Investment rigidity and policy measures

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Summary

This paper assesses the impacts of decoupled government transfers on production decisions of a sample of Kansas farms. Our empirical analysis is based upon a reduced-form application of the dual model of investment under uncertainty developed by Sckokai (2005), which is extended to a consideration of irregularities in the capital stock adjustment cost function. To do so we adopt the threshold regression methods proposed by Hansen (1999). The econometric results support the existence of three regimes characterised by different economic behaviour. Our analysis suggests that in a dynamic setting that allows for irregularities in the capital adjustment cost function, decoupled transfers can have a powerful influence on production decisions. The dynamics of the stock of capital cause this influence to grow over time.

Key words: Investment, Decoupling, Threshold Behaviour

JEL classification: Q12, Q18

1. Introduction

With the proliferation of decoupled instruments over the last two decades as a key element in agricultural policy formulation in developed countries, several studies seek to assess the impacts of these instruments on farmers' decisions. Published work in this area considers the three chief mechanisms through which policy measures can affect agricultural production.

The first group contains papers studying the partially decoupled area payments introduced in the European Union (EU) by the 1992 Common Agricultural Policy (CAP) reform, focusing on the static effects of policy under risk neutrality. In this scenario, policies will only impact on farmers' economic decisions as long as they alter relative market prices. Papers within this group include Guyomard et al. (1996), Moro and Sckokai (1999) and Serra et al. (2005) and have generally used a theoretical framework approach that assumes perfect markets and risk neutral producers.

Price-neutral policies can also influence production in a static framework with risk averse economic agents, by means of altering price or revenue uncertainty and exogenous income. A more recent avenue of research on decoupling has explicitly allowed for risk and risk preferences (Sckokai and Moro, 2006; Serra et al., 2006). This literature generally builds upon Sandmo's (1971) seminal paper demonstrating that lump sum transfers, by means of altering farm household wealth, can affect individuals' risk preferences and their economic decisions.

More incipient is the literature considering the dynamic effects of policy. Farm output is a function of different inputs including the level of capital, which depends on

past decisions on investments. To the extent that lump sum transfers can alter investment demand, the effects of decoupled policies on production may play a more important role in a dynamic setting. The latter constitutes a third mechanism through which agricultural policy can affect economic decisions, i.e., through the dynamic investment response, which will have long-lasting impacts on production. Our paper will focus on assessing this dynamic response.

As detailed in the literature, in a world with perfect capital markets, statically decoupled payments are not likely to influence a farm's capital stock. However, decoupled payments may have the effect of stimulating farm investments in the presence of capital market imperfections such as financial constraints on borrowing, which will carry their output effects into future years. The literature on this topic has been sparse with Sckokai (2005) and Coyle (2005) being two notable exceptions. Following the modern theory on investment under uncertainty (Dixit and Pindyck, 1994), which recognizes the importance of uncertainties related to future market conditions in the decision to invest, Sckokai (2005) not only assesses the dynamic investment effects, but also allows for risk preferences and some degree of uncertainty affecting production and investment decision choices. Our empirical application is based upon the framework proposed by Sckokai (2005).

In line with the typical classical dynamic setting, the literature on the effects of decoupling on investment decisions has assumed convex investment costs that allow quasi-fixed inputs to adjust smoothly over time to their optimal level, where the shadow value of capital equals its marginal adjustment costs (Lucas, 1967; Rothschild, 1971). Irregularities in the adjustment cost function however, may prevent firms from adjusting

to changing market conditions. Following Abel and Eberly (1994) and Boetel et al. (2007), we extend the previous literature on decoupling by allowing for these irregularities by specifying threshold-type behaviour in investment demand. To do so, we adopt the threshold regression estimation procedures proposed by Hansen (1999). Hansen's threshold estimation procedures are a relatively new technique within the investment literature and they have not been previously applied to assess the impacts of decoupling, which constitutes the main novelty of our analysis.

Our empirical analysis focuses on assessing the impacts of the extensive reform that the US farm policy underwent in 1996. The reform was embodied in the 1996 Federal Agriculture Improvement and Reform (FAIR) Act and involved a reduction in the coupled element of income support. Price supports were cut and the negative effects of price changes on farmers' incomes were compensated by production flexibility contract (PFC) payments that did not require the production of certain crops and were not linked to actual production or prices, and by a deficiency payment that guaranteed a minimum support price for program crops. Our objective is to determine the dynamic investment effects of PFC payments using farm-level data from the Kansas Farm Management Association dataset.

2. Adjustment cost irregularities in agriculture

Typically, the adjustment cost function is assumed to be strictly convex with a value of zero at zero investment, which allows a smooth adjustment of quasi-fixed inputs to their

optimal level. The existence of irregularities (such as nonconvexities) leads to nonsmooth adjustment and is likely to prevent firms from continuously adapting to changing market conditions, leading to the asset fixity problem. Fixed costs of adjustment as well as irreversibility have been identified as the main reasons causing the asset fixity problem (Galbraith and Black, 1938; Johnson, 1958; Arrow, 1968; Dixit and Pindyck, 1994; Abel and Eberly, 1994). Fixed costs of adjustment such as managerial decision costs, fixed costs of placing orders, etc., are nonnegative costs that do not depend on the level of investment and that are incurred when investment is nonzero.

Irreversibility occurs when capital goods cannot be sold at the same price as they were purchased. This is likely to occur when firms use specialized assets that complicate intersectoral and even intrasectoral adjustments. Recent research has focused on the relationship between irreversibility and uncertainty both at the theoretical and empirical levels (Pindyck, 1991; Abel and Eberly, 1994; Chavas, 1994; Chang and Stefanou, 1988; Oude Lansink and Stefanou, 1997; Pietola and Myers, 2000; Boetel et al., 2007).

Asset fixity in agriculture has been widely documented in the literature and results are quite mixed. Early studies on the topic (Tweeten and Quance, 1969; Houck, 1977; Traill et al., 1978) essentially estimate irreversible supply and factor demand equations by splitting data into two portions, one corresponding to output price increases and the other to output price declines, and they fit different regressions to each portion. Irreversibility is assessed by testing whether the slopes of the two regressions differ. Results generally provide evidence in favor of asset fixity in US agriculture or in several of its subsectors. Validity of the testing is however conditional upon accurate classification of the data in order to represent the true underlying economic process.

Chambers and Vasavada (1983) test for asset fixity in US agriculture using the putty-clay hypothesis. All forms of fixity considered are statistically rejected. By using investment dynamic dual models and testing the hypothesis that the capital adjustment rate is equal to minus one (and whose rejection is interpreted as evidence of irreversibility), Vasavada and Chambers (1986) and Howard and Shumway (1988) obtain evidences in favor of the quasi-fixity problem in US agriculture and in the US dairy sector, respectively.

Nelson et al. (1989) test for asymmetries in investment in US agriculture by using a Markov chain model of transition between investment and disinvestment. They find some evidence supporting asymmetry, which is stronger in specialized assets. Specialized farm quasi-fixed assets such as farm real estate or agricultural machinery have little uses outside the agricultural sector and are thus more prone to display the asset fixity problem.

Most of the empirical analyses on asset fixity in agriculture, including the papers cited above, have not explicitly modeled this problem. A few exceptions are Chang and Stefanou (1988), Oude Lansink and Stefanou (1997), Pietola and Myers (2000), and Boetel et al. (2007). Chang and Stefanou (1988) allow for asymmetric adjustment in the dynamic dual approach using an endogenous switching model and a tobit switching model to correct for selectivity bias. They find symmetry to be rejected for Pennsylvania dairy farms. Following Abel and Eberly (1994), Oude Lansink and Stefanou (1997) use a threshold model to characterize investment demand in the Dutch cash crop sector. In their model, however, observations on zero investments are not used and only the investment and disinvestment decisions are estimated by a Tobit procedure. Their results show that it is optimal for the producer neither to invest nor to disinvest for a range of shadow prices;

moreover, adjustment is found to be asymmetric, being faster in the contracting regime than in the expanding regime. Pietola and Myers (2000) use a stochastic dual model of investment under uncertainty that allows for asymmetry in investment response during capital expansion and contraction phases. However, the model does not postulate a threshold decision rule as proposed by Abel and Eberly (1994). Focusing on assessing structural adjustment in the Finnish hog sector, labour investment is found to be asymmetric.

In the spirit of Abel and Eberly (1994), Boetel et al. (2007) address the issues of asymmetries in investment behaviour and the possible existence of a sluggish regime in the demand for quasi-fixed inputs, by adopting a relatively new threshold estimation procedure proposed by Hansen (1996, 1999, 2000). Their results suggest the relevance of allowing for investment rigidity when estimating supply and variable input demand in the US hog industry. Our empirical application follows Boetel et al. (2007) in that we also use Hansen's (1996, 1999, 2000) threshold estimation procedures to allow for irregularities in capital adjustment costs.

3. The Model and Estimation Methods

The literature addressing agricultural investment decisions based on the duality theory developed by McLaren and Cooper (1980) and Epstein (1981) has generally imposed rather restrictive assumptions on risk and risk preferences. More recent developments have allowed for nonstatic price expectations and risk though assuming risk neutral

economic agents (see Luh and Stefanou, 1996; and Pietola and Myers, 2000). In a static expectations framework, Sckokai (2005) has allowed for risk and risk preferences. Our empirical analysis builds on the dynamic dual model of investment under uncertainty developed by Sckokai (2005) by considering irregularities in the capital stock adjustment cost function.

Under the assumption that farmers are risk averse and take their decisions with the aim of maximizing the discounted utility over an infinite horizon, the value of the firm can be represented as (Sckokai, 2005):

$$J(.) = \max_{I,x} \int_0^\infty e^{-rt} u(A, \sigma_A^2) \text{ s.t. } \dot{k} = (I - \delta k), \tag{1}$$

where function u is a farmer's utility function which is assumed to depend on the expected farm's wealth $A = A_0 + \bar{p}\, y - wx - ck + S$ and its variance σ_A^2, while r is the interest rate, $\dot{k}$ is the time derivative of the capital path, I is the level of gross investments, δ is the capital depreciation rate and k are the units of capital stock. Concerning the specification of A, A_0 is a farm's initial wealth, x is the quantity used of a variable input that can be adjusted at no cost, $y = f(x, k, I)$ is a farm's single output production function, p is the market output price, which is assumed to be a random variable with mean $\bar{p}$ and variance σ_p^2, hence $\sigma_A^2 = f\left(\sigma_p^2\right)$, w is the variable input price, c is the capital rental price and S are decoupled payments. The Hamilton-Jacobi-Bellman equation corresponding to the optimization program is:

$$rJ = \max_{I,x} \left\{ u + J_k \left(I - \delta k \right) \right\} \tag{2}$$

where the subscript k denotes the first derivative of J. The first derivatives of this expression with respect to output and input prices will yield the investment demand, output supply and input demand equations $\dot{k}(r, A_0, \bar{p}, w, c, S, \sigma_p^2, k)$, $y(r, A_0, \bar{p}, w, c, S, \sigma_p^2, k)$ and $x(r, A_0, \bar{p}, w, c, S, \sigma_p^2, k)$.

The theoretical framework by Sckokai (2005) does not consider irregularities in the capital adjustment cost function. Abel and Eberly (1994) develop a theoretical framework based on an augmented adjustment cost function that allows for differences between purchase and resale asset prices, asymmetries in fixed capital adjustment costs, and a kink in the conventional adjustment cost function at its origin. Within this framework, capital investment is a non-decreasing function of the asset's shadow price, J_k. However, it does follow a threshold-type behaviour characterised by a lower and an upper critical value of the shadow price. Optimal gross investment is expected to be positive (negative) for shadow prices above (below) the upper (lower) threshold. For shadow prices in the range comprised between the two thresholds, capital may not adjust (or may adjust more slowly) to exogenous shocks.

As shown by Boetel et al. (2007), Abel and Eberly's (1994) threshold-type behaviour can be empirically estimated by following Hansen (1996, 1999, 2000) threshold estimation procedures. We apply these estimation methods to assess the dynamic investment effects of decoupled transfers. As noted above, the use of Hansen's

threshold methods in assessing the impacts of decoupling constitutes the main novelty of our analysis.

Boetel et al. (2007) only allow the slope coefficient on capital stock in the investment demand equation to switch among regimes, thus permitting adjustment speed to long run equilibrium to vary by regime. By further allowing for asymmetry in immediate short run responses, we extend their empirical implementation by also allowing the coefficient on the output price in the investment demand equation to vary across regimes. In order for output supply and variable input demand to reflect investment regimes, these equations are estimated conditional on the stock of capital as well as on investment levels.[1] Contrary to Boetel et al. (2007), the system of first-order conditions is estimated simultaneously to avoid inefficiencies in the estimation process.

As is well known, the empirical counterparts for the output supply and input demand equations can be derived by specifying a functional form for the value function J. However, the result is a nonlinear system of equations that seriously complicates the computational implementation of threshold regression methods. These methods generally assume that while a variable adjusts differently (but nonlinearly) across regimes, there is a linear adjustment within each regime. We thus estimate a reduced-form of the equations of the system where the optimal output supply and input demand equations are expressed as:

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[1] We thank an anonymous referee for this suggestion.

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\begin{cases}
\dot{k} = \boldsymbol{\beta}'_{11}\mathbf{m}_1 T\left(J_k < J_k^l\right) + \boldsymbol{\beta}'_{12}\mathbf{m}_1 T\left(J_k^l \leq J_k \leq J_k^u\right) + \boldsymbol{\beta}'_{13}\mathbf{m}_1 T\left(J_k > J_k^u\right) + e_1 \\
y = \boldsymbol{\beta}'_2 \mathbf{m}_2 + e_2 \\
x = \boldsymbol{\beta}'_3 \mathbf{m}_2 + e_3
\end{cases}
\tag{3}
$$

where all $\boldsymbol{\beta}$'s are vectors of parameters and $\mathbf{m}_1$ and $\mathbf{m}_2$ are the vectors of exogenously

determined explanatory variables, namely $\mathbf{m}_1 = \left(r, A_0, \bar{p}, w, c, S, \sigma_p^2, k_{-1}\right)$ and

$\mathbf{m}_2 = \left(r, A_0, \bar{p}, w, c, S, \sigma_p^2, k_{-1}, I_{-1}\right)$, with k_{-1} and I_{-1} denoting the lagged values of capital

and investment, respectively.[2] $T(.)$ is an indicator function taking the value of one if the

condition inside the parenthesis is met and zero otherwise. Since the shadow values of the

quasi-fixed input J_k are not observable, we assume that there exists a mapping between

these shadow values and the lagged values of net farm income on a per acre basis.[3] The

upper and lower thresholds are represented by J_k^u and J_k^l respectively and $\boldsymbol{\varepsilon} = \left(e_1, e_2, e_3\right)$

is the vector of independently and identically distributed errors.

The econometric methods used to estimate the system in (3) are described in

Hansen (1996, 1999, 2000). Hansen's (1999) proposal to estimate a single equation

model using threshold techniques is generalized to our system of equations using

sequential conditional iterated SUR in two stages, as in Serra and Goodwin (2003).

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[2] Lagged values of k and I have been used to avoid endogeneity issues.

[3] Since Hansen (1999) does not provide a method to objectively choose among different specifications of

the threshold variable, different alternatives were considered and we selected the one producing results

more compatible with previous research and economic theory.

In the first stage a grid search is carried out to estimate the threshold parameters J_k^l and J_k^u. The lower threshold is searched over the minimum and median of the lagged net farm income, while the upper threshold is searched over the range that goes from the median to the maximum value of the lagged net farm income. The search is restricted to ensure an adequate number of observations in each regime. For a given pair $\left(J_k^l, J_k^u \right)$, regression coefficients are estimated by SUR.[4] From this estimation the logarithm of the determinant of the variance-covariance matrix of the residuals Σ is derived as $S\left(J_k^l, J_k^u \right) = ln \left| \hat{\Sigma} \left(J_k^l, J_k^u \right) \right|$, with $\hat{\Sigma} \left(J_k^l, J_k^u \right)$ being a multivariate SUR estimate of $\Sigma = var(\varepsilon)$ conditional on J_k^l and J_k^u.

In the second stage of the estimation process, the SUR estimate of $\left(J_k^l, J_k^u \right)$ is obtained by minimizing function $S\left(J_k^l, J_k^u \right)$, which is equivalent to maximizing a likelihood function $\left(\hat{J}_k^l, \hat{J}_k^u \right) = \underset{J_k^l, J_k^u}{\operatorname{argmin}} S\left(J_k^l, J_k^u \right)$ (Hansen and Seo, 2002). To test for the significance of the differences in parameters across regimes, we use the likelihood ratio proposed by Hansen (1999) and Lo and Zivot (2001). Since this test does not follow a standard distribution, its value is compared against the critical values derived from the

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[4] The error variance-covariance matrix used in SUR estimation is specified as usual ($\Sigma \otimes \mathbf{I}$, where $\mathbf{I}$ is the identity matrix) to allow for cross-equation correlation. The estimate of the cross-equation error covariance matrix is obtained by first fitting the model using ordinary least squares.

bootstrap procedure outlined in Hansen (1996). Confidence intervals for the threshold parameters are derived as in Hansen (1999).[5]

3. Empirical Implementation

The model is estimated using farm-level data for a sample of Kansas farms observed from 1997 to 2001 which corresponds to the implementation of the FAIR Act. Micro data are derived from the Kansas Farm Management Association (KFMA) database. Aggregate data are also used to define those variables unavailable at the farm-level. Since the KFMA database does not register input and output prices, national-level input and output price indices are taken from the National Agricultural Statistics Service (NASS). The United States Department of Agriculture (USDA) provides state-level marketing assistance loan rates and PFC payment rates. The Federal Reserve provides data on the federal funds rate.

Our analysis concentrates on those farms specialized in production of the most relevant crops in Kansas, i.e., wheat, corn, grain sorghum and soybeans. In this regard, we only consider those farms whose sales of the four crops represent at least 80 per cent of total sales. We define a single output category (y) that aggregates the production of wheat, corn, grain sorghum and soybeans. To do so, national-level crop price indices and

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[5] The econometric theory concerning confidence intervals for threshold parameters has been developed by Hansen (1999) for a single equation model. Although our system of equations is estimated jointly for efficiency issues, only one equation is estimated with threshold effects.

farm-level income from each individual crop are aggregated using appropriate index number methods to form composite price and quantity indices. More specifically farm-level Divisia price indices are built from these data which allow deriving farm-level quantity indices by dividing total income by the Divisia price index. Once the aggregate output price index is built, we define expected output prices at the farm level using the adaptive expectation hypothesis as suggested by Chavas and Holt (1990).

The aggregate variable input includes pesticides and insecticides, fertilizer, seed, gas-fuel-oil and irrigation energy. National-level input price indices and farm-level expenditures on each input are aggregated using the same index methods as is the case of outputs. Capital aggregate price (z) and quantity (k) indices are built in the same fashion and include vehicles, machinery and buildings. The rental price for capital (c) is computed by assuming that the current asset price can be derived as a continuously discounted sum of all future rents on the depreciated asset (see Epstein and Denny, 1983; and Pietola and Myers, 2000). According to this assumption, the rental price of capital is computed as $c = (r + \delta)z$, where c is the rental price, r is the interest rate corresponding to the annual federal funds interest rate and δ is the farm-level capital depreciation rate.

The Kansas database does not register PFC government payments. In its place, a single measure including all government payments received by each farm is available. We estimate farm-level PFC payments by approximating the acreage of the program crops (base acreage) and the base yield for each crop using farm-level data. The approximation uses the 1986-1988 average acreage and yield for each program crop and farm and allows to construct a balanced panel of 148 farms. PFC payments per crop are computed by multiplying the base acreage, the base yield and the PFC payment rate by

0.85.[6] PFC payments per crop are then added to get total direct payments per farm. This estimate is compared to actual government payments received by each farm. If estimated PFC payments exceed actual payments, the first measure is replaced by the second.

Initial wealth A_0 is computed as the lagged value of a farm's total assets (excluding the lagged capital stock already measured by k_{-1}). The variance of the output price is defined at the farm-level strictly following Chavas and Holt (1990), who propose a weighted sum of the squared deviations of past prices from their expected values. The value of the net farm income is computed as the value of farm production less operating expenses and depreciation. Its lagged value on a per acre basis is taken as the threshold variable. Summary statistics for the variables in the analysis are presented in table 1.

Table 1 here

Some details pertaining to the empirical estimation are described here. Following Sckokai (2005) all prices, subsidies and initial wealth are normalized by the capital rental price in the interest of parsimony. The variance of price is normalized by the square of the capital rental price. Since the capital rental price comprises the interest rate, r is not included again as a single explanatory variable to avoid multicollinearity issues. A total of 57 county-level dummy variables are incorporated in the final estimation to account for unobserved regional differences in land quality, farm management skills, agricultural production techniques, climate, etc. The inclusion of these dummies involves implementing a restricted version of the fixed effects panel data technique, in which

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[6] In doing this, we follow the formula devised to calculate PFC (see Young and Shields, 1996).

farms are assumed to be heterogeneous across regions, while homogeneity within regions is assumed though only for the unobserved variables. An F test for the significance of these effects is computed for each regime.[7]

Table 2 here

The point estimates of the two thresholds and their asymptotic 95 per cent confidence intervals are reported in table 2. The distribution of threshold estimates might depend on the data and the bootstrap size may not have an accelerated rate of convergence (Hansen, 1999). This may explain the wider confidence intervals for the first threshold parameter. The lower threshold is 9.38 and the upper equals 91.54, thus corresponding to small and large lagged returns to unpaid labour, management and equity on a per acre basis.[8] These thresholds separate firms into three different groups: those receiving low returns per acre (disinvestment regime), the ones with intermediate returns (no investment regime) and the group benefiting from the highest net farm income per acre (investment regime). The no investment regime concentrates 498 observations, while the disinvestment and investment regimes have 156 and 86 observations, respectively. The null hypothesis of no threshold against the alternative of two thresholds is rejected

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[7] As suggested by an anonymous referee, by extending Hansen's (1997) econometric theory to the multivariate setting, inference on parameter estimates can be probably carried out as if the thresholds were a priori known. As a result, tests for fixed effects to address specification issues can be computed within each regime.

[8] The first and the second threshold correspond to the 21th and 88th percentiles of the distribution of J_k.

using the likelihood ratio test proposed by Hansen (1999).[9] Fixed effects are found to be statistically significant.

Table 3 here

The regression slope parameter estimates and their standard errors are presented in table 3.[10] Allowing for two regime-dependent variables in the investment demand equation (lagged stock of capital and expected output price), the slope parameters of the lagged stock of capital take values ranging between -1 and 0. While this implies that capital adjusts to its long-run equilibrium, it is important to note that since these parameters are closer to 0 than to -1, our estimates are closer to non-stationarity than to stationarity. These coefficients are all statistically significant and differ across regimes. As expected, the lowest value corresponds to the central (no investment) regime, while the highest values are registered in the extreme (investment and disinvestment) regimes. In analogy with Boetel et al. (2007), capital adjustment is found to be asymmetric and shows a faster adjustment in the investment than in the disinvestment regime. Expected output price coefficients in the investment demand equation are also greater in magnitude in the extreme regimes. While in the extreme regimes these parameters are statistically significant at the 5 per cent confidence level, the price coefficient in the no investment regime is only statistically significant at the 10 per cent level. The non-threshold

[9] The null of one threshold against two thresholds was also tested and rejected (with a p-value of 0.01). Finally the null of zero versus one threshold was also rejected (p-value = 0.05).

[10] In order to save space, we do not present regional dummy parameter estimates, which are available from the authors upon request.

estimations for output supply and variable input demand find that increases in the lagged capital stock and in the expected output prices result in increases in output supply and variable input demand. Increases in the lagged value of investment demand are also found to motivate higher levels of variable input use and output produced.

Higher variable input prices are found to significantly reduce both output supply and input demand (table 3). The coefficients on the variance of output price have the expected negative sign and are statistically significant in the output supply and variable input demand equations. Hence, an increase in risk reduces production. The negative effects of risk may be related both to risk aversion and to the option value of waiting.[11]

The coefficient on decoupled payments is of particular interest, since it is positive and statistically different from zero in all the three equations. As shown by Sckokai (2005), decoupled payments can impact production levels by altering farmers' risk preferences and also through dynamic effects by stimulating investment demand. Focusing on the risk effects, consider initial wealth coefficient estimate which is positive and statistically significant in all three equations. Hence, an increase in wealth increases input use and output produced. The relevance of wealth in explaining production decisions is compatible with the relevance of risk attitudes in explaining production behaviour.[12] It is widely accepted that an economic agent's degree of risk aversion decreases with wealth (Sandmo, 1971; Hennessy, 1998). Hence, wealthier farmers, in being less risk averse, are likely to be more prone to expand their business size. Since

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[11] As noted by an anonymous referee, separating these two effects becomes very difficult in empirical analyses.

[12] The relationship between wealth and risk preferences should only be carefully established as we do not observe risk attitudes.

decoupled payments contribute to enhance wealth, they lead to increasing output supply and input demand. The second payment-type effects comprise the dynamic effects, which should be relevant because lump sum transfers not only motivate variable input use but also capital investments. This hypothesis is confirmed by the computed elasticities of output and inputs with respect to the policy instruments.

We analyse the sensitivity of the decision variables with respect to decoupled payments and, for comparison purposes, to output prices to understand the workings of the output supply/input demand system and to better assess the impacts of policy reform. As in Boetel et al. (2007), ours is a dynamic recursive system. The elasticities are derived at the data means for all three regimes for different lengths of run. The base-scenario solves for the system of equations by forcing the solution to be in each regime alternatively and holding the explanatory variables at their mean levels. Once we have the regime-dependent solution, we increase decoupled payments by 5 per cent and the solution to the system is re-computed. A comparison of the quantities in the base scenario with those derived after the shock allows computing the elasticities for different time periods. The same operation is repeated to assess the impacts of a shock in output prices. Results for the impacts of an output price increase and of a decoupled payment increase are presented in tables 4 and 5, respectively.

Tables 4 and 5 here

Empirical results show that both short-run and long-run price and payment elasticities are inelastic. Expected price elasticities are positive and decline as we move

from the extreme regimes towards the central regime. With regards to the extreme regimes, prices are found to be more influential in good rather than in bad economic scenarios. These results are compatible with the change in expected price parameter estimates across regimes: while price coefficients in the extreme regimes are highly significant and larger than in the central regime, output price in the central regime is not significant at the 5 per cent confidence level (although it is significant at the 10 per cent level).

Payment elasticities tell a different story, since the influence of government support is generally more relevant in difficult economic situations than in more prosperous times (table 5). Decoupled payments exert a positive influence on investment demand. However, the impact of these payments declines as the shadow price of capital increases and thus as we move from the disinvestment to the investment regimes. This pattern is especially clear in the intermediate and in the long-run. The impact of decoupled payments on output supply and input demand follows a similar path. This result is important and shows that the main role of subsidies is to stimulate production during difficult times.

When comparing the relative strength of price and payment elasticities, we find that price is the most powerful economic incentive in favorable economic situations, while payments can be more influential during economic difficulties. In the disinvestment regime, for example, while prices have a stronger impact than PFC payments on investment demand, variable input use increases more as a result of government support. Hence, it is likely that in the disinvestment regime, decoupled payments are mainly devoted to increase output by means of increasing variable input use. In the no

investment regime where output prices are only statistically significant at the 10 per cent level, PFC payments are more relevant than prices in stimulating output supply and input demand.

The derived payment impacts are higher than the ones reported by previous analyses that have ignored the dynamic investment response, as well as the irregularities in the capital stock adjustment function (see Serra et al., 2006; Moro and Sckokai, 1999). Both payment and price elasticities increase over time as a result of the dynamic effects. Price elasticities experience considerable increases within the ten-year period studied (investment demand elasticities increase between 300 and 350 per cent, while output supply and variable input demand elasticities experience increases between 50 and 200 per cent). Investment demand payment elasticities experience similar increases as the corresponding price elasticities. Output and variable input payment elasticities experience smaller increases, ranging from 40 to 80 per cent.

4. Concluding remarks

This paper assesses the impacts of decoupled government transfers on production decisions of a sample of Kansas farms observed from 1997 to 2001. Our empirical analysis is based upon a reduced-form application of the dual model of investment under uncertainty developed by Sckokai (2005) which is extended to a consideration of irregularities in the capital stock adjustment cost function. Following Boetel et al. (2007), we adopt the threshold estimation procedure proposed by Hansen (1999).

We allow the slope coefficient of the lagged capital stock in the investment demand equation to switch among investment regimes, thus permitting the adjustment speed to long run equilibrium to vary by regime. In addition, extending the work by Boetel et al. (2007), we also consider asymmetry in immediate short run responses by allowing the expected output price coefficient in the investment demand equation to change among regimes.

The econometric results support the existence of three different regimes characterised by different economic behaviour. A first group includes firms receiving a low per acre return to unpaid labour, management and equity (disinvestment regime), firms receiving an intermediate income belong to the second group (no investment regime), while the third group is composed by firms receiving the highest income (investment regime). Firms in the no investment regime have the slowest capital adjustments, while those in the disinvestment and investment regimes adjust capital stock at a quicker rate.

In order to determine the impacts of decoupled payments on production decisions, we compute the elasticities of the decision variables with respect to these payments and, for comparison purposes, with respect to output prices. Results suggest that in our dynamic setting price elasticities are positive and decline as we move from the extreme towards the central regimes. Payment elasticities tell a different story: the influence of government support is generally more important in difficult economic situations than in more prosperous times. This result is important and shows that the main role of subsidies is to stimulate production during difficult situations.

When comparing the relative strength of price and payment elasticities, we find that price is the most powerful economic incentive in favorable economic situations, while payments can be more influential during economic difficulties. It is also noteworthy that the derived payment impacts are higher than the ones reported by previous analyses that have ignored the dynamic investment response, as well as the irregularities in the capital stock adjustment function. Both payment and price elasticities increase over time since the dynamics of the stock of capital cause the influence of both prices and subsidies to grow over time.

Acknowledgements

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Table 1. Summary statistics for the variables used in the analysis (N=740)

Variable		Estimate (standard deviation)
k_{-1}	Lagged capital stock (index)	188,391.330 (150,011.440)
r	Interest rate	0.052 (0.008)
$\bar{p}$	Expected output price (index)	1.119 (0.247)
S	PFC payments (constant 1998 USD)	15,179.650 (9,239.380)
w	Variable input price (index)	1.050 (0.054)
c	Capital rental price (index)	0.167 (0.039)
A_0	Initial wealth (constant 1998 USD)	543,379.870 (471,451.770)
σ_p^2	Variance of output price	0.059 (0.039)
$\dot{k}$	Time derivative of capital (index)	4,336.130 (35,532.970)
y	Output quantity (index)	165,155.240 (143,883,760)
x	Variable input quantity (index)	70,056.550 (61,850.000)
J_k	Assets' shadow price (constant 1998 USD per acre)	41.445 (46.310)

Note: Divisia indices are computed using 1998 as the base year. Quantity indices are obtained by dividing income (or expenditures) by the corresponding price index.

Table 2. Threshold estimates for the estimated system and specification tests

Threshold	*Estimate*	*95 per cent confidence intervals*
Lower	9.380	-7.620 – 15.380
Upper	91.545	83.545 – 95.545

Specification Tests		*Test value (p value)*
LR test		15.251 (0.019)
F test for fixed effects	Disinvestment regime	1.22 (0.080)
	No investment regime	3.690 (0.000)
	Investment regime	2.070 (0.000)

Table 3. Parameter estimates for the estimated system

Variable	Investment demand			Output supply	Variable input demand
	Disinvestment regime N=156	No investment regime N=498	Investment regime N=86		
k_{-1}	-0.120**	-0.066**	-0.148**	0.098**	0.030**
	(0.020)	(0.015)	(0.026)	(0.005)	(0.002)
$\bar{p}$	12,119.377**	8,732.635*	17,321.187**	4,378.452**	2,450.672**
	(6,326.576)	(5,132.204)	(6,297.730)	(1,856.957)	(859.568)
w			-16,635.920**	-9,813.390**	-4,790.567**
			(5,829.503)	(2,156.964)	(998.278)
σ_p^2			-1,678.029	-2,049.679*	-1,600.813**
			(3,261.260)	(1,215.775)	(562.811)

* (**) denotes statistical significance at the 10 (5) per cent significance level. Values in parenthesis are standard errors.

Table 3. Parameter estimates for the estimated system (continued)

Variable	Investment demand	Output supply	Variable input demand
S	0.766**	0.371**	0.248**
	(0.211)	(0.079)	(0.037)
A_0	0.010**	0.006**	0.003**
	(0.004)	(0.001)	(0.001)
I_{-1}		0.025*	0.026**
		(0.014)	(0.006)
R-squared	0.20	0.78	0.99

* (**) denotes statistical significance at the 10 (5) per cent significance level. Values in parenthesis are standard errors.

Table 4. Elasticities under the different investment regimes: Responses (in per cent) to a permanent 5 per cent output price increase

Period	Investment demand			Output supply			Input demand		
	Disinvestment regime	No investment regime	Investment regime	Disinvestment regime	No investment regime	Investment regime	Disinvestment regime	No investment regime	Investment regime
1st	0.735	0.513	1.024	1.283	1.158	1.418	1.637	1.489	1.787
5th	1.737	1.229	2.267	2.029	1.655	2.371	2.174	1.849	2.455
10th	2.440	1.781	3.010	2.553	2.056	2.943	2.552	2.149	2.859

Table 5. Elasticities under the different investment regimes: Responses (in per cent) to a permanent 5 per cent decoupled payments increase

Period	Investment demand			Output supply			Input demand		
	Disinvestment regime	No investment regime	Investment regime	Disinvestment regime	No investment regime	Investment regime	Disinvestment regime	No investment regime	Investment regime
1st	0.615	0.596	0.599	1.343	1.308	1.337	2.003	1.944	1.692
5th	1.452	1.425	1.326	1.966	1.887	1.887	2.450	2.351	2.373
10th	2.039	2.065	1.760	2.404	2.353	2.217	2.764	2.689	2.604