EFFECTS OF DECOUPLING ON THE AVERAGE AND THE VARIABILITY OF OUTPUT

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Summary

Previous research has ignored the influence of inputs on output risk when assessing the effects of decoupled income-support payments on production decisions. This paper studies the impacts of agricultural policy decoupling on output variability and mean by explicitly considering the influence of agricultural input use on the stochastic component of production. We develop a theoretical framework that studies production responses of agricultural producers to apparently decoupled payments. Results show that, under DARA preferences, government transfers will have the effect of increasing production risk. Inferences on the effects of payments on output mean are also made. In our empirical application we use farm-level data collected in Kansas to illustrate the model.

Keywords: decoupling, output risk, risk preferences, Just-Pope production function.
JEL: Q12, Q18

Introduction

Recent years have witnessed important agricultural policy reforms worldwide. These reforms have usually been adopted in the context of protectionist trade policy dismantling processes mandated by global and/or regional trade agreements, and have been characterized by a certain degree of decoupling. Decoupling is a term used to designate the process that consists of breaking the linkage between farm income-support measures and farmers' production decisions. A common objective behind decoupling is the reduction of efficiency losses usually associated to coupled policies such as price supports or deficiency payments (Chambers, 1995).

The literature on production impacts of agricultural policies has shown that, in the context of a deterministic world or when agents are neutral to risk, only those policies that alter relative market prices impact on farmers' decisions. Several studies have assessed the effects of coupled or partially decoupled policies assuming risk neutrality (see, for example, Moro and Sckokai, 1999; or Guyomard, Baudry, and Carpentier, 1996). A recent paper by Serra et al. (2005) concludes that the partially decoupled compensatory payments introduced by the 1992 reform of the Common Agricultural Policy (CAP) can intensify production practices by stimulating an increase in the consumption of inputs such as pesticides. The use of a risk neutral theoretical framework to study the impacts of more recent decoupled instruments such as the production flexibility contracts introduced in the US in 1996, or the single farm payment defined by the 2003 CAP reform, would lead to the conclusion that these income-support mechanisms are fully decoupled as they do not have any impact on farmers' production decisions. However, in a world with uncertainty, apparently decoupled payments can have production implications. An extensive literature has shown that lump sum payments can affect economic agents' risk attitudes by altering farm household wealth (see, for example Sandmo, 1971; Just and Zilberman, 1986; Bar-Shira, Just, and Zilberman, 1997; or Hennessy, 1998). This effect is known as the wealth effect of policy. Specifically, the literature (Hennessy, 1998) shows that if farmers have decreasing absolute risk aversion (DARA) preferences, a decoupled program that increases expected profits will increase input use as the magnitude of support increases.

The conclusion that decoupled payments will yield an increase in input use, derives from a model that does not account for the effects that inputs can have on the stochastic component of production. As Just and Pope (1978) explain, agricultural inputs can increase or decrease output variability. These authors propose a stochastic specification of input-output response to correctly capture this matter. Our paper investigates the impacts of decoupled policies on production decisions taken by risk adverse agents, by explicitly considering the effects of input on output variability. Our conceptual framework is based on the model of production under uncertainty developed by Leathers and Quiggin (1991). We extend this model to allow for decoupled government transfers. We also extend their comparative statics analysis to derive policy-induced changes on output mean and variability. Our framework offers an improved picture of farmers' behaviour by assessing the effects of policy instruments on input consumption, production mean and risk. Following Newbery and Stiglitz (1979), and Bar-Shira, Just, and Zilberman (1997), risk preferences are approximated through a function of expanded wealth. Under the assumption of DARA preferences, we show that an increase in lump sum payments will boost input use only if the input is risk-increasing. However, if the input has the effect of reducing output variance, its use will decline. Hence, we conclude that lump sum payments in agriculture will increase output variability. Implications of decoupled payments for the output mean are also derived. Our model shows the relevance of accounting for the effects of input on the stochastic element of output when studying production effects of policy measures. It also shows that the net effects of decoupling cannot always be predicted by theory, which makes it necessary to resolve the question by empirical study. In this paper we learn from the American experience on decoupling by assessing the effects of the 1996 Federal Agriculture Improvement and Reform Act on production decisions taken by a sample of Kansas farms.

Conceptual Framework

In order to analyze how decoupled payments may influence farm production decisions we extend Leathers and Quiggin (1991) model of production. Because production decisions are often subject to uncertainty, we consider producers' risk preferences. Output variability is explicitly modelled in order to account for the effects of agricultural inputs on the stochastic component of output. A decoupled payment is defined as an income-support payment exogenously determined and not conditional upon actual production or prices.

Suppose a single-output firm produces output y. Following Just and Pope (1978), the single-output production function is represented by $y = f(x) + h(x)\varepsilon$, where x is a variable input,[1] $f(x)$ is the deterministic component of production, $h(x)$ is a function that captures the relationship between inputs and output variability, and ε is a stochastic disturbance with $E(\varepsilon) = 0$ and $E(\varepsilon^2) = 1$. An input will cause production risk to increase (stay constant) [decrease] if $var\left[y\right]_x > (=)[<] 0$, where $var\left[y\right]_x$ represents the first derivative of output variance with respect to input x.[2] Different examples have been cited of risk-increasing and risk-decreasing inputs. Frost protection, irrigation or pesticides, have generally been considered by previous literature as inputs that reduce output variability, while fertilizers have often been associated to an increase in production risk (Just and Pope, 1978; or Just and Zilberman, 1983). It should be noted however, that pesticides have also been seen by many authors as risk-increasing (Horowitz and Lichtenberg, 1994) or risk-neutral inputs (Hurd, 1994).

It is assumed that producers take their decisions with the aim of maximizing the expected utility of wealth $\max_x E\left[u(W)\right] = \max_x E\left[u\left(W_0 + py - wx + gov\right)\right] = \max_x E\left[u\left(W_0 + pf(x) + ph(x)\varepsilon - wX + gov\right)\right]$, where W represents farm's total wealth, W_0 stands for farm's initial wealth, p is the market output price, w is the variable input price, and gov represent decoupled government payments. For simplicity, it is assumed that output and input prices are certain variables, with the agricultural output being the only source of uncertainty. The first order condition of the expected utility maximization problem can be expressed as:

[1] A single input is used in this theoretical model for the sake of simplicity. However, in the empirical application the model is generalized and two inputs are considered.

[2] See Ramaswami (1992) for an alternative though compatible definition of risk-increasing and risk-decreasing inputs.

$$\frac{\partial E\left[u(W)\right]}{\partial x} = E\left[u_W\left(py_x - w\right)\right] = 0 \qquad (1)$$

Subscripts in (1) denote partial derivatives. Following Newbery and Stiglitz (1979), u_W can be expanded around expected wealth, $\bar{W} = W_0 + p\bar{y} - wx + gov$. This yields the following expression: $u_W = \bar{u}_W + \bar{u}_{WW}(W - \bar{W}) = \bar{u}_W + \bar{u}_{WW}p(y - \bar{y})$, where $\bar{u}_W$ and $\bar{u}_{WW}$ represent the first and second-order derivatives of the utility function evaluated at the expected wealth ($\bar{W}$), and $\bar{y}$ represents farmer's expected output. Substituting the Taylor series expansion into (1) and rearranging terms yields:

$$pE\left[y_x\right] + \frac{\bar{u}_{WW}}{\bar{u}_W}p^2E\left[\left(y - \bar{y}\right)y_x\right] = w \qquad (2)$$

It can be shown that $E\left[\left(y - \bar{y}\right)y_x\right]$ is equivalent to one half the derivative of the output variance with respect to x, i.e. $E\left[\left(y - \bar{y}\right)y_x\right] = \left(\frac{1}{2}\right)var\left[y\right]_x$. The Arrow-Pratt coefficient of absolute risk aversion is $R = -\frac{\bar{u}_{WW}}{\bar{u}_W}$. Following Bar-Shira, Just and Zilberman (1997), we assume that R is a function of a farm's expected wealth and can be represented by the following expression: $R = -\frac{\bar{u}_{WW}}{\bar{u}_W} = \eta\bar{W}^{\beta}$, where η and β are parameters. If farmers are risk-averse, then $\eta > 0$ (which involves $R > 0$), a risk-neutral behaviour would imply $\eta = 0$ ($R = 0$), while $\eta < 0$ ($R < 0$) represents a risk-seeking attitude. We assume farmers to be risk-averse ($\eta > 0$). β is the wealth elasticity of absolute risk aversion. If farmers have decreasing absolute risk aversion (DARA) preferences, $\beta < 0$. Increasing absolute risk aversion (IARA) preferences are represented by $\beta > 0$, while constant absolute risk aversion (CARA) attitudes involve $\beta = 0$ (see Chavas, 2004, chapter 4 for more detail). We assume here that farmers have DARA preferences ($\beta < 0$). It is important to note that our measure of risk aversion based on expected wealth is only an approximation to farmer's actual risk preferences. This approximation does not change with different realizations of the random output because it is measured at its expected value, but varies with the level of the farmer's expected wealth. Substituting the coefficient of absolute risk aversion as a function of a farm's expected wealth in (2) yields:

$$pE\left[y_x\right] - \left(\frac{1}{2}\right)\eta\bar{W}^{\beta}p^2var\left[y\right]_x = w \qquad (3)$$

Equation (3) can also be expressed as:

$$CE = MC \qquad (4)$$

where $CE = pE\left[y_x\right] - \left(\frac{1}{2}\right)\eta\bar{W}^{\beta}p^2var\left[y\right]_x = E\left[MI\right] - RP$ is the certainty equivalent of marginal income, $E\left[MI\right] = pE\left[y_x\right]$ is the expected value of the marginal output, $RP = \left(\frac{1}{2}\right)\eta\bar{W}^{\beta}p^2var\left[y\right]_x$ represents the risk premium, and $MC = w$ is the marginal cost of using an additional unit of input. Equation (4) shows that the maximization of the expected utility requires the certainty equivalent of marginal income be equal to the marginal cost (MC).[3] Comparative statics are used below in order to determine the effects of government payments on input use and output variability[4] and mean.

Farmers in our model have two income sources: decoupled government transfers and market revenue. Agricultural policy in developed countries has usually involved price-support measures that keep market prices artificially high. As explained above, price supports represent a form of coupled income-support. Given the fact that we do not have experimental data that allows to compare two situations, one with only coupled and the other with exclusively decoupled support, we compare the effects of decoupled payments with the effects of prices representing a coupled element of support. For comparison purposes, we also assess the effects of a change in input prices on farmers' production decisions. Throughout the comparative statics analysis, it is assumed that farmers are decreasingly absolute risk averse and that the expected marginal productivity of input is positive.

The effects of decoupled government payments on input use can be derived by totally differentiating equation (3):

$$\frac{dx}{dgov} = \frac{\left(\frac{1}{2}\right)\eta\beta\bar{W}^{\beta-1}p^2 var\left[y\right]_x}{E\left[u(W)\right]_{xx}} = \frac{RP_{gov}}{E\left[u(W)\right]_{xx}} \tag{5}$$

where $E\left[u(W)\right]_{xx} = pE\left[y_{xx}\right] - \left(\frac{1}{2}\right)\eta\beta\bar{W}^{\beta-1}\left[pE\left[y_x\right]-w\right]p^2 var\left[y\right]_x - \left(\frac{1}{2}\right)\eta\bar{W}^{\beta}p^2 var\left[y\right]_{xx} < 0$ represents the second order condition of the optimization problem, and RP_{gov} is the marginal government transfer effect of risk premium. The sign of (5) depends on the sign of the numerator, which in turn depends on the sign of $var\left[y\right]_x$. If $var\left[y\right]_x > (=)[<]0$ then $\frac{dx}{dgov} > (=)[<]0$. An increase in decoupled government payments will result in an increase in farm households' wealth, which will induce a reduction in farmers' degree of risk aversion. Given this change in risk preferences, farmers will increase the demand for risk-increasing inputs, while reducing the application of the risk-reducing ones. This result, which is compatible with the findings of MacMinn and Holtmann (1983), shows that the risk premium will decrease if x is a risk-increasing input, but will grow if x reduces output risk.

The sensitivity of output variance with respect to government transfers can be determined by the following expression:

$$\frac{dvar\left[y\right]}{dgov} = \frac{dvar\left[y\right]}{dx} \cdot \frac{dx}{dgov} = \frac{RP_{gov} var\left[y\right]_x}{E\left[u(W)\right]_{xx}} \tag{6}$$

Under our assumption of DARA preferences, $\frac{dvar\left[y\right]}{dgov} > 0$ which shows that an increase in subsidies will increase output risk. Adjustments in output mean to changes in government payments can be expressed as:

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[3] Consistently with Pope and Kramer's (1979) work, equation (3) shows that if an input is risk-reducing (increasing) and economic agents are risk averse, the expected value of marginal output will need to be smaller (greater) than the input price in order to maximize the expected utility.

[4] An input could have different impacts on marginal and on average risk. For instance, while pesticides can reduce total risk, they may increase risk at the margin. As Hurley, Mitchell, and Rice (2004) explain, risk at the margin is of primary concern to farmers. Our analysis is at the margin and thus focuses on the impacts of decoupling on output marginal risk.

$$\frac{dE[y]}{dgov} = \frac{dE[y]}{dx}\frac{dx}{dgov} = \frac{RP_{gov}E[y_x]}{E\left[u(W)\right]_{xx}} \tag{7}$$

The sign of expression (7) depends entirely on $var\left[y\right]_x$. Consistently with changes in input consumption, output mean will grow (stay constant) [decline] with lump sum payments if $var\left[y\right]_x > (=)\left[<\right]0$. The comparative statics developed above lead to the following proposition:

PROPOSITION 1. *Under the assumption of DARA preferences and positive expected marginal productivity (*$E\left[y_{\mathbf{x}}\right] > 0$*),*

A. $\frac{dx}{dgov} > \left(=\right)\left[<\right]0$ *if* $var\left[y\right]_x > \left(=\right)\left[<\right]0$

B. $\frac{dvar\left[y\right]}{dgov} > 0$

C. $\frac{dE[y]}{dgov} > \left(=\right)\left[<\right]0$ *if* $var\left[y\right]_x > \left(=\right)\left[<\right]0$.

The impact of a change in output prices on input consumption can be derived by totally differentiating equation (3). This yields to the following expression:

$$\frac{dx}{dp} = -\frac{E\left[y_x\right] - \left[\left(\frac{1}{2}\right)\eta\beta\bar{W}^{\beta-1}E\left[y\right]p^2 + \eta\bar{W}^{\beta}p\right]\mathrm{var}\left[y\right]_x}{E\left[u(W)\right]_{xx}} = -\frac{E\left[y_x\right] - RP_p}{E\left[u(W)\right]_{xx}} \tag{8}$$

Expression $RP_p = \left[\left(\frac{1}{2}\right)\eta\beta\bar{W}^{\beta-1}E\left[y\right]p^2 + \eta\bar{W}^{\beta}p\right]\mathrm{var}\left[y\right]_x$, the marginal price effect of the risk premium, shows that a change in output price has two effects on the risk premium. The first effect, the risk aversion effect, measures the risk premium adjustment to a modification to a farmer's risk preferences in response to a change in output prices. The second effect, the price-variance effect, captures the risk premium adjustment to a change in a farm's income risk caused by an output price change. If we ignore the influence of inputs on the stochastic element of production, the first effect will be negative ($\left(\frac{1}{2}\right)\eta\beta\bar{W}^{\beta-1}E\left[y\right]p^2 < 0$), while the second will be positive ($\eta\bar{W}^{\beta}p > 0$). However, both effects must be corrected by the influence of input on the output's variance ($\mathrm{var}\left[y\right]_x$). If x is a risk-increasing input, the signs of the two effects will not change. However, if x is risk-decreasing, the two effects will work in opposite directions. If the difference between the expected marginal output and the change in the risk premium is positive ($E\left[y_x\right] - RP_p > 0$), the demand for input x will increase. Otherwise, the demand will decline. This lays out the necessary conditions for a failure in the 'law of supply', that contends that the quantity supplied by price-taking producers will rise in response to an increase in output prices. An increase in profit risk above the increase in its mean will originate this failure. This result is in accord with the findings of Just and Zilberman (1986) and represents an extension of their work.

The sensitivity of output variance with respect to output prices can be computed as:

$$\frac{dvar\left[y\right]}{dp}=\frac{dvar\left[y\right]}{dx}.\frac{dx}{dp}=-\frac{\left(E\left[y_x\right]-RP_p\right)var\left[y\right]_x}{E\left[u(W)\right]_{xx}} \tag{9}$$

An increase in output variance involves $\frac{dvar\left[y\right]}{dp}>0$. If input x is risk-increasing, this condition will be met when $E\left[y_x\right]-RP_p>0$, i.e., when the expected marginal income is above the marginal risk premium. If, on the other hand, input x is risk-decreasing, condition $\frac{dvar\left[y\right]}{dp}>0$ will require $E\left[y_x\right]-RP_p<0$ in which case the use of x will decline therefore boosting output variability. The inverse is true for the case where $\frac{dvar\left[y\right]}{dp}<0$. The sensitivity of output mean with respect to output prices can be determined by the following expression:

$$\frac{dE[y]}{dp}=\frac{dE[y]}{dp}\frac{dx}{dp}=-\frac{\left[E\left[y_x\right]-RP_p\right]E[y_x]}{E\left[u(W)\right]_{xx}} \tag{10}$$

The sign of expression (10) depends on the sign of $E\left[y_x\right]-RP_p$. As shown before, if the difference is positive, input use will grow, which in turn will increase output mean. Otherwise, production will decline. As noted, this latter case involves the failure of the 'law of supply.' Expressions (8) to (10) allow formulating proposition number 2 as follows.

PROPOSITION 2. *Under the assumption of DARA preferences and positive expected marginal productivity (*$E\left[y_x\right]>0$*),*

A. $\frac{dx}{dp}>(=)[<]0$ *if* $E\left[y_x\right]-RP_p>(=)[<]0$

B. $\frac{dvar\left[y\right]}{dp}>0$ if $var\left[y\right]_x>(<)0$ and $E\left[y_x\right]-RP_p>(<)0$

$\frac{dvar\left[y\right]}{dp}<0$ if $var\left[y\right]_x>(<)0$ and $E\left[y_x\right]-RP_p<(>)0$

$\frac{dvar\left[y\right]}{dp}=0$ if $E\left[y_x\right]-RP_p=0$

C. $\frac{dE[y]}{dp}>(=)[<]0$ *if* $E\left[y_x\right]-RP_p>(=)[<]0$

By totally differentiating equation (3), we can also assess the effects of input prices on input consumption:

$$\frac{dx}{dw}=\frac{1-\left(\frac{1}{2}\right)\eta\beta\bar{W}^{\beta-1}xp^2\,\text{var}\left[y\right]_x}{E\left[u(W)\right]_{xx}}=\frac{1-RP_w}{E\left[u(W)\right]_{xx}} \tag{11}$$

Expression $RP_w=\left(\frac{1}{2}\right)\eta\beta\bar{W}^{\beta-1}xp^2\,\text{var}\left[y\right]_x$ represents the marginal effect of input price on the risk premium. The sign of $\frac{dx}{dw}$ depends on $\text{var}\left[y\right]_x$. If $\text{var}\left[y\right]_x>0$, i.e. the input is risk-increasing, the numerator of expression (11) will be positive, which involves an increase in the risk premium and a reduction in the demand for x. However, if $\text{var}\left[y\right]_x<0$, i.e. the input is risk-reducing, the net effect of a change in input price on input use will depend on whether $\left|RP_w\right|\gtrless 1$. Proposition 3 thus contemplates the possibility of a positively slopped demand for inputs, which again is compatible with and represents an extension of the work by Just and Zilberman (1986). The sensitivity of output variance with respect to input prices can be computed as:

$$\frac{dvar\left[y\right]}{dw}=\frac{dvar\left[y\right]}{dx}\cdot\frac{dx}{dw}=-\frac{\left(1-RP_w\right)var\left[y\right]_x}{E\left[u(W)\right]_{xx}} \tag{12}$$

As shown above, if $var\left[y\right]_x>0$ then $\frac{dx}{dw}<0$ and thus $\frac{dvar\left[y\right]}{dw}<0$, which involves that when risk-increasing inputs become more costly, production variance will be reduced. However, if $var\left[y\right]_x<0$, production variance will increase (decrease) if $\left|RP_w\right|<(>)1$. This last result is expected since when $\left|RP_w\right|<1$, the use of the risk-decreasing input slows down and raises output risk. Conversely, when $\left|RP_w\right|>1$ the use of risk-decreasing inputs increases lowering output risk. The sensitivity of output mean with respect to input prices can be determined by the following expression:

$$\frac{dE[y]}{dw}=\frac{dE[y]}{dx}\frac{dx}{dw}=-\frac{\left[1-RP_w\right]E[y_x]}{E\left[u(W)\right]_{xx}} \tag{13}$$

The sign of expression (13) depends on the sign of $1-RP_w$. As explained before, if x is a risk-increasing input, $1-RP_w>0$ thus making $\frac{dE[y]}{dw}<0$. However, if the input is risk-decreasing, the sign of $1-RP_w$ cannot be anticipated, which indicates that output mean could either increase or decrease. Expressions (11) to (13) lead to our third proposition:

PROPOSITION 3. *Under the assumption of DARA preferences and positive expected marginal productivity (*$E\left[y_{\mathbf{x}}\right]>0$*),*

A. $\frac{dx}{dw}<0$ if $\text{var}\left[y\right]_x>0$. *If* $\text{var}\left[y\right]_x<0$, $\frac{dx}{dw}>(=)[<]0$ if $\left|RP_w\right|>(=)\left[<\right]1$

B. $\frac{dvar\left[y\right]}{dw}<0$ if $var\left[y\right]_x>0$. *If* $var\left[y\right]_x<0$, $\frac{dvar\left[y\right]}{dw}<(=)[>]0$ if $\left|RP_w\right|>(=)\left[<\right]1$

C. $\frac{dE\left[y\right]}{dw}<0$ if $var\left[y\right]_x>0$. *If* $var\left[y\right]_x<0$, $\frac{dE\left[y\right]}{dw}>(=)[<]0$ if $\left|RP_w\right|>(=)\left[<\right]1$.

The comparative statics developed above show the relevance of accounting for the influence of inputs on output risk when studying supply effects of decoupling. We show that, contrary to what previous analyses have concluded, an increase in lump sum payments does not necessarily motivate an increase in input use. Specifically, we show that under DARA preferences, input demand will increase if the input is risk-increasing, but will decline if it is risk-decreasing. The comparative statics analysis also shows that the net effects of decoupling cannot always be predicted by theory, making it necessary to resolve the question empirically. In the next sections we carry out an empirical analysis. A parametric representation of the model is specified and estimated using farm-level data for a sample of Kansas farms. The results section presents the outcomes of this estimation.

Model Specification

Generalizing the model outlined in the previous section, we define y as a function of two inputs x_1 and x_2, where x_1 represents the quantity used of pesticides and x_2 measures the fertilizer applied. In order to adequately capture the particular role of pesticides as damage-control inputs, we adopt the Lichtenberg-Zilberman damage control technology model. Following previous literature on damage abatement (Babcock, Lichtenberg, and Zilberman, 1992; Carrasco and Moffit, 1992; Lichtenberg and Zilberman, 1986; Oude Lansink and Carpentier, 2001; or Chambers and Lichtenberg, 1994), the deterministic component of production is defined as a concave function in which the abatement activity enters multiplicatively $f(x_1,x_2)=g(x_1)*s(x_2)$. Function $g(x_1)$ defines the role of damage control agents to production in terms of their capacity to reduce crop damage. It is represented by a nondecreasing concave function. Because abatement cannot exceed potential output (Lichtenberg and Zilberman, 1986), function $g(x_1)$ must be defined in the (0,1) interval, with $g(x_1)=1$ representing perfect pest abatement and $g(x_1)=0$ denoting no abatement. Since data on damage abatement are rarely observed, the usual practice is to specify a parametric representation of $g(x_1)$. Following previous analyses on damage control in agriculture (Chambers and Lichtenberg, 1994; Lichtenberg and Zilberman, 1986; Babcock, Lichtenberg, and Zilberman, 1992; Carpentier and Weaver, 1997), we adopt the exponential function: $g(x_1)=(1-e^{-\alpha_1 x_1})$, where α_1 is a parameter. Function $s(x_2)$ represents maximum potential output when damage abatement levels are equal to 1. It is assumed that $s(x_2)$ follows a Cobb-Douglas specification and is defined as: $s(x_2)=\alpha_0 x_2^{\alpha_2}$, with α_0 and α_2 being parameters.

The stochastic component of y, i.e. $h(x_1,x_2)$, is a measure of the standard error of production, being $h^2(x_1,x_2)$ the output variance: $var\left[y\right]=E\left[\left(y-\bar{y}\right)^2\right]=h^2(x_1,x_2)$. The parametric representation of variance is defined[5] as: $h^2(x_1,x_2)=e^{\gamma_0+\gamma_1 x_1+\gamma_2 x_2+\gamma_{11}x_1^2+\gamma_{22}x_2^2}$, where $\gamma_0,\gamma_1,\gamma_2,\gamma_{11}$, and γ_{22} are parameters. Output mean and variance functions are estimated using a three-stage feasible generalized least

[5] It is important to note that different specifications for both the output mean and variance were considered. We settled with the ones that yielded results consistent with economic theory. The different specifications considered include translog, CES, and quadratic forms.

squares procedure outlined in Just and Pope (1978).[6] Once the production function is specified, the optimization problem can be expressed as: $\max_{x_1,x_2} E\left[u(W)\right] = \max_{x_1,x_2} E\left[u(W_0 + \check{s})\right] =$

$\max_{x_1,x_2} E\left[u\left(W_0 + p\alpha_0(1-e^{-\alpha_1 x_1})x_2^{\alpha_2} + p\sqrt{e^{\gamma_0+\gamma_1x_1+\gamma_2x_2+\gamma_{11}x_1^2+\gamma_{22}x_2^2}}\,\varepsilon - w_1x_1 - w_2x_2 + gov \right)\right]$. s shown in the conceptual framework section, the first-order conditions of the optimization problem $\frac{\partial E\left[u(W)\right]}{\partial x} = 0$ can be reduced to mean-variance equations of the form: $pE\left[y_x\right] - \left(\frac{1}{2}\right)\eta\bar{W}^{\beta}p^2 var\left[y\right]_x = w$. By replacing the expressions $E\left[y_x\right]$ and $var\left[y\right]_x$ by their parametric representations, the following system of first-order conditions can be derived:

$$\begin{cases} p\alpha_0\alpha_1 e^{-\alpha_1x_1}x_2^{\alpha_2} - \left(\frac{1}{2}\right)\eta\bar{W}^{\beta}p^2 e^{\left(\gamma_0+\gamma_1x_1+\gamma_2x_2+\gamma_{11}x_1^2+\gamma_{22}x_2^2\right)}(\gamma_1 + 2\gamma_{11}x_1) = w_1 \\ p\alpha_0\alpha_2(1-e^{-\alpha_1x_1})x_2^{\alpha_2-1} - \left(\frac{1}{2}\right)\eta\bar{W}^{\beta}p^2 e^{\left(\gamma_0+\gamma_1x_1+\gamma_2x_2+\gamma_{11}x_1^2+\gamma_{22}x_2^2\right)}(\gamma_2 + 2\gamma_{22}x_2) = w_2 \end{cases} \quad (14)$$

Parameters that represent producers' risk preferences (η and β) are derived through the estimation of the system of equations (14) using maximum likelihood. Parameters of the production function are not re-estimated and are taken from the results of applying a three-stage feasible generalized least squares to estimate $y = f(x_1,x_2) + h(x_1,x_2)\varepsilon$.

In order to determine the effects of decoupling on output variability and mean, we compute the elasticities of output variance and mean with respect to government payments, output prices and, for comparison purposes, input prices. These elasticities are constructed based on the generalization of formulas (6), (7), (9), (10), (12), and (13) derived from the comparative statics analysis to a two-input model[7] and can be expressed as: $e_{var[y]\_gov} = \frac{dvar\left[y\right]}{dgov}\frac{gov}{var\left[y\right]}$, $e_{var[y]\_p} = \frac{dvar\left[y\right]}{dp}\frac{p}{var\left[y\right]}$, $e_{var[y]\_w_i} = \frac{dvar\left[y\right]}{dw_i}\frac{w_i}{var\left[y\right]}$, $e_{E[y]\_gov} = \frac{dE\left[y\right]}{dgov}\frac{gov}{E\left[y\right]}$, $e_{E[y]\_p} = \frac{dE\left[y\right]}{dp}\frac{p}{E\left[y\right]}$, and $e_{E[y]\_w_i} = \frac{dE\left[y\right]}{dw_i}\frac{w_i}{E\left[y\right]}$.

The next section presents a description of the data utilized to econometrically estimate our model.

Empirical Application

As noted above, significant agricultural policy reforms worldwide have often involved a certain degree of decoupling. The US farm policy underwent an extensive reform in 1996. The passage of the Federal Agriculture Improvement and Reform (FAIR) Act involved a reduction in the coupled element of income supports. Price supports were cut in favour of Production Flexibility Contract (PFC) payments that did not require the production of certain crops and were not linked to actual production or prices, and a deficiency payment that guaranteed a minimum support price for program crops.

[6] Though we tried to estimate the production function by maximum likelihood techniques, the optimization process did not converge.

[7] The generalization of the model to allow for more than one input increases the complexity of the comparative statics results. Whether the inputs are complements or substitutes becomes an important factor (see Pope and Kramer, 1979 for further detail) and does not allow to draw a clear conclusion about the sign of formulas (5) to (13). Empirical results are thus necessary to determine the effects of government payments and prices on output mean and variability.

Our empirical application focuses on the analysis of the effects of US agricultural policy decoupling on production decisions taken by a sample of Kansas farms. Farm-level data are obtained from farm account records from the Kansas Farm Management Association database for the period 1998-2001. Retrospective data for these farms are also used to define some lagged variables used in the analysis.[8] Our period of study corresponds to a time during which the FAIR Act was in force. PFC payments correspond to our definition of decoupled payments.

Our analysis is based on farm-level data, but aggregates are also used to define important variables that are unavailable in the farm-level dataset. These aggregates are taken from the United States Department of Agriculture (USDA) and the National Agricultural Statistics Service (NASS). USDA provided state-level PFC payment rates and NASS facilitated country-level price indices and state-level output prices and quantities.

Table 1 contains summary statistics for the variables used in the analysis. Two variable inputs are considered. Input x_1 includes pesticides and insecticides and x_2 represents fertilizer. Input prices (w_1 and w_2) are measured using national price indices because they are unavailable in the Kansas dataset. Thus, x_1 and x_2 are defined as implicit quantity indices and computed as the ratio of input use in currency units to its corresponding price indices.

Table 1. Summary statistics for the variables of interest

Variable	Mean (Standard deviation) n= 2,384
y	104,315.98 (120,636.51)
p	0.91 (0.06)
X_1	14,209.34 (17,177.62)
w_1	0.99 (0.01)
X_2	18,809.25 (20,829.04)
w_2	1.00 (0.06)
gov	11,412.08 (9,337.62)
Wealth	656,214.29 (577,944.67)

Note: all monetary values are expressed in constant 1998 currency units

A single output category (y) is also defined as a quantity index. Variable y aggregates the production of the predominant crops in Kansas (wheat, corn, grain sorghum, and soybeans). The output price p is defined as an aggregate Paasche index representing actual market prices. To build the Paasche index, unit prices for the crops considered are defined as state-level output prices. State-level production is also employed to derive the price index.

The Kansas database does not separate government payments into the component payments. Instead, a single measure that includes all government payments received by each farm is available. To derive an estimate of farm-level PFC payments, program crops base acreage and base yield are approximated using farm-level data. The approximation uses the 1986-88 average acreage and yield

[8] To be able to do so, a complete panel is built out of our sample.

for each program crop and farm. PFC payments per crop are derived by multiplying 0.85 by the base acreage, yield and the PFC payment rate. PFC payments per crop are then added to get total direct payments per farm. Estimated direct payments are compared to actual government payments received by each farm. In case estimated PFC payments exceed total actual payments, the first measure is replaced by the second.[9] Farms' initial wealth (W_0) is approximated by the farms' net worth.

Results

Parameter estimates for the deterministic element of production, $f(x_1,x_2)$, are all statistically significant and have the expected sign. The pest damage abatement parameter estimate (α_1) allows to compute the value of the damage abatement function $g(x_1)=(1-e^{-\alpha_1 x_1})$, which is 0.87 at the data means. This suggests that production losses due to pest damage are, on average, on the order of 13% of potential output.

Table 2. Parameter estimates and summary statistics for the production function

Parameter Value (Standard error)	Deterministic component of production	Stochastic component of production
α_0	678.0000** (145.5000)	
α_1	1.4500E-04** (1.3000E-05)	
α_2	0.5405** (0.0193)	
γ_0		18.3589** (0.19375)
γ_1		4.5240E-05** (1.3602E-05)
γ_2		7.3627E-05** (1.1766E-05)
γ_{11}		-2.1407E-10** (1.2748E-10)
γ_{22}		-2.6990E-10** (7.4085E-11)
F-Statistic	1662.4500**	180.2300**

Note: An asterisk (*) denotes statistical significance at the α = 0.1 level
Two asterisks (**) denote statistical significance at the α = 0.05 level

Parameter estimates representing the stochastic component of production, $g(x_1,x_2)$, show that both inputs exert a statistically significant influence on output variability. Their influence follows an inverted 'U' shape. At the data means, $\text{var}\left[y\right]_{x_i} = h^2(x_i)_{x_i} > 0$ for i = 1,2, which involves that both inputs are, on average, risk-increasing. The literature has often considered fertilizers as an example of inputs that increase output variability. However, pesticides have been widely believed to reduce production risk. As Horowitz and Lichtenberg (1994) explain, the analyses that support the hypothesis that pesticides are risk-reducing (see, for example, Feder, 1979), are based on the assumption that pest

[9] This happens in 7% of our observations.

damage is independent of other elements influencing output. Using a model that explicitly accounts for the interdependence between pesticides and other production conditions, Horowitz and Lichtenberg (1994) show that pesticides may in fact be risk-increasing in a variety of circumstances. Specifically, pesticides will increase output variability whenever pest populations tend to increase with good crop growth conditions. In such a situation, the use of pesticides will result in an increase in production in already good states of nature, thus increasing output risk. These theoretical results provide a very useful instrument for interpreting our empirical findings, which are compatible with previous research. Horowitz and Lichtenberg (1993), for example, show that farmers with crop insurance tend to use more pesticides, which is expected for a risk-increasing input. Farnsworth and Moffit (1981) also find pesticides to increase cotton yield risk in California.

Table 3. Parameter estimates and summary statistics for the coefficients of risk aversion.

Parameter	Mean predicted value (Standard deviation)
η	0.0224**
	(0.0050)
β	-0.30178**
	(0.0177)
Wald test ($\eta = 0$ and $\beta = 0$)	441461**

Note: An asterisk (*) denotes statistical significance at the α = 0.1 level
Two asterisks (**) denote statistical significance at the α = 0.05 level

Parameter estimates for the system of first-order conditions (14) are presented in Table 3. They provide evidence that farmers in our sample exhibit DARA preferences ($\eta > 0$ and $\beta < 0$). Previous studies have also found evidence that farmers are decreasingly absolute risk averse (see for example Bar-Shira, Just and Zilberman, 1997; or Chavas and Holt, 1990). Elasticities of output risk and mean with respect to decoupled government payments, output, and input prices are computed at the data means.[10] Results are offered in table 4. As noted before, both x_1 and x_2 have the effect of increasing output variability at the data means. Thus, and in accordance to what our theoretical model predicts, demand for x_1 and x_2 will increase with an increase in lump sum payments, thus raising output risk. Output mean will grow as well, but with a relative magnitude below the variance. It is important to note that, in spite of the fact that decoupled payments exert a statistically significant influence on the output mean and variance, elasticity values are very small indicating that substantial changes in payments are required to generate perceptible changes in production and production risk. Also, as predicted by theory, the use of both inputs will increase with a decline in their respective prices thus raising production variance and mean. Relative changes in output variance will be more substantial than changes in the output mean. Elasticities also show that a reduction in output price supports will motivate an increase in x_1 and x_2 use and an increase production variance. This last result involves that, at the data means, the price-variance effect outweighs the sum of the change in the expected marginal income and the risk aversion effect. The output mean price elasticity is also negative at the data means, thus indicating that an increase in prices may reduce agricultural production.

Thus, from the empirical results above we conclude that, for our sample of Kansas farms, a decoupling process consisting of a reduction in price-support measures in favour of lump sum payments, may have the effect of boosting output variance and mean by increasing the use of risk-increasing inputs. Our results also show that, relative to price supports, lump-sum payments cause only very small distortions on production, requiring very large changes in these payments to generate

[10] In order to determine whether these elasticities are significant, we use a bootstrapping approach. To do so, we utilize 1,000 pseudo-samples of the same size of the actual sample, drawn with replacement, to provide a sample of elasticity estimates. The variance and the elasticity values are derived from the variance and the mean of the replicated elasticities.

perceptible effects. It is important to note, however, that our results need to be interpreted with care. The stochastic element of production has been specified as a function that only depends on input use. The variability of output, however, is also likely to depend on other issues such as the variability in crop growth conditions (temperature, precipitation, sunshine duration, etc.), or the fluctuations in pest levels. Both sources of uncertainty, which we do not observe, may play a relevant role and interact with the effects of input use on output variance.

Table 4. Elasticity estimates

Elasticity	Mean value (Standard deviation)
$e_{var[y]\_gov}$	0.00448** (0.00001)
$e_{var[y]\_p}$	-1.28558** (0.00571)
$e_{var[y]\_w_1}$	-0.04661 ** (0.00002)
$e_{var[y]\_w_2}$	-0.17101** (0.00015)
$e_{E[y]\_gov}$	0.00208** (0.00001)
$e_{E[y]\_p}$	-0.59390** (0.00272)
$e_{E[y]\_w_1}$	-0.03011** (0.00007)
$e_{E[y]\_w_2}$	-0.07414** (0.00004)

Note: An asterisk (*) denotes statistical significance at the $\alpha = 0.1$ level
Two asterisks (**) denote statistical significance at the $\alpha = 0.05$ level

Concluding Remarks

This paper investigates the effects of decoupling on farmers' production decisions and, specifically, on output variability and mean. Previous literature (Horowitz and Lichtenberg, 1994; Feder, 1979; Just and Pope, 1978) has explained that input use will not only alter output mean, but it may also affect output risk. To the extent that farmers are not neutral to risk, the analysis of policy effects should explicitly consider the contribution of agricultural inputs on the stochastic element of production.

To consider this matter we use an extended version of Leathers and Quiggin (1991) model of production under uncertainty that allows for decoupled income supports. We also extend their comparative statics analysis to derive policy-induced changes on output mean and variability. Our framework offers an improved picture of farmers' behaviour by assessing the effects of policy instruments on input consumption, production mean and risk. The theoretical model shows that under the assumption that farmers are characterized by DARA preferences, an increase in decoupled payments will only increase input use if the input is risk-increasing. However, if it is risk-decreasing, its use will drop. Hence, lump sum payments will result in an increase in output variability. This finding contrasts with previous analyses that have ignored the role of inputs in the stochastic component of production. These studies have concluded that an increase in lump sum payments will inevitably lead to an increase in input use, independently of the type of input. We also consider the effects of lump sum payments on output mean. We use farm-level data collected in Kansas to illustrate our model. Consistent with theory, results suggest that decoupling may result in an increase in output variability and mean for the farms in our sample.

Several directions for further work are apparent. One main area of consideration should be the incorporation in the model of other sources of risk that cause output to fluctuate. The function that represents output variability has been specified as a function that depends only on input use. However, it is likely that output variability also depends on other factors such as crop growth conditions and pest levels. These other uncertainty sources may play an important role in explaining output variability and may interact with the effects of input use on output fluctuations. The collection of better data to capture these issues would allow assessing the degree to which our results are sensitive to the model specification.

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