The Acreage and Borrowing Effects of Direct Payments Under Uncertainty: A Simulation Approach

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Abstract

We use simulation methods in an expected utility maximization framework to analyze a farmer's optimal resource allocation in the presence of government payments, decoupled and not. This framework is extended to incorporate the optimal choice of investment levels in the presence of credit constraints. Further extensions include a wealth-dependent interest rate and decreasing marginal yields. We find decoupled payments affect the optimal choices of the credit-constrained farmer through a collateral-enhancement effect, so they do distort production. The 2005 proposal by Senators Grassley, Dorgan, Hagel, and Johnson to tighten limits on commodity payments is not found to affect payments of the typical Kansas farmer.

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1. Introduction

Meant to signal a transition away from market intervention by the U.S. government, the 1996 Farm Bill replaced the traditional mechanisms of income support awarded on a per unit basis by Production Flexibility Contract (PFC) payments, fixed annual lump-sum installments based on historical production. These payments, meant to decline each year until the expiration of the Act, were expected not to distort production or trade, and so be consistent with the market liberalization commitments agreed to in the Uruguay Round negotiations. But any perceptions that these payments were temporary were dismissed when the 2002 Farm Bill was passed by Congress, replacing PFC payments by Direct Payments (DP) (Goodwin and Mishra 2005). The bill also institutionalized the *ad hoc* Market Loss Assistance (MLA) payments in place in the late 1990s due to the decline in world commodity prices and localized yield shortfalls, making Counter-Cyclical Payments (CCP) available when market prices went below the target levels defined in the legislation. Like PFC and DP, CCP were calculated using historical base acres and yields. Other highlights of the bill included the opportunity to update crop bases and, under some conditions and only for the purposes of CCP, yield bases.

From the many controversial issues involved in the Congressional debate leading up to the 2002 Farm Bill, perhaps none was more contentious than the setting of tighter limits on the level of farm payments (Miller *et al.* 2003). This, however, did not happen, and the limits were continued from the previous bill (the limits per individual farmer were kept at $40,000 for DP, $65,000 for CCP and $75,000 for marketing loans, a total limit of $180,000, increased two-fold to $360,000 through the still in place "three-entity rule").[1] Using a simulation approach similar to

[1] Because there was no limit on the use of generic certificates (allowing unlimited LDP and marketing loan gains), $360,000 was not an effective cap.

Hennessy (1998), Goodwin (2006) evaluated the effects of proposals to strengthen limits on acreage for corn, soybeans, wheat, cotton, and rice in several important producing states under discussion in the Senate. Like in Miller *et al.* (2003), results suggested payment limits were unlikely to affect acreage decisions except for cotton and rice, where the probability that the limits would be binding was greater.[2] Indeed Hennessy's work was paramount in showing how, in the presence of uncertainty, support policies deemed decoupled in a deterministic world affect the decisions of risk-averse producers so that they are not, in effect, decoupled. While Hennessy and Goodwin both assumed a farmer choosing inputs to maximize expected utility of total profits, they did not consider the possibility of the farmer being unable to attain the desired level of inputs due to credit constraints. But studies have shown that farmers facing binding credit constraints will under-invest relative to those who are unconstrained in the credit market (Briggeman *et al.* 2008, Guirkinger and Boucher 2006). As such, further analysis on whether and by how much the presence of government payments distorts production decisions, and should stricter payment limitations matter for those decisions, ought to include the presence of capital market imperfections, or credit constraints. Naturally, the probability that the constraint is binding should decrease with the increasing availability of signaling and/or screening devices.[3]

We revisit the analysis of farmers' optimal resource allocation in the presence of government payments, decoupled and not, and extend it to incorporate the optimal choice of investment levels in the presence of credit constraints. We further extend our theoretical model to allow for decreasing marginal yields and a wealth-dependent interest rate. We then use this

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[2] For these crops, government payments per acre are generally higher than for corn, soybeans or wheat.

[3] These include elements such as a positive credit history, the individual characteristics and skills of the borrower, a sufficiently good performance and satisfactory risk exposure of the credit-funded project. Additionally, the availability of collateral and the interest rate the farmer is willing to accept should also decrease the likelihood that the credit constraint is binding.

framework to perform two analyses. First, we analyze the production effects of a 100 percent increase in DP for a credit constrained farmer. Second, we observe the production effects of more stringent payment limits on FD, CCP and LDP such as those proposed by Senators Grassley, Dorgan, Hagel, and Johnson in February of 2005.

We proceed as follows. In the next section we present the theoretical framework that links the acreage and borrowing decisions to the financial conditions of the farm, namely the amount and type of government payments received. Along with the data, the following section discusses the simulation methods and the econometric techniques used to retrieve some of the variables necessary in the study. The results of the simulation for the general framework are then presented. The policy application is then performed using this extended model. Some concluding remarks are finally offered.

2. Conceptual framework

The model assumes a representative farmer who must make land management decisions while facing unknown future values of prices and yields. For tractability we focus on single crop farms. Given some subjective opinion about the joint distribution of prices and yields, P_t and Y_t, respectively, and her initial endowment of land $\bar{A}_t$ at time *t*, the farmer must choose δ, the ratio of planted acres to operated acres $(0 \leq \delta \leq 1)$ so that $A_t = \delta \bar{A}_t$, and B_t, the amount to borrow, to maximize her expected utility of wealth W_t, including changes brought about by discounted future expected profits. This is described by

$$(1) \qquad V_t = \sum_{t=0}^{T} (1+\beta)^{-t} U[W_t]$$

where the utility function $U[\cdot]$ is assumed to be twice differentiable and quasi-concave and β is the discount rate.

Wealth in period t is comprised by several categories of income, including market and government support-augmented income, along with initial liquidity and other sources of income. It consists of profits derived from production π_t, government payments GP_t, initial liquidity W_0, and exogenous income OW_t. Because both prices and yields are not observed by the farmer when production decisions are made, revenue from production ($P_t Y_t \delta \bar{A}_t$) is a risky variable. Alternatively, input prices and per acre costs (ω_{jt}, the per acre cost of input j and fixed costs FC_t) are known at the time crop acreages are allocated and the other relevant decisions are made. Implied in our profit function is the assumption that technology is linear in acreage and that marginal yields are constant in the neighborhood of the optimal level of acreage such that, all else equal, an additional acre will generate a constant addition to total output. This assumption is relaxed in a later section.

Government payments include Direct Payments (DP_t), Counter-Cyclical Payments (CCP_t) and Loan Deficiency Payments (LDP_t). DP, which do not depend on current market conditions but on historical base, are calculated using the payment rate $DP\text{rate}_\text{t}$, base acreage $bacres$, and base yield $byield$. They are subject to the payment limit $DP\lim$, defined by the 2002 Farm Bill. DP are given by

(2) $$DP_t = \min\left(DP\lim, 0.85 \cdot DP\text{rate}_\text{t} \cdot bacres \cdot byield\right)$$

Contrary to DP, CCP and LDP depend on market conditions, in particular prices, as they are available for covered commodities whenever the effective price is less than the target price. Like DP, CCP depend on historical acres and yields. CCP are given by

(3) $$CCP_t = \min\left(CCP\lim, 0.85 \cdot CCP\text{rate}_\text{t} \cdot bacres \cdot byield\right)$$

where $CCP\text{rate}_t$ is the commodity's payment rate given by

$$(4) \qquad CCP\text{rate}_t = \max\left(0, \left(P_t^T - DP\text{rate}_t\right) - \max\left(\text{LR}_t, \text{P}_t\right)\right)$$

where P_t^T is the target price, LR_t is the national loan rate, and $CCP\lim$ is the payment limit.

Contrary to DP and CCP, LDP depend on current acreage, since they are a loan farmers receive per unit of production. LDP are given by

$$(5) \qquad LDP_t = \min\left(LDP\lim, \max\left(0, \left(LLR_t - P_t\right) \cdot Y_t \cdot \delta \overline{A}_t\right)\right)$$

where LLR_t is the local (county) loan rate, $LDP\lim$ is the payment limit, set by the Farm Bill, and $\delta \overline{A}_t$ is the number of acres put into production. Government payments can thus be rewritten as $GP_t = GP_t\left(\delta \overline{A}_t; P_t, Y_t\right)$, which emphasizes their dependence on market conditions and the farmer's acreage choice, in turn linked to borrowing, as we explain next.

Farmers endowed with relatively little liquidity may ask for a loan to finance production. In this case, the maximum size of the loan depends on the both the borrower and the lender. We assume that in response to asymmetric information all loans are collateralized with the farmer's wealth at the end of the lending period, so that the loan amount is bounded by the relative size of the debt the bank allows the farmer to incur. This implies the upper limit on the loan amount is a certain fraction of the farmer's wealth, γW_t, where $0 \le \gamma \le 1$ is the allowable debt factor, depending on a number of features that typically characterize the financial profile of a potential borrower as viewed by the lending institution.[4] In addition to the limit on potential relative debt, the farmer also faces a credit cost that is increasing in the loan amount. We model this cost as

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[4] These features include the past relationship of the farmer with the lending institution, the level of assets of the farm (that can act as collateral) and/or the level of liabilities, the number of years the farm has been in business, and the characteristics of the proposed investment.

αB_t, where $0 \le \alpha \le 1$ is chosen by the lender to reflect the financial characteristics of the borrower. This cost decreases the farmer's level of wealth. We begin by modeling this cost as independent of wealth but relax this assumption later.

Before we move on to presenting the farmer's optimization problem there are two issues that need to be clarified. These relate to the temporal aspects of the model. First, this is a model of farmers' behavior in a single period. It is not a model of farm dynamics. The model describes the moment in time when the farmer is making the decision of how many acres to plant and how much money to borrow with only an expectation about future prices and yields (and consequently government payments). The second issue that needs to be clarified is the information known by the agents in this model at the moment the loan is negotiated. As mentioned, the farmer has only a subjective opinion about future prices and yields when she goes to bank to borrow to expand acreage. We assume the lender has the same expectation about future prices and yields, *i.e.* market returns, as the farmer and so evaluates the farmer's expected wealth at the end of the lending period to judge her credit worthiness, whether to lend, and how much to lend at the beginning of the period.[5]

With this background, the farmer's optimization problem of choosing δ and B_t given unknown future values of prices and yields is characterized by equations (6) to (10).

(6) $$\max_{\{\delta, B_t\}} U\left(W_t\right)$$

(7) $$W_t = W_o + OW_t + \left(P_t Y_t - \sum_{j=1}^{J} \omega_{jt}\right)\delta \bar{A}_t - FC_t + GP_t\left(\delta \bar{A}_t ; P_t, Y_t\right) - \alpha B_t$$

subject to

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[5] This symmetry may arise for a number of reasons. For example, the farmer may prepare a budget describing the uses of funds and expected market conditions at the time she asks for the loan. Or the bank's experience in granting loans to farmers in the region for similar projects may supply them with similar information as the farmer.

(8) $$W_o + B_t = \left(\sum_{j=1}^{J} \omega_{jt} \right) \delta \bar{A}_t$$

(9) $$\gamma W_t \geq B_t\,,\ 0 \leq \gamma \leq 1$$

(10) $$A_t \leq \delta \bar{A}_t\,,\ 0 \leq \delta \leq 1$$

Equation (7) is a statement of the wealth level of the farmer, which depends on initial liquidity W_o and exogenous income OW_t, unknown market returns minus known costs $\left(P_t Y_t - \sum_{j=1}^{J} \omega_{jt} \right) \delta \bar{A}_t - FC_t$, government payments $GP_t\left(\delta \bar{A}_t\,; P_t, Y_t \right)$ and the cost of credit αB_t.

Equation (8) is the budget constraint, limiting expenditures on inputs to the value of the farmer's liquidity plus borrowing. This constraint can be thought of as a "cash on hands" constraint, limiting production to the farmer's ability to cover variable costs when planting decisions are made.

Equation (9) is the credit constraint, rationing the amount of the loan the farmer can request. The farmer is credit constrained if the amount of the loan she would like to borrow is greater than the fraction of wealth the lender specifies as the maximum debt allowed. We further allow the borrowing amount to be negative. While we specifically calibrate the amount of initial liquidity to avoid the situation when the farmer has more liquidity than she can spend on production, poor market conditions could in principle induce the farmer not to produce and set operated acres to fallow. We address this issue in greater detail in the next section. Finally, equation (10) simply states the farmer cannot allocate more land to production than her initial endowment.

Given this framework, we can now explore the interaction between the farmer's endowments, the credit constraints, and the various types of government payments set by policy.

Recall that government payments vary with current acreage choices solely when prices are low, specifically if they are lower than the loan rates. We begin by solving the budget constraint with respect to borrowing and substituting this into the cost of credit term in the wealth expression. To avoid clutter let $A_t^* = \delta^* \overline{A}_t$, where δ^* is the optimum ratio of planted to total acreage. At the optimum, the level of wealth given planted acreage and borrowing is given by

$$(11) \qquad W_t^*\left(A_t^*\right) = \left(1+\alpha\right)\left[W_o + OW_t - FC_{it}\right] + \left(P_t Y_t - \left(1+\alpha\right)\sum_{j=1}^{J}\omega_{jt}\right)A_t^* + GP_t\left(A_t^*; P_t, Y_t\right)$$

which can be thought of as support- and other sources of income-augmented profit function, depending fundamentally on the variable of choice and the parameters of the model. For a nonnegative level of planted acres, the wealth maximizing condition for an optimum is given by

$$(12) \qquad \frac{\partial W_t^*(\cdot)}{\partial A_t^*} = \left(P_t Y_t - \left(1+\alpha\right)\sum_{j=1}^{J}\omega_{jt}\right) + \frac{\partial GP_t^*(\cdot)}{\partial A_t^*} = 0 \quad \Leftrightarrow P_t Y_t + \frac{\partial GP_t^*(\cdot)}{\partial A_t^*} = \left(1+\alpha\right)\sum_{j=1}^{J}\omega_{jt}$$

which implies acres will be put into production if expected market returns and government payments cover the borrowing-cost-augmented variable production costs. We now describe the three thresholds of interest that may arise. This description will help clarify the role government payments may play in affecting the farmer's choices.

The first threshold occurs when expected market returns and government payments are insufficient to cover the borrowing cost augmented variable production costs. This scenario is associated with expected very bad yields, very low prices, or both. In this case the farmer will choose to set all her land aside and not produce. No borrowing will take place. On the contrary, the farmer should save. The second threshold involves positive market returns greater than variable costs but smaller than the borrowing cost augmented variable production costs. In this scenario, the farmer will choose to put all her acreage she can afford based on initial income into production, but again not to borrow. However, if prices are low enough that LDP should be in place, these payments may be used to cover borrowing costs and some positive amount of borrowing may take place. In the first and second cases, the borrowing constraint is unlikely to be binding. Finally, the last threshold involves a situation when market returns are sufficiently high to cover production and borrowing costs. The farmer will put all her acres into production and borrow so as to finance expanding acreage, the limit to this expansion being the borrowing cost and credit constraint. In this setting, it is unlikely that coupled government payments have acreage effects, because a situation of high market returns will probably be associated with high prices. However, even if the only government transfers the farmer is receiving are DP, with are independent of current acreage, the increase in wealth increases the credit limit, thereby making the credit constraint to be less limitative. We now turn to the application of this model and observe the impact of different levels of liquidity and credit limits upon the farmer's acreage and borrowing decisions in the presence of credit constraints.

3. Modeling issues

We model a sole-operator producing winter wheat in Kansas. Following Goodwin (2006) and Hennessy (1998) we use a utility function that is flexible enough to accommodate different degrees of risk aversion. This utility function, first suggested by Pratt (1964), and a modification of the negative exponential form, has the desirable property that risk aversion recedes toward zero as wealth becomes very large. The utility function is given by

(13) $$U\left[W_t\right] = -e^{-\lambda W_t} + \beta W_t$$

where $\{\beta, \lambda\}$, $\beta > 0$ are the parameters characterizing this function. An advantage of this utility function is its ability to accommodate different risk preferences, such as Constant Absolute Risk Aversion (CARA) or DARA preferences; for example, if preferences are assumed to be CARA,

$\beta = 0$. This allows us to experiment with different degrees of risk aversion in our calculation of optimal acreage and borrowing choices. Following Goodwin (2006) we set $\lambda = 1\times10^{-4}$ and $\beta = 9\times10^{-5}$. The coefficient of absolute risk aversion associated with this utility function is given by

$$(14)\qquad \rho\left(\mathrm{W_t}\right) = \frac{\lambda^2 \mathrm{e}^{-\lambda\pi}}{\lambda \mathrm{e}^{-\lambda\pi} + \beta}$$

The farmer is making acreage and borrowing decisions while facing unknown future values of prices and yields. For a given number of random draws N, and letting *i* refer to the ith realization of prices and yields, the expected utility function is given by

$$(15)\qquad E\left[U\left[W_t\left(\delta\overline{A}_t, B_t; P_{it}, Y_{it}\right)\right]\right] = \frac{1}{N}\sum_{i=1}^{N} U\left[-e^{-\lambda W_t\left(\delta\overline{A}_t, B_t; P_{it}, Y_{it}\right)} + \beta W_t\left(\delta\overline{A}_t, B_t; P_{it}, Y_{it}\right)\right]$$

which highlights the dependence of expected utility on the parameters underlying the joint distribution of prices and yields. We simulate a large number (10,000) of correlated, random, log-normally distributed prices and Beta-distributed yields and define the objective and constraint functions in terms of these simulated values. We choose the ratio of planted to operated acres δ and borrowing B_t that maximize this function for the simulated correlated price-yield pairs.

Aside from conducting the experiment for different levels of payment limits, we alter some parameters of the model to allow us to observe the sensitivity of the solution to the degree to which the farmer is credit constrained. In particular, we experiment with different levels of initial liquidity and allowable debt. These variables are inextricably linked to the financial condition of the farmer, and so to her access to credit. We also carry out our experiment for six different scenarios for costs, prices, yields and preferences. The first scenario is the baseline. The second scenario depicts a low cost situation, when production costs and rents are 60 percent of those in the baseline. In the third scenario, in addition to the low cost environment, prices are 60 percent lower than in the baseline. This scenario should imply greater CCP than the previous. The fourth scenario maintains the low cost environment but prices are 140 percent higher than those in the baseline. In the fifth scenario the environment is one of low costs, rents, and prices, but yields are above average by 140 percent; this scenario should result in the greatest governmental transfers. The sixth scenario is one of low costs, rents and prices, but preferences are assumed to be CARA (so $\beta = 0$). All else constant, these varying circumstances let us observe three things. First, allowing for different cost and risk preferences scenarios allows us to potentially characterize farmers with different cost structures and/or different behaviors towards risk. Second, we are able to observe how the degree to which a farmer is credit constrained affects her optimal choices of acreage and borrowing under different market conditions. Finally, we are able to observe how the optimal values interact with market conditions and ultimately result in different levels of government payments.

There is a long-standing belief in the literature that crop yields are skewed, and possibly bimodal. Skewness in yields is expected due to adverse weather conditions and because of the biological constraints that naturally limit the maximum yields attainable during any given year. At the individual farm level, skewness may also depend on chemical applications, soils, and the investment in harvest equipment, all of which reduce the risk of extremely low yields. Because it can exhibit both negative and positive skewness, the Beta distribution is often used in the literature, and it is the distribution chosen to model yields in this study. The Beta probability density distribution is given by equation (16), where yields were scaled to lie in the unit interval by defining the maximum possible yield as 150 percent of the average yield

(16) $$f\left(y;\alpha,\beta\right)=\frac{y^{(\alpha-1)}\left(1-y\right)^{(\beta-1)}}{B\left(\alpha,\beta\right)}$$

where $\{\alpha,\beta\}$ are the parameters of the distribution and $B\left(\alpha,\beta\right)$ is the Beta function appearing as a normalization constant to guarantee the total probability integrates to unity. We discuss this matter further in the next section, where the data are presented.

While the exact magnitude of price-yield correlation varies depending on the level of analysis, prices of agricultural products tend to be high when yields are low, and vice-versa. For a particular farm, yields and prices need not be related because the output of that farm should not affect prices in a noticeable manner. For a region or a state, however, since yields of individual farms tend to be positively correlated, they also tend to be correlated with prices. Like Goodwin (2006) we assume that correlation to be -0.2 at the state level and use this to convert random draws from a multivariate normal distribution with a known degree of correlation to Beta and log-normal random draws with known correlation. Prices are assumed to follow a log-normal distribution. We now discuss the data used to model our simulation to reflect the acreage and borrowing decisions of a wheat grower in Kansas in 2004.

4. Data

The data come from a variety of sources, as information is required on prices, yields, production costs, government policy parameters, and other relevant factors. Because we are trying to model a Kansas farmer, we use farm-level records from the Kansas Farm Management Association (KFMA). The KFMA farms are full-time commercial operations, which are mainly farms with gross sales exceeding $100,000. Of the 61,593 farms counted in the 1997 Agricultural Census, 13,436 farms had gross sales exceeding that number (21.81 percent). The KFMA farms represent, according to Albright (2001), the various farming areas and farm types in Kansas. The model refers to 2004, the second year of the 2002 Farm Bill. We start by discussing the variables that are taken from these data and then move on to describing the other data sources along with the assumptions we use.

Some summary statistics describing the KFMA data appear in Table 1. There were 577 farms in our sample. These farms produced wheat during 2004 and also during the years 1998-2001, the reference period for base updates allowed by the 2002 Farm Bill. All nominal variables were converted to real terms by dividing by the Production Price Index for All Commodities published by Bureau of Labor Statistics, (2004=100).

Table 1. Key variables for selected KFMA farms, 2004

Variables	Average	St. Dev	Median
Total acres operated	1,872.11	1,335.58	1,520.00
Owned operated acres	592.66	757.54	325.00
Total cropacres	1,430.13	1,079.94	1,165.00
Owned cropacres	435.27	590.43	239.00
Total wheat acres	532.73	456.71	415.00
Owned wheat acres	150.93	235.35	72.00
Yield (bu/acre)	40.02	14.80	42.92
Wheat base acres	408.20	309.93	348.67
Wheat base yield (bu/acre)	34.34	7.11	34.79
Average 98-01 wheat acres	515.60	411.65	427.98
Average 98-01 wheat yield (bu/acre)	44.01	8.32	44.10
Lagged Net Worth ($1,000)	0.00	0.00	0.00
Debt to asset ratio	0.1781	0.1944	0.1335
Number of farms		577	

As expected, acres variables of the median farm are lower than those of the average farm; in order to avoid the upward distortions brought about by the fact that there are a few very large farms in the data, we use the median farm as our reference. Total operated acres, the maximum number of acres the farmer can operate is then set at 1,520 acres. This variable, along with all the other variables used to calibrate the model, is described in Table 2. About one quarter of total operated acres is devoted to growing crops. For the average farmer, wheat accounts for nearly 40 percent of total planted acres.

Table 2. Parameters for simulation

Variable	Value
Utility function parameters	
Lambda (Utility function)	1.00E-04
Beta (Utility function)	9.00E-05
Yield distribution parameters	
Alpha	13.84
Beta	6.92
Maximum yield (bu)	60
Price volatilities	0.21
Farm wealth, costs and allowable debt	
Initial (and maximum) total operated acres	1,520
Initial exogenous income	
Scenario 1: low liquidity ($)	24,439.88
Scenario 2: average liquidity ($)	48,879.76
Scenario 3: high liquidity ($)	73,319.64
Other sources of income	200,000.00
Debt factor	
Scenario 1: low allowable debt	0.13
Scenario 2: high allowable debt	0.25
Cost of credit	0.05
Variable costs ($ per acre)	41.91
Rents ($ per acre)	59.8
Fixed costs ($ per acre)	102.76
Policy variables	
DP limit ($)	40,000
CCP limit ($)	60,000
LDP limit ($)	150,000
Base acres – KFMA	428
Base yield – KFMA	44
FDP rate	0.52
Harvest national price ($)	3.19
Harvest state price ($)	3.00
Target price ($)	3.92
National loan rate (for CCP)	2.75
Local (county) loan rate (for LDP)	2.89

Because the 2002 Farm Bill allowed for base acres to be updated, and for those farmers who did so by adjusting them to reflect the 1998-2001 period, yield base for the purposes of calculating CCP could also be updated, we calculated the average wheat acres and yields for that reference period. For both the average and the median farmer, we found the 1998-2001 average acres and yields were greater than the 1996 Farm Bill acre and yield bases. And while average yields for the KFMA farms seem to have increased by almost 27 percent over the period, they are only slightly above the 43.25 bu/acre average for the state. Because the updated bases would imply greater CCP, we assume the farmer in our model chose to update her bases to the 1998-2001 values. Since the Farm Bill only allowed the base yield update to be used in the calculation of CCP, and even so only 93.5 percent of the 1998-2001 average yields could be used, we revise the CCP equation as

$$(4.17) \quad CCP_t = \min\left(CCP\lim, 0.85 \cdot CCP\text{rate}_\text{t} \cdot bacres_{98-01} \cdot 0.935.byield_{98-01}\right)$$

where $bacres_{98-01}$ and $byield_{98-01}$ are the 1998-2001 acres and yields averages, respectively.

There is an assortment of statistical approaches to represent yield distributions; these can be divided into two broad categories, depending upon whether they draw on a parametric distribution or whether they draw on nonparametric techniques. Most studies that recover the distribution of agricultural yields employ parametric methods, differing mainly in their choice of parent distribution. Each distribution has its merits, and as Ozaki *et al.* (2006) pointed out, "the characteristics of crop yields may be idiosyncratic and may vary by location, crop, and production practice. Thus, it is unlikely that any single parametric approach will be universally supported across different applications." (p. 5). Because of its ability to deal with skewness, we use the Beta distribution to estimate the parameters underlying the yield distribution.

State-level yield data for Kansas from 1970 to 2004 were used to model our yield distribution; these data are readily available online from USDA. As in Goodwin (2006), the data were detrended by assuming that yields over the period are dominated by a linear trend and that deviations from the trend should be proportional to the trend. We regressed yields on time to obtain predicted yields $\hat{y}_t$ and deviations from the trend $\hat{e}_t / \hat{y}_t$. Yields were then re-centered on the predicted yield for 2004 using $\tilde{y}_t = (1 + \hat{e}_t / \hat{y}_t)\hat{y}_{2004}$. This specification is common to some crop insurance products such as the Group Risk Plan. Estimation using Maximum likelihood found $\alpha = 13.84$ and $\beta = 6.92$, and a goodness of fit Chi-squared test had a p-value of 0.8726, so the appropriateness of the distribution was not rejected by the data. Because state-level data were used to estimate these parameters, and farm-level yields are expected to be show greater variability than more aggregated data, we added a normally-distributed random shock to each replicated state-average yield; these shocks have zero mean and variance equal to 75 percent of the standard deviation of the detrended state average yield series.

Price volatilities are average historical values taken from unpublished data reported by the Chicago Board of Trade and the New York Commodity Exchange. These volatilities are taken from Goodwin (2006) as are rents, variable costs and fixed costs, which came from the State Extension Services from Kansas, and state and national average prices. We defer to the original paper for an overview of the methods employed to recover these values. Because fixed costs are on a per acre basis, we multiplied the total endowment of land by this cost to generate the final value used in the application.

We model three different cases for the initial liquidity of the farmer. These cases represent 25 percent, 50 percent, and 75 percent of the amount necessary to put the farmer's land endowment into production in the low cost scenarios ($92,759.52).[6] To see why we impose the low cost scenario, consider the following. When deciding how many acres to produce and how much money to borrow, the farmer is matching sources and uses of funds so that the equality of the budget constraint always holds. In terms of the optimum use of her endowment of land three situations may arise. First, the farmer may have enough liquidity put all her land into production. This is the case if her liquidity is equal to at least the endowment of land times variable costs. In

[6] Total variable costs per acre (rents plus variable costs) are $41.91+59.8=$101.71 in the baseline scenario, and $61.026 in the low cost scenarios. Putting all operated acres into production would then cost $154,599.2 in the baseline scenario or $92,759.52 in the low cost scenario.

this situation, the farmer does not borrow. She does not need to if she decides to put all her land into production (whether she does depends on expected prices and yields). Second, the farmer may have some amount of initial liquidity, but not enough to cover putting all her land into production. If this is the case, and depending on the expectation about futures prices and yields, she may choose to put as much land to production as she can by using a combination of her own funds and borrowing or simply by using her own funds. Finally, if the farmer's liquidity is greater than the cost of putting all her land into production, she cannot apply that extra liquidity into production and must save. Since our goal is to model a credit constrained farmer, the first and third possibilities are not interesting and we give the farmer less liquidity than that required to put all her land into production. Given the upper bound defined above we define the low liquidity level as $W_{0,1}$=\$23.189,88, the average liquidity level as $W_{0,2}$=\$46,379.76, and the high liquidity level as $W_{0,3}$=\$69,569.64.

The allowable debt factor represents the proportion of wealth the farmer is allowed to borrow. KFMA debt to asset ratios serve as reference values for this parameter. The average debt to asset ratio (about 17 percent) is above that of the median farm (about 13 percent) and the farmer on the 25 percentile has a debt to asset ratio of about 5 percent, while that on the 75 percentile has a debt to asset ratio of about 25 percent. We observe how the optimal solution changes as we first set the percentage debt factor to that of the median farm, so that $\gamma_1=0.13$, and then set the factor to that of the farmer on the 75 percentile, so that $\gamma_2=0.25$.

Like initial liquidity, the choice of the amount of the other farm income variable requires some attention to the condition that the farmer is credit constrained. If, for example, we set this value to that of the lagged net farm income of the median farmer (\$1,089.68 thousand), excluding other sources of income such as government payments, and considering the lowest allowable debt factor of 0.13, the farmer can borrow up to $141.64 thousand. This means that, at the lowest level of liquidity ($23.19 thousand), the credit constraint is not binding and the farmer can afford to plant all her acres by borrowing. This led us to set the variable at $200 thousand. Since the credit constraint is not binding for the higher liquidity case, this allows us to observe the different optimal choices under the credit constrained and unconstrained cases. Finally, the policy variables such as the DP rate, payment limits, target price and the national loan rate came from the 2002 Farm Bill.

5. Simulation results

This section presents the results from the simulation, which we perform for different values of liquidity and allowable debt. Furthermore, each of our experiments is performed for six different scenarios. In each scenario we take 10,000 random draws of correlated prices and yields. The first scenario is the baseline, and the second to fifth scenarios vary in their treatment of costs, prices, and yields; as in Goodwin (2006), our baseline scenario uses the costs taken from the state crop budgets and assumes the 2004 state harvest-time price as a mean value for expected prices. The sixth scenario differs from the previous in its assumption about risk preferences. Table 3 summarizes the parameterization of the different scenarios.

Table 3. Simulation scenarios

Scenarios	Description	Costs	Prices	Yield	Preferences
1	Baseline scenario	Baseline	Baseline	Baseline	DARA
2	Low costs	60 % of baseline	Baseline	Baseline	DARA
3	Low costs and prices	60 % of baseline	60% of baseline	Baseline	DARA
4	Low costs, high prices	60 % of baseline	140% of baseline	Baseline	DARA
5	Low costs and prices, high yields	60 % of baseline	60 % of baseline	140% of baseline	DARA
6	Low costs and prices, and CARA preferences	60 % of baseline	60 % of baseline	Baseline	CARA

Note: Baseline values for prices and yields are those generated by the correlated log-normal and Beta distributions. Parameters for these distributions and baseline values for costs are described in Table 2.

We expect increasing levels of liquidity to increase the number of acres planted. The effect of liquidity on borrowing depends on the degree to which the farmer is constrained by credit. To understand why note that, all else constant, higher levels of liquidity imply a lesser need for borrowing in order to finance current production. So, for the farmer who is not credit constrained, higher levels of liquidity unequivocally lead to less borrowing. However, for the farmer who *is* credit constrained, higher levels of liquidity also imply greater wealth, which in turn enhances the farmer's ability to borrow. In this case, higher levels of liquidity should lead to more borrowing. Because we can follow the farmer's decisions for different levels of allowable debt for a given level of liquidity, and for different levels of liquidity for a given level of allowable debt, we can observe the production effects of lessening the degree to which the farmer is constrained by credit and those of increasing her liquidity. Finally, greater wealth could further induce positive production effects via its effect on risk aversion. This was shown by Sandmo (1971), who suggested that under DARA preferences, increases in wealth should make producers more willing to take on risk and increase production.

The second scenario assumes all production costs and rents are 60 percent of the levels reported in the crop budget. These lower costs could represent, for example, farms that are more efficient or that have lower rents. We expect optimal acreage and borrowing to be higher than in the baseline. In addition to low production costs, the third scenario assumes market prices are 60 percent of those in the previous scenarios. This reduction in marginal returns for a given level of yields causes the acreage and borrowing decisions to be especially sensitive to government payments, namely the coupled type. Indeed, we expect CCP and LDP to be high in this scenario, as both types of payments are triggered by prices falling beneath the target level. The fourth scenario has low costs and high prices. Specifically, we assume prices are 140 percent of their levels in the baseline scenario. While we expect production to expand relative to the previous scenarios, this level of prices should lead to much smaller LDP and CCP payments than in all previous scenarios, especially the third. The fifth scenario still uses low costs and prices, but yields are assumed to be 140 percent of the baseline. As in the previous scenario, higher returns should expand production. Additionally, the combination of low prices and high yields should bring about the greatest value in government payments, as LDP depend both on current prices and yields. Finally, the sixth scenario, while similar to the third scenario in terms of low costs and prices, assumes that utility is CARA ($\beta = 0$). From equation (14) this implies $\rho(W_t) = \lambda = 10^{-4}$. How the optimal acreage and borrowing decisions compare to those in scenario 3 under our assumption of DARA depends greatly on the value taken by the absolute risk aversion coefficient, which in turn depends on the level of wealth. Following Sandmo (1971) we expect a greater level of absolute risk aversion to lead to a lower level of production.

5.A. Acreage and borrowing decisions in the presence of credit constraints

Tables A.1 through A.6 (in the Appendix) report the simulation results. In each table, along with the optimal acreage and borrowing decisions, we report the average and standard deviation of final wealth, payment receipts (DP, CCP and LDP), yields, and prices.[7]

Table A.1 reports the results for the baseline scenario. The interaction of costs, expected prices and yields, and DARA preferences keeps optimal acreage under the farmer's endowment for all levels of liquidity. Beginning with the lowest level of liquidity and allowable debt, the farmer puts only 299 acres to production, borrowing \$7,224. DP receipts are \$9,793, well below their limit of \$40,000; because they depend on historical acres and yields, these payments are the

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[7] For each scenario and under each level of liquidity and allowable debt, we also calculated the average risk aversion coefficient and the number of DP, CCP, and LDP limit hits (the number of replications the limit on the specific payment was reached). These results are not shown but are available upon request.

same across all scenarios and liquidity and allowable debt levels. CCP receipts are slightly higher, $10,597; except when price conditions vary (scenarios 3 and 4), these payments remain unchanged across all scenarios, and across liquidity levels within scenarios. The farmer receives $2,497 in LDP; as acres change across the scenarios, and across levels of liquidity or allowable debt within scenarios, the relative change in these payments equals that of acres. When liquidity doubles to $46,380, both borrowing and acres increase, by 11.97 percent and by 79.09 percent, respectively. The increase in payments allowed by the additional liquidity and borrowing, combined with the additional liquidity, increase wealth by about $29,269, or 30.09 percent. The direction of the effects is very similar to when liquidity further increases to its highest level, but the magnitude is smaller. This is a credit constrained farmer. When allowed to borrow a greater percentage of her wealth, borrowing and acres both increase. Relative to the low allowable debt case, borrowing increases by 77.97 percent across all liquidity levels and acres increase by between 8.89 and 18.52 percent in the high and low liquidity cases, respectively; the increased ability to borrow increases farmer's wealth by about 1 percent. Overall our results allow us to observe the following. First, increases in liquidity increase both borrowing and acres. And as liquidity increases, the magnitude of the relative changes in borrowing and acres decreases. Second, allowing the farmer to borrow a greater portion of her wealth allows her to expand production. Both of these changes bring about additional LDP receipts, further increasing wealth. Finally, the observed increases in production are consistent with those expected under DARA preferences.

Table A.2 reports the results for the low cost scenario (scenario 2). Low costs, set at 60 percent of those in the baseline scenario, boost the farmer's overall liquidity, allowing her to plant and borrow more than before. For the lowest level of allowable debt, acres increase by between 87.05 percent and 112.58 percent and borrowing increases by between 115.96 and 107.26 percent, for the lowest and highest levels of liquidity, respectively. Both these ranges increase for the higher level of allowable debt. In the high liquidity case, allowing the farmer to borrow a greater percentage of her wealth finally allows her to put all her acres into production. She actually borrows a lesser amount than in the average liquidity case, suggesting she is no longer credit constrained. As expected, wealth is generally greater under this scenario.

Table A.3 reports the results for the low cost and low price scenario (scenario 3), where both prices and costs are set at 60 percent of the baseline. Price per bushel is now at around $1.80. Compared to the low cost scenario (scenario 2), both acres and borrowing increase despite the price decrease. This positive production effect is explained by the increase in the coupled elements of support CCP and LDP, triggered by prices falling below the target level. Additionally, across all levels of liquidity and allowable debt, CCP increase by 64.05 percent, and because they depend on current production, LDP increase between 431 percent and 443 percent, for the high and low levels of liquidity, respectively. This range, which corresponds to the high level of allowable debt case, is slightly higher than that of the low level allowable debt case. Under these poor price conditions, LDP limits are reached, and the number of times this happens increases with the farmer's liquidity and ability to borrow. When the farmer is allowed to borrow up to 13 percent of her wealth, the limit is reached in 1 percent of the replications in the high level of liquidity case, but when she is allowed to borrow up to 25 percent of her wealth, LDP limits are reached in the average and high levels of liquidity. Indeed, when the farmer is endowed with the highest level of liquidity, the number of times the limit is reached more than doubles relative to that in the low allowable debt case. Finally, despite the government outlays, wealth is slightly lower than in scenario 2.

Table A.4 reports the results for the low cost and high prices scenario (scenario 4), where prices are set at 140 percent of the baseline, about $4.2/bu. This scenario should bring about the smallest amount of coupled support. In fact, when compared to the low cost scenario (scenario 2), and across both levels of allowable debt, CCP decrease by 78.84 percent in the low and high levels of liquidity cases and by 33.60 percent in the average level of liquidity case; LDP decrease by about 94 and 76 percent for those levels of liquidity, respectively. Despite the decrease in the coupled amount of support, the increase in revenue is enough to increase wealth, though this increase is very small in magnitude, about 1 percent. Interestingly, the 140% percent increase in prices boosts planted acres in the average and high liquidity cases relative to the low price scenario (scenario 3), but not in the low liquidity case, where planted acres decrease by about 3 acres in the low allowable debt case, and remain unchanged in the higher allowable debt case.

Table A.5 reports the results for the low cost and prices, and high yields scenario (scenario 5). Prices are back to the level defined in the third scenario, where expected coupled government outlays were at their maximum. Because CCP depend on historical bases, given that expected prices are the same across these scenarios, so is their value. On the contrary, LDP are determined by current production, so that the combination of better yields and low prices results in a much higher level of payments. These increase as higher liquidity and higher allowable debt permit the farmer to put more land into production. The payment limit on LDP is reached the greatest number of replications under these cost, price, and yield conditions. For the highest level of liquidity, the limit on LDP is reached about 8 to 9 percent of the replications. This number is slightly lower for the average liquidity case, varying between 0.22 percent and 3 percent of the replications, for the lower and higher levels of allowable debt, respectively. Stricter payment limitations should have their greatest impact in this scenario.

Finally, and again maintaining the assumption of low costs and prices as in scenario 3, Table A.6 reports the results where preferences are assumed to be CARA. The higher absolute risk aversion coefficient suggests the farmer will be less inclined to put acres into production. Indeed she uses some of her initial liquidity to save. Furthermore, while acres increase as liquidity increases, they do not respond to changes in allowable debt. This is consistent with the farmer's inclination towards saving. Relative to scenario 3, in the low allowable debt case, acres decrease by between 42.12 percent and 49.84 percent, for the average and high levels of liquidity, respectively, and in the high allowable debt case by between 52.00 percent and 58.58 percent, for the high and low levels of liquidity, respectively. Combined with the lower LDP proceeds, the lower profits from production explain the decrease in wealth across the scenarios.

5.B. Extensions

This section extends our general framework. To relax the assumption that all acres are equal, we incorporate decreasing marginal yields into our model. We also allow for the level of wealth to affect the cost of credit. Intuitively, richer borrowers should be better able to overcome the signaling difficulties that arise in imperfect credit markets and obtain credit at better conditions. We begin by discussing the impact of changing our assumption regarding technology and then move on to discussing that of having a wealth-dependent interest rate.

5.B.1. Decreasing marginal productivity of acres

So far, our framework assumes all acres are equal in the sense that yields are stable across space. This assumption is unrealistic, as heterogeneity of various factors within the field should cause yields to vary. For example, differing soil moisture content or irregular fertilizer application should cause yields to differ across individual fields within a farm. We now assume that acres differ in their productivity. Furthermore, we assume that the farmer knows the productivity of her field and opts to put the most productive acres into production first.

The assumption of decreasing marginal yields enters our model by multiplying the Beta-distributed randomly drawn yield $yield_t$ by a correction factor. This correction factor acts as a "penalty" function, such that the new, acres-dependent yield $yield_t^P$ is given by

(18) $$yield_t^P = yield_t\left(\tau_0 - \tau_1 A_t^2\right)$$

where $A_t = \delta \overline{A}_t$ are the previously defined number of acres produced, and $\tau_0 > 0$ and $0 \leq \tau_1 \leq 1$ are parameters. This function implies that as more acres are added to production, yields decrease at a decreasing rate; note that if $\tau_0 = 1$ and $\tau_1 = 0$ we are back to the general framework.

We calibrate parameters τ_0 and τ_1 to reflect some of the characteristics of our data. In particular, they satisfy the following two conditions. First, at the value of acres the farmer is endowed with, the acres-dependent value of yield is 80 percent of the Beta-distributed randomly drawn yield. Second, at the average number of acres planted by the KFMA farms that grew wheat in the 1998-2001 years, there is no "penalty", and $yield_t^P = yield_t$, or $\tau_0 - \tau_1 A_t^2 = 1$. This generates a system of two equations in two unknowns with a single solution at $\tau_1 = 7.70\text{E}-08$ and $\tau_0 = 1.0219$. Relative to the general framework, representing yields in this manner gives the farmer an incentive to add acres until the KFMA average is reached, while penalizing her if that threshold is passed. Because in all but the low liquidity, low allowable debt case in the baseline scenario, optimal acres are greater than the KFMA average, we expect planted acres to be above those of the general framework in the low liquidity level in the baseline scenario, and below those of the general framework in the average and high levels of liquidity in the baseline scenario and for all liquidity levels in the other scenarios.

The effects of acknowledging that not all acres are equal are as expected.[8] For the case when in the general framework acres are below the KFMA average, in the low liquidity level case in the baseline scenario, acres, borrowing, and wealth expand. For both levels of allowable debt, these variables increase by about 0.06 percent, 0.24 percent, and 0.61 percent, respectively. For the average and high liquidity levels, since acres in the general framework are above the KFMA average, assuming decreasing marginal yields lowers acres, borrowing, and wealth in all but the sixth scenario, where the optimal decisions of the farmer do not change with the new assumption about technology. For the other scenarios, the greatest decrease occurs in the high allowable debt and liquidity case, where in the general framework the farmer was putting all acres into production. In the high allowable debt case, under low cost and price conditions, acres decrease by 6.32 percent, borrowing decreases by 25.29 percent, and wealth decreases by 9.51 percent. Finally, the number of times the limit on LDP is reached is also responsive to the change. For example in scenario 3, for this level of debt, the number of times the limit on LDP is reached decreases by 100 percent in the average liquidity scenario and by 95.65 percent in the high liquidity case. The decrease in scenario 5 is slightly smaller, of 80.51 percent and 76.67 percent for those levels of liquidity, respectively.

5.B.2. Wealth-dependent cost of credit

In general, market interest rates are assumed to reflect four elements: (1) a return to productive capital; (2) an adjustment in order to reflect a positive rate of time preference; (3) a premium for expected inflation, and (4) a risk premium (Goodwin and Mishra 2000). It is the last element, the risk premium, which would explain why at a point in time and for identical size and term loans, different borrowers face different interest rates. Different borrowers with different financial

[8] Results available upon request.

profiles are expected to exhibit different degrees of creditworthiness and, consequently, represent different probabilities of default. Intuitively, individuals with greater levels of wealth or lower liabilities should have better credit profiles. This, in turn, could lead to lower interest rates.

Recall from equation (7) that wealth is a function of initial and other sources of income, profits from production minus fixed costs, government payments, and the cost of credit, which we assumed to be independent of the level of wealth. However we can think of this cost as being composed by two elements, a fixed element α_0 and a wealth-dependent element $\psi\left(Wealth_t\right)$, $\psi' < 0$, so that the full cost of credit CC_t is given by

$$(19) \qquad CC_t = \left(\alpha_0 + \psi\left(Wealth_t\right)\right)B_t$$

where B_t is the borrowing amount defined earlier. For simplicity, assume $\psi\left(Wealth_t\right)$ is linear in wealth, so that $\psi\left(Wealth_t\right) = \theta Wealth_t$, $\theta < 0$. Now wealth is given by

$$(20) \qquad W_t = \frac{1}{1+\theta B_t}\left[W_o + OW_t + \left(P_t Y_t - \sum_{j=1}^{J}\omega_{jt}\right)\delta\overline{A}_t - FC_t + GP_t\left(\delta\overline{A}_t; P_t, Y_t\right) - \alpha_0 B_t\right]$$

which is necessarily greater than the level of wealth given by equation (7) because $\theta < 0$. We further require $1+\theta B \neq 0$.

Using ARMS data for 1997, Goodwin and Mishra (2000) found that farms with higher levels of wealth appeared to have lower farm interest rates. These rates were also decreasing in the term of the loan, the degree of diversification of the farm, the experience of the operator, and the fact that the operator lived on the operation. On the contrary, higher levels of liabilities increased interest rates. Because of our inability to actually observe the interest rates paid by the farmers using the KFMA data, we turned to the values found by Goodwin and Mishra to calibrate our wealth-dependent cost of credit element, and assumed that a $100,000 increase in wealth would lead to a decrease in the interest rate of 0.0865 percentage points.[9] Relative to the general framework, we expect acres to exhibit an increased sensitivity to changes in liquidity, as liquidity simultaneously finances production and adds to the wealth and collateral of the farmer. The effects on borrowing are not so clear. On the one hand, greater wealth implies a lower wealth-dependent cost of credit. On the other hand, the cost of credit is higher than before, which can deter the farmer from borrowing as much as in the general framework.

Assuming a wealth-dependent interest rate has the expected results. The extra interest rate cost decreases acres, borrowing, LDP receipts, and wealth across both levels of allowable debt, across the different levels of liquidity, and across all scenarios except for the sixth. But the change is very small in magnitude. In the low allowable debt case, the biggest decrease in acres occurs in the fifth scenario for the low liquidity level, where acres decrease by 0.0061 percent. In the high allowable debt case, this decrease, also the greatest, is of 0.0149 percent. But the new credit cost assumption has no effect upon the farmer's optimal decisions in the high liquidity and allowable debt case, when the farmer can put all her acres into production, though wealth decreases by about 0.02 percent. Finally, as liquidity increases from one level to the next, the relative increase in acres is greater under the wealth-dependent interest rate framework. But this general wealth effect is, as the other changes, very small and almost negligible in magnitude.

6. Policy applications

As in Hennessy (1998) and Goodwin (2006), we use our extended framework to perform two policy applications. We first evaluate the impact of a 100 percent increase in DP on the decisions for how many acres to plant, how much to borrow, wealth, LDP payments, and the number of

[9] In what the denominator in equation (20) is concerned, it will be positive for any amount of borrowing below $115,606,936.42, well above the value allowed in our simulation.

times the limit on LDP payments was reached. We then move on to observe the impact of stricter payment limitations on these optimal choices.

6.A. Effects of doubling Direct Payments

In spite of their designation, there are several potential mechanisms through which decoupled payments may have production effects, namely credit constraints. We have hypothesized that these effects could happen in two ways. First, they could be used to finance additional production investment. Second, they could improve the collateral of a liquidity constrained in need of borrowing to finance current production. Our framework describes the latter. The manner in which the farmer's problem was modeled incorporates DP as enhancing the farmer's wealth (see equation (7)), thereby increasing her ability to borrow (see equation (9)), but not her current liquidity (given by equation (8)). The addition of DP exclusively in equation (7) implies that any change in this term alters only the collateral of the farmer. We now examine the acreage and borrowing effects of a 100 percent increase in DP while holding everything else constant. We are not interested in the event that caused this change. However, we assume it was not caused by a change in base acres or base yields, since this would alter the amount of CCP received. Since our goal is to observe the production effect of this change, *ceteris paribus*, we just assume that DP doubled.

Table A.7 and Table A.8 (in the Appendix) report the simulation results from doubling DP, from the initial value $9,792.64 to twice that, $19,585.28. The tables differ in the levels of allowable debt. We again report results for optimal acres and borrowing, wealth, LDP receipts, and in addition report the number of times the limit on these payments was reached. In each table, columns (1) and (2) refer to the low liquidity case, columns (3) and (4) refer to the average liquidity case, and columns (5) and (6) refer to the high liquidity case. And for each level of liquidity, the first column reports the results from the original level of DP, and the second column reports the results from the doubled DP. There was no change to the number of times the CCP limit was reached and the new value assumed for DP still falls below the $40,000 limit for these payments.

Under DARA preferences, for the combination of liquidity and allowable debt levels that cause the farmer to be credit constrained, our results reveal that decoupled payments do have production effects. In the low allowable debt case, acres increase by between 3.0 percent to 3.8 percent in the low liquidity case, by between 1.8 percent and 2.1 percent in the average liquidity case, and by between 1.3 percent and 1.5 percent in the high liquidity case. In all these cases, the baseline scenario always shows the greatest change; this is also valid for borrowing, which increases by 16.0 percent, 14.3 percent, and 13.0 percent for this scenario and across these three levels of liquidity, respectively, and by about 7 percent for the other scenarios. In Table A.8, in the high level of allowable debt, acres increase by between 4.0 percent and 5.7 percent for the low liquidity case, and by between 2.6 percent and 3.4 percent in the average liquidity case; the baseline scenario again depicts the greatest changes. Because in the high level of liquidity the farmer is not constrained by credit in the low cost scenarios, the additional collateral has no effects except for in the baseline scenario, where acres increase by 2.4 percent. The relative changes in wealth are very similar across the tables, varying between 5.1 percent and 10.6 percent in the low liquidity level, between 3.8 percent and 8.0 percent in the average liquidity level, and between 3.1 percent and 6.5 percent in the high liquidity case. Finally, the increase in the number of acres planted also brings about an expansion in both the amount of LDP payments received and in the number of replications in which the limit on these payments is reached. Under CARA preferences, however, doubling DP has no effects.

Overall, our results suggest DP have production effects. Moreover, these effects are exacerbated by the presence of credit constraints. Even though the farmer's liquidity did not change, DP enhance the farmer's collateral so that she can put more acres into production.

6.B. Production effects of stricter payment limits

The usual argument set forth to tighten government payments is one of equity among farmers, as larger farms receive the bulk of these payments. Supporters of tighter payments claim they facilitate farm consolidation, raise the price of land, and put smaller, family-sized farming operations at a competitive disadvantage. Aside from large farms, other controversial recipients of the payments include, among others, millionaire and businessman Maurice Wilder and billionaire businessman David Rockefeller.[10] Despite the fact that in principle farm support programs should not discriminate among recipients, it is becoming increasingly politically difficult to justify the escalating concentration of payments to a few large farms (and/or millionaires with other sources of income). Along with being extremely costly to the federal budget, this undermines the public support for farm subsidies. To alleviate the problem of non-farmers collecting subsidies and income supports, the 2008 Farm Bill denies commodity payments to individuals with non-farm income of more than $500,000 and discontinues DP for individuals with more than $750,000 in net farm income. But big payments go to big farms because support is generally tied to units of production. Larger farms usually have greater historical acreage and thus receive larger payments.

In February of 2005, Senators Grassley and Dorgan introduced Senate Bill 385, where they proposed DP, CCP and LDP payment limits to be reduced to $40,000, $60,000, and

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[10] See, for example, the article "Farm aid going to millionaires" by the Environmental Working Group, August 2008, found in http://www.ewg.org/node/27007.

$150,000, respectively, per farmer. We now evaluate the production effects of this measure. Relative to our general framework, the policy merely decreases the limit on CCP by $5,000. For the wheat farmer in our model, whose historical acres and yields have caused CCP to vary between $2,241.96 and $17,384.65 in the high price and low price scenarios, respectively (scenarios 4 and 3), this policy change should not affect production. Indeed, this is the case. For the base yield assumed and the levels of prices implied in our scenarios, the lower payment limit for CCP could only be attained by a farmer with much higher base acres. For the average price in the baseline scenario, $3/bu, it would take a base of about 1,467 acres to reach the payment limit, and for the average price in the lower price level scenarios, $1.80, it would take a base of about 2,348 acres to reach the payment limit (in principle, under the high price scenario, price, CCP should not be collected). Only very large farms have these base acres. In our KFMA data, the farm at the 90 percentile had a base acreage of 833 acres, and even the farm at the 95 percentile had a base acreage of 1,116 acres. Only the farm at the 99 percentile had a base acreage of 1,625 acres, greater than the required minimum base acreage to reach the payment limit in the baseline price scenario. And out of the 914 acres in the sample, only nine farms had greater yield acreage (the maximum base was 2,471). These were, in general, very large farms. Six out of these nine farms operated more than 1,351 acres in 2004. According to the 2002 Census of Agriculture, out of the 24,236 farms that produced wheat in Kansas, 1,773 had 1,000 acres or more, about 7.3 percent. Of these large farms, the vast majority was in the 1,000 to 1,999 category, 1,519 farms, or 6.3 percent of total Kansas farms. However, the 1,000 acres or more farms represent about 32.77 percent of wheat growing Kansas acres. Given that large farms are expected to have large historical bases, while this tighter limit would presumably affect only a small number of farms, it could nonetheless represent non-negligible savings for the Federal budget.

7. Conclusions

In 1998 Hennessy showed how, in the presence of uncertainty, decoupled payments may distort production. His framework was used by Goodwin (2006) to observe the acreage effects of more stringent payment limits. However none of these applications allowed for the optimal decisions of farmers to be constrained by their ability to obtain credit. This type of constraints, pervasive in agriculture, has been shown by empirical studies to cause under-investment in agriculture, and so should be included in the analysis. Furthermore, the literature has identified credit constraints as a potential coupling mechanism of decoupled payments. These may, when farmers are unable to obtain credit at all or under good conditions, provide liquidity to allow investment in production to occur, or enhance the farmers' collateral such that better credit conditions can be attained. Our analysis filled in this gap, extending the framework used by these authors to incorporate the presence of capital market imperfections, or credit constraints. We further expanded our framework to include the possibility of decreasing marginal yields and a wealth-dependent interest rate. Our use of several liquidity levels and degrees of credit-worthiness (allowable debt), along with several cost, price, yields, and preferences scenarios allowed us to observe the optimal choices of farmers with different cost structures and different behaviors towards risk. We were also able to observe how these choices changed with market conditions and ultimately resulted in different levels of government payments, coupled and decoupled.

We find that credit constraints matter. When the farmer is not endowed with enough liquidity to put all her acres into production, and the market conditions are such that she would like to do so, allowing her to borrow a greater percentage of her wealth expands acreage. For example, in the baseline scenario, slackening the constraint allowed the farmer to increase planted acres by between 8.89 and 18.52 percent in the high and low liquidity cases, respectively. When she is not constrained by credit, decoupled payments only affect her wealth – this could potentially bring about other distortions in production than those considered in this study, as general wealth effects have been identified as another potential coupling mechanism.

Finally, we used our extended framework to analyze the impact of two different policy measures, a 100 percent increase in DP and a tightening of payment limits as proposed by Senators Charles Grassley and Byron Dorgan in the 109th Congress.. While the tightening of payment limits is likely to have no effect on average sized farmers, our results showed that, in the presence of credit constraints, DP have important and nonnegligible production effects. Indeed, when farmers are liquidity constrained, the presence of these payments has a "collateral-enhancement effect" such that more production can take place even though the actual liquidity of the farmer does not change. For example, in the baseline scenario, in the low allowable debt case, doubling DP increased planted acres by between 1.5 and 3.8 percent in the high and low liquidity cases, respectively. In the high allowable debt case, these values increased to between 2.4 and 5.7 percent, respectively. This finding is extremely important as decoupled payments are typically viewed as a non-distorting means of supporting agriculture. But if the payments alter the farmers' optimal choices and result in additional crop production, prices and returns decrease, and so they fail in supporting farm household income. The causal relationship we observe between payments and acreage may also undermine the economic rationale of the WTO's green box category of support, which specifically requires support to not distort trade or at most cause minimal distortion. Finally, there is the potential for environmental consequences if the payments do stimulate production.

8. References

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A. Appendix

Table A.1. Scenario 1: Baseline

		Liquidity scenarios					
	Variables	Low liquidity ($23,189.88)		Average liquidity ($46,379.76		High liquidity ($69,569.64)	
γ = 0.13	Acres		299.03		535.53		772.03
	Borrowing ($)		7,224.29		8,089.14		8,953.98
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	94,764.37	8,186.99	124,033.35	13,581.28	153,302.32	19,684.86
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	10,597.34	6,412.61	10,597.34	6,412.61	10,597.34	6,412.61
	Loan Deficiency Payments ($)	2,497.41	3,797.84	4,472.62	6,801.57	6,447.83	9,805.30
	Yields (bu/acre)	40.08	7.56	40.08	7.56	40.08	7.56
	Prices ($)	3.00	0.64	3.00	0.64	3.00	0.64
γ = 0.25	Acres		354.41		597.54		840.67
	Borrowing ($)		12,856.91		14,396.05		15,935.19
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	95,916.34	9,319.11	125,323.22	15,146.14	154,730.10	21,504.68
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	10,597.34	6,412.61	10,597.34	6,412.61	10,597.34	6,412.61
	Loan Deficiency Payments ($)	2,959.92	4,501.19	4,990.50	7,589.12	7,021.08	10,677.05
	Yields (bu/acre)	40.08	7.56	40.08	7.56	40.08	7.56
	Prices ($)	3.00	0.64	3.00	0.64	3.00	0.64

Table A.2. Scenario 2: Low costs and rents

		Liquidity scenarios					
	Variables	Low liquidity ($23,189.88)		Average liquidity ($46,379.76		High liquidity ($69,569.64)	
γ = 0.13	Acres		635.66		1,039.88		1,444.10
	Borrowing ($)		15,601.92		17,080.07		18,558.23
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	191,399.14	16,123.36	241,424.52	26,848.41	291,449.91	37,839.42
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	10,597.34	6,412.61	10,597.34	6,412.61	10,597.34	6,412.61
	Loan Deficiency Payments ($)	5,308.87	8,073.27	8,684.82	13,207.12	12,060.77	18,340.98
	Yields (bu/acre)	40.08	7.56	40.08	7.56	40.08	7.56
	Prices ($)	3.00	0.64	3.00	0.64	3.00	0.64
γ = 0.25	Acres		844.22		1,268.20		1,520.00
	Borrowing ($)		28,329.55		31,013.54		23,189.88
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	204,646.84	21,599.12	255,927.33	33,040.75	296,270.82	39,914.97
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	10,597.34	6,412.61	10,597.34	6,412.61	10,597.34	6,412.61
	Loan Deficiency Payments ($)	7,050.71	10,722.11	10,591.69	16,106.93	12,694.64	19,304.91
	Yields (bu/acre)	40.08	7.56	40.08	7.56	40.08	7.56
	Prices ($)	3.00	0.64	3.00	0.64	3.00	0.64

Table A.3. Scenario 3: Low costs and prices

	Variables	Low liquidity ($23,189.88)		Average liquidity ($46,379.76		High liquidity ($69,569.64)	
		Liquidity scenarios					
γ = 0.13	Acres		646.236532		1050.402173		1454.567813
	Borrowing ($)		16,247.35		17,722.08		19,196.82
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	191,296.17	14,183.70	236,588.57	23,003.29	281,869.88	31,803.82
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	17,384.65	900.09	17,384.65	900.09	17,384.65	900.09
	Loan Deficiency Payments ($)	28,659.36	12,117.79	46,583.34	19,696.43	64,507.32	27,275.07
	Yields (bu/acre)	40.08	7.56	40.08	7.56	40.08	7.56
	Prices ($)	1.80	0.39	1.80	0.39	1.80	0.39
γ = 0.25	Acres		863.37		1,287.24		1,520.00
	Borrowing ($)		29,498.17		32,175.64		23,189.88
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	202,547.60	18,920.67	248,860.27	28,172.07	285,249.10	33,210.15
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	17,384.65	900.09	17,384.65	900.09	17,384.65	900.09
	Loan Deficiency Payments ($)	38,288.84	16,189.34	57,086.86	24,137.55	67,409.11	28,502.02
	Yields (bu/acre)	40.08	7.56	40.08	7.56	40.08	7.56
	Prices ($)	1.80	0.39	1.80	0.39	1.80	0.39

Table A.4. Scenario 4: Low costs and high prices

	Variables	Low liquidity ($23,189.88)		Average liquidity ($46,379.76		High liquidity ($69,569.64)	
		Liquidity scenarios					
γ = 0.13							
	Acres		643.44		1,052.61		1,461.78
	Borrowing ($)		16,076.78		17,856.90		19,637.02
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	209,184.26	26,055.05	275,832.61	43,510.98	342,480.96	61,032.48
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	2,241.96	4,257.87	2,241.96	4,257.87	2,241.96	4,257.87
	Loan Deficiency Payments ($)	329.18	1,922.06	538.50	3,144.32	747.83	4,366.58
	Yields (bu/acre)	40.08	7.56	40.08	7.56	40.08	7.56
	Prices ($)	4.20	0.90	4.20	0.90	4.20	0.90
γ = 0.25							
	Acres		863.17		1,296.68		1,520.00
	Borrowing ($)		29,486.23		32,751.13		23,189.88
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	231,899.77	35,415.24	301,063.32	53,958.49	348,499.48	63,527.71
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	2,241.96	4,257.87	2,241.96	4,257.87	2,241.96	4,257.87
	Loan Deficiency Payments ($)	441.59	2,578.44	663.36	3,873.38	777.61	4,540.49
	Yields (bu/acre)	40.08	7.56	40.08	7.56	40.08	7.56
	Prices ($)	4.20	0.90	4.20	0.90	4.20	0.90

Table A.5. Scenario 5: Low costs and prices, and high yields

	Variables	Liquidity scenarios Low liquidity ($23,189.88)		Average liquidity ($46,379.76		High liquidity ($69,569.64)	
$\gamma = 0.13$							
	Acres		663.10		1,077.67		1,482.98
	Borrowing ($)		17,276.72		19,386.26		20,930.41
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	222,910.47	20,338.81	287,940.68	32,969.41	350,799.21	43,807.64
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	17,384.65	900.09	17,384.65	900.09	17,384.65	900.09
	Loan Deficiency Payments ($)	41,170.38	17,407.72	66,909.80	28,290.89	92,073.99	38,930.86
	Yields (bu/acre)	56.11	10.59	56.11	10.59	56.11	10.59
	Prices ($)	1.80	0.39	1.80	0.39	1.80	0.39
$\gamma = 0.25$							
	Acres		905.17		1,338.08		1,520.00
	Borrowing ($)		32,049.31		35,278.05		23,189.88
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	246,675.42	27,736.41	313,102.91	40,345.13	354,100.38	44,620.77
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	17,384.65	900.09	17,384.65	900.09	17,384.65	900.09
	Loan Deficiency Payments ($)	56,199.88	23,762.51	83,077.97	35,127.14	94,372.75	39,902.82
	Yields (bu/acre)	56.11	10.59	56.11	10.59	56.11	10.59
	Prices ($)	1.80	0.39	1.80	0.39	1.80	0.39

Table A.6. Scenario 6: Low costs, prices and CARA preferences

	Variables	Liquidity scenarios Low liquidity ($23,189.88)		Average liquidity ($46,379.76		High liquidity ($69,569.64)	
$\gamma = 0.13$							
	Acres		357.65		608.00		729.60
	Borrowing ($)		-1,364.10		-9,275.95		-25,045.07
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	176,342.08	7,901.17	213,664.21	13,350.06	244,314.64	16,001.85
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	17,384.65	900.09	17,384.65	900.09	17,384.65	900.09
	Loan Deficiency Payments ($)	15,860.97	6,706.36	26,963.65	11,400.81	32,356.37	13,680.97
	Yields (bu/acre)	40.08	7.56	40.08	7.56	40.08	7.56
	Prices ($)	1.80	0.39	1.80	0.39	1.80	0.39
$\gamma = 0.25$							
	Acres		357.65		608.00		729.60
	Borrowing ($)		-1,364.10		-9,275.95		-25,045.07
		Mean	St. Dev.	Mean	St. Dev.	Mean	St. Dev.
	Wealth ($)	176,342.08	7,901.17	213,664.21	13,350.06	244,314.64	16,001.85
	Direct Payments ($)	9,792.64	-	9,792.64	-	9,792.64	-
	Counter-Cyclical Payments ($)	17,384.65	900.09	17,384.65	900.09	17,384.65	900.09
	Loan Deficiency Payments ($)	15,860.97	6,706.36	26,963.65	11,400.81	32,356.37	13,680.97
	Yields (bu/acre)	40.08	7.56	40.08	7.56	40.08	7.56
	Prices ($)	1.80	0.39	1.80	0.39	1.80	0.39

Table A.7. The effects of doubling DP on selected variables, low allowable debt

γ = 0.13		Liquidity scenarios					
		Low liquidity ($23,189.88)		Average liquidity ($46,379.76)		High liquidity ($69,569.64)	
		Direct Payments					
		$9,792.64	$19,585.28	$9,792.64	$19,585.28	$9,792.64	$19,585.28
Variable	Scenarios	(1)	(2)	(3)	(4)	(5)	(6)
Acres	1	299.19	310.61	535.52	546.92	771.34	782.71
	2	635.25	654.68	1,035.83	1,055.06	1,431.64	1,450.60
	3	645.78	665.20	1,046.20	1,065.43	1,422.12	1,422.05
	4	642.91	662.56	1,047.53	1,066.93	1,446.26	1,465.33
	5	662.34	682.22	1,071.25	1,090.83	1,468.79	1,487.76
	6	357.65	357.65	608.00	608.00	729.60	729.60
Borrowing ($)	1	7,240.88	8,402.67	8,088.15	9,247.93	8,883.17	10,039.83
	2	15,577.14	16,762.76	16,832.65	18,006.58	17,797.55	18,954.93
	3	16,219.48	17,404.69	17,465.84	18,639.26	17,216.36	17,212.34
	4	16,044.59	17,243.34	17,546.61	18,730.87	18,689.87	19,853.79
	5	17,230.16	18,443.11	18,994.53	20,189.49	20,065.04	21,222.13
	6	-1,364.10	-1,364.11	-9,275.95	-9,275.95	-25,045.07	-25,045.07
Wealth ($)	1	95,333.61	105,362.72	124,008.76	133,969.81	150,915.24	160,771.18
	2	190,599.36	201,438.25	233,092.11	243,535.88	265,749.36	275,632.94
	3	190,477.04	201,098.06	228,757.82	239,017.04	258,069.11	267,860.29
	4	208,025.71	219,592.94	264,265.36	275,290.64	307,071.89	317,335.70
	5	221,519.22	232,992.48	275,704.06	286,623.48	316,041.21	326,181.23
	6	176,842.32	186,635.07	213,214.87	223,008.30	242,747.18	252,541.94
LDP payments ($)	1	2,536.20	2,631.63	4,471.51	4,562.37	6,287.48	6,371.27
	2	5,256.50	5,406.69	8,124.65	8,248.21	10,328.97	10,414.74
	3	28,344.94	29,139.49	43,497.12	44,148.65	54,614.57	54,612.95
	4	325.62	334.90	502.29	509.87	636.76	641.95
	5	40,631.93	41,763.98	62,082.04	62,995.78	78,021.39	78,629.36
	6	16,051.59	16,051.59	26,785.16	26,785.16	31,736.45	31,736.45
Number of LDP limit hits	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	1	1
	4	0	0	0	0	0	0
	5	0	0	6	8	160	177
	6	0	0	0	0	0	0

Note: The number of LDP limit hits is the number of replications the limit on LDP was reached.

Table A.8. The effects of doubling DP on selected variables, high allowable debt

γ = 0.25		Liquidity scenarios					
		Low liquidity ($23,189.88)		Average liquidity ($46,379.76)		High liquidity ($69,569.64)	
		Direct Payments					
		$9,792.64	$19,585.28	$9,792.64	$19,585.28	$9,792.64	$19,585.28
Variable	Scenarios	(1)	(2)	(3)	(4)	(5)	(6)
Acres	1	354.68	375.00	597.30	617.54	838.85	858.99
	2	840.94	875.78	1,253.68	1,287.73	1,497.41	1,497.34
	3	859.78	894.58	1,272.02	1,306.02	1,422.12	1,422.05
	4	858.84	894.29	1,277.84	1,312.29	1,520.00	1,520.00
	5	898.89	934.97	1,319.95	1,353.95	1,520.00	1,520.00
	6	357.65	357.65	608.00	608.00	729.60	729.60
Borrowing ($)	1	12,884.87	14,951.06	14,371.86	16,430.56	15,750.07	17,797.73
	2	28,129.62	30,255.69	30,127.38	32,205.40	21,811.20	21,807.31
	3	29,278.92	31,402.68	31,246.27	33,321.43	17,216.56	17,212.42
	4	29,221.40	31,385.05	31,601.45	33,704.16	23,189.88	23,189.88
	5	31,665.58	33,867.77	34,171.60	36,246.15	23,189.88	23,189.88
	6	-1,364.10	-1,364.11	-9,275.95	-9,275.95	-25,045.07	-25,045.07
Wealth ($)	1	96,462.58	106,651.64	124,874.00	134,920.12	151,206.90	161,042.15
	2	200,887.41	212,225.97	239,059.36	249,480.09	265,937.68	275,728.47
	3	198,812.54	209,772.26	232,845.22	242,964.46	258,069.11	267,860.29
	4	226,362.46	238,887.34	276,784.91	288,019.16	308,669.41	318,460.09
	5	240,098.77	252,415.09	287,509.01	298,451.19	316,889.24	326,679.92
	6	176,842.32	186,635.07	213,214.87	223,008.30	242,747.18	252,541.94
LDP payments ($)	1	2,998.30	3,166.45	4,960.45	5,118.77	6,779.10	6,922.89
	2	6,794.10	7,041.84	9,430.79	9,615.19	10,617.75	10,617.48
	3	36,790.77	38,093.20	50,608.88	51,570.35	54,614.65	54,612.98
	4	424.00	439.31	585.73	596.91	656.12	656.12
	5	53,554.06	55,407.84	72,737.49	74,021.71	79,627.89	79,627.89
	6	16,051.59	16,051.59	26,785.16	26,785.16	31,736.45	31,736.45
Number of LDP limit hits	1	0	0	0	0	0	0
	2	0	0	0	0	0	0
	3	0	0	0	0	1	1
	4	0	0	0	0	0	0
	5	0	1	61	78	203	203
	6	0	0	0	0	0	0

Note: The number of LDP limit hits is the number of replications the limit on LDP was reached.