to assess the impact of U.S. agricultural support policies on land values, the one referred before was chosen for two reasons. First, while most of the research addresses the impacts of farm policies on land rental rates (Weersink *et al.*, 1999; Lamb and Henderson, 2000; Lence and Mishra, 2003; Roberts, Kirwan and Hopkins, 2003; Shaik, Helmers and Atwood, 2005; Kirwan, 2005), the study by Goodwin, Mishra and Ortalo-Magne focuses on the impacts of DP (rather than agricultural subsidies in general) on the prices of farmland (rather than on farmland rental rates). This makes it a perfect match with the model developed in this dissertation, where the farmer receives DP and purchases land rather than renting it. Secondly, the regions for which the study is conducted correspond to the regions where most of the U.S. corn production takes place, thus making it, again, a perfect match for the corn farming households considered here.

In order to perform the simulation, the upper bound of the range suggested by Goodwin, Mishra and Ortalo-Magne was used to define a baseline case in which DP did not exist and the price of land is equal to the current price divided by 106 percent. Thus, the simulation consists of moving from a regime without DP and with certain base price of land, to another with the current level of DP and a price of land that is 6 percent bigger than that of the baseline case.

According to the simulation results, when the price of land increases in response to the emergence of DP, a reduction in the farm size could be expected not only along the optimal path, but also at the steady state (see Figure 5). The rationale for this result at the steady state stems from the fact that, as land becomes more expensive, its net profitability goes down and the marginal reward of an additional acre of farmland becomes negative. Thus, the farmer is better off by owning a smaller farm which, in light of the marginal diminishing returns of land, bears a larger marginal productivity that compensates for the increased price of land. In fact, the simulation for a 6 percent increase in the land prices brought about by the emergence of DP, ends up producing an 11 percent contraction in the steady-state farm size.

The third simulation has to do with the fact that, when farmers are entitled to receive a guaranteed amount of DP every period, the expectation of increased cash flows over time increase the farmers' creditworthiness with the financial system, thus making necessary to assess how the farmers modify (if at all) their production choices given the increase of their creditworthiness. Increased creditworthiness in this context does not mean that the farmers will be allowed to borrow more money –since no limit is imposed on the amount of credit they can borrow–, but instead that their increased repayment capacity will be rewarded through a lower cost of funds. In other words, the supply of credit faced by the farmer increases.

The way chosen to capture such an effect in this simulation exercise –and given the structure of the model–, is through a reduction in the base interest rate paid on any debt level that does not exceed 10 percent of the market value of land holdings. Given that the farmer has to pay a penalty above the base interest rate beyond that threshold of debt-to-asset ratio –penalty that increases on the debt-to-asset ratio–, the reduction of the base interest rate implies a shift downwards and to the right of the supply of credit.

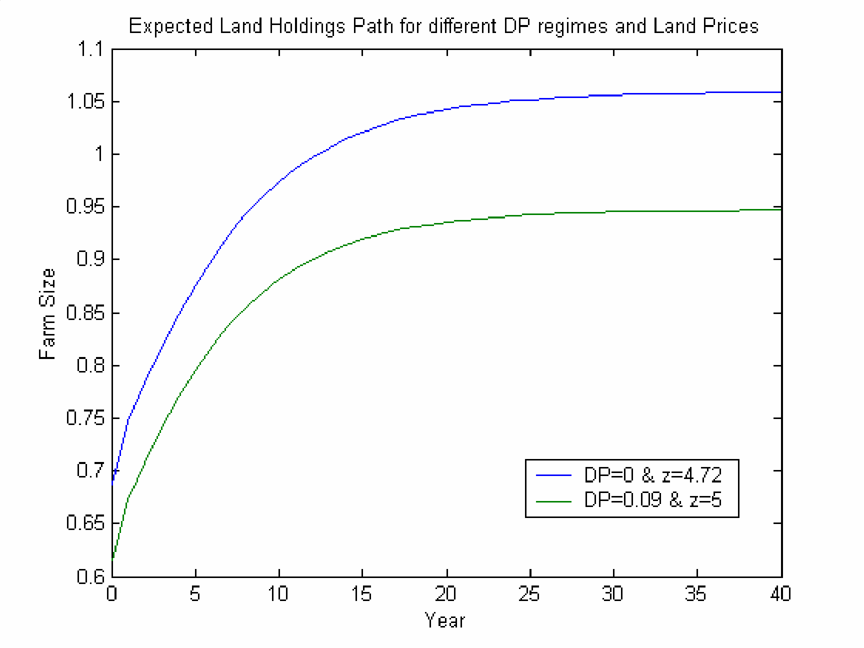

Figure 5: Effect of DP on Expected Farm Size Path

after a 6 percent increase in the price of land

Two different regimes were defined: one without DP and with a base interest rate of 5.2 percent; and another, with DP at their current level and a base interest rate of 4.2 percent. This reduction of one percentage point in the base interest rate represents the increase in the creditworthiness of farmers.

The results indicate that the reduced cost of credit will lead the farmer to acquire more debt, not only in the steady state but also along the optimal path. Given a higher level of debt, a larger farm size is needed in order to preserve the same financial cost of debt, both at the steady state and along the optimal path. Thus, the increased creditworthiness of the farming household leads it to increase the land holdings both at the steady state and along the optimal path, as shown by Figure 5. In addition, this simulation for a one percentage point reduction in the base interest rate brought about by the emergence of DP, produced a 5 percent increase in the long-run optimal farm size.

The bottom line of this simulation is that the expected increase in the farmer's creditworthiness brought about by DP is likely to increase farm size not only along the optimal path, but also permanently. This permanent expansion of farm sizes would induce a permanent expansion of corn production and a reduction of its international price, thus causing a negative impact on developing countries that are net corn exporters and a positive impact on developing countries that are net corn importers.

5. Conclusions

This dissertation addresses the issue of the potential impact of DP on agricultural output by developing and solving a continuous-choice, continuous-state dynamic deterministic optimization model for a representative U.S. corn farming household that operates over an infinite horizon and faces credit rationing –represented hereby through an interest rate that is monotonically increasing on the debt-to-asset ratio.

The dynamic model is parameterized using the USDA's ARMS database and it is solved using numerical approximation techniques, as a way of getting around the nonlinearities involved –which even prevent the computation of a closed-form solution for the steady state. Then, a series of simulations are performed to verify how the representative corn farming household's dynamically optimum production choices change under different levels of DP and different scenarios for the impacts of DP on the household's creditworthiness and the price of land.

The results obtained for the solution of the model bear a satisfactory level of accuracy – the approximation residual for the value function is less than 0.00004. The expected land accumulation path over a 40-year horizon shows that farm size grows at a decreasing rate as time advances, so that the farmer achieves a steady state in farm size around the 36th year.

The simulation for different values of DP shows that this policy instrument leads the representative farming household it to increase the size of its farm temporarily but not permanently. This is, the land holdings in the steady state do not change as DP get bigger, but the farmer achieves a steady state sooner since the farm size grows faster along the optimal path.

In turn, the guaranteed cash flow generated by DP increases the household's creditworthiness, which is simulated in the model through a reduction in the base interest rate on loans. The simulation shows that the increased creditworthiness leads the representative farming household to increase the size of its farm not only along the optimal path –thus reinforcing the initial direct effect of DP–, but also in the long run. In fact, the simulation for a one percentage point reduction in the base interest rate brought about by the emergence of DP, produces a 5 percent increase in the long-run optimal farm size.

However, if all corn farming households want to follow what the representative one does, they will increase the demand for farmland and bid its price up. Such an increase in the price of land brought about by the DP produces not only a contraction of farm size along the optimal path, but also in steady state. In fact, the simulation for a 6 percent increase in the land prices brought about by the emergence of DP, ends up producing an 11 percent contraction in the steady-state farm size.

Under the existence of DP, increased prices of land and increased farmer's creditworthiness have opposite effects on the farm size along the optimal path as well as at the steady state. What the final outcome of the three effects together is will depend on factors such as how far from their optimum farm size US farmers may be, how burdensome credit constraints are, how much room for financial innovation there is and how elastic the supply of land may be. Further empirical research is needed to explore each one of these in detail.

Whatever the magnitude and direction of the final result, the findings of this paper shed some light that can be a valuable input for both domestic agricultural policymaking in developed nations and the multilateral negotiations in the WTO. As it has been pointed out by authors like Young and Westcott (2000), DP represent an improvement in terms of making U.S. agriculture more responsive to market signals. However, this dissertation shows that DP are likely to have a permanent impact on agricultural output (unless the direct effect together with the creditworthiness effect, are perfectly offset by the land prices effect). That does not mean that an optimal policy is the elimination of DP. In fact, if DP (second-best policy to address capital market imperfections) were to be replaced by financial innovation (first-best policy), agricultural output would still expand and the foreseen impacts on international markets would be equivalent to those of DP, given the market power of the U.S.

A couple of final considerations are worth to mention. First, the scenario recreated in the dynamic model developed and solved in this paper corresponds to the one with the smallest number of possible channels for the DP to affect the farming household's production decisions. The role of risk together with the household's preferences –as shown by the work of Hennessy (1998) –, is set aside, while the credit rationing mechanism chosen can be considered as the least binding one. Therefore, the permanent impact on agricultural output that DP are revealed to have by the simulations hereby presented, could be expected to be even larger under more restrictive forms of credit-rationing and/or when the role of risk is considered. Showing an impact of DP on agricultural output in a simpler scenario makes the result stronger.

Secondly, the model showed to be very sensitive, in terms of the stability of the solution, to changes in certain parameter values and to the formulation of the credit-rationing mechanism. The final version of the model, being the one that showed the greater stability of the solution, only allowed to deviate 35 percent around the steady-state values to solve the model and perform the simulations. In light of the effort put to get around this stability issue, this range was considered enough for the purposes of the paper but it does not preclude the chance that more work is done to improve the stability of the model.

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