Hedging Yield with Weather Derivatives: A Role for Options

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Abstract

While there are few risk management alternatives available to specialty crop growers, weather derivatives provide an important advancement. As with the use of any derivatives contract, the behavior of the basis will ultimately determine the net-hedged outcome. However, when using weather derivatives to hedge yield risks for specialty crops, growers face a unique form of basis risk because weather (temperature) and yield are nonlinearly related. Using the forecast encompassing principle, this research shows that the nonlinear relationship between yield and weather creates a role for options in an optimal hedging program. The results suggest that weather derivative instruments with nonlinear payoffs, such as options, be used in combination with linear payoff instruments, such as swaps or futures, to minimize basis risk associated with the nonlinear relationship between yields and weather.

Key Words: Weather Derivatives, Forecast Encompassing, Composite Hedges

JEL: Q14, G13

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Introduction

Weather derivatives are an important new tool for agribusiness risk management. Weather derivatives are a particularly important financial innovation for growers of crops in which few or no risk management tools are available, such as the case with specialty crops (Blank). Defined generally, weather derivatives are financial instruments with a value that is contingent on an underlying weather index. The form of the instrument can be a futures contract, an option, a swap, or a hybrid security that combines features of each. Typically, the underlying security is either cooling degree days (CDD) – the cumulative amount by which the daily temperature exceeds 65 degrees Fahrenheit over a specified time period at a specific weather station – or heating degree days (HDD), which are defined opposite to CDD. A grower who believes she would be harmed by high temperatures, therefore, would perhaps buy a CDD futures contract or CDD call option. In this case, the rise in the value of the futures contract or call option, if temperatures are indeed high, would offset her perceived loss in revenue due to lower yields or crop quality.

Advancements have been made in developing and assessing methods to fairly price weather derivatives for hedging specialty crops, as well as determining the technological relationship between specialty crop yields and weather (Richards, Manfredo, and Sanders; Fleege et. al). Furthermore, Fleege et. al provide initial evidence based on Monte Carlo simulation methods of the hedging effectiveness of weather derivatives for representative specialty crop enterprises in California. Indeed, procedures to fairly price weather derivative contracts, along with evidence of their potential risk management effectiveness, are crucial to the development of an active over-the-counter market in weather derivatives. However, the severity of weather basis risk has contributed to apparent liquidity problems in both board-traded and over-the-counter weather contracts.

Basis risk resulting from the use of weather derivatives to hedge yields is inherently different, and more complex, than basis risk arising from the use of traditional exchange traded futures and options contracts. Specifically, basis is dependent on the relationship between yields and weather for a particular crop. Thus, when using weather derivatives to hedge yield risk, growers are likely to face two sources of basis risk: 1) spatial basis risk because the reference weather index almost certainly differs from their actual weather experience at the farm level and 2) technological basis risk because weather, or more specifically temperature, and yield are often nonlinearly related (Richards, Manfredo, and Sanders). In this paper, we focus on the second of these problems and examine whether growers should hedge their weather exposure using a linear derivative instrument (e.g., a futures contract or swap) or a nonlinear instrument (options). This is particularly relevant given the suggestion that options positions do play an important hedging role when the relationship between the underlying variable and the hedging instrument is nonlinear (Broll, Chow, and Wong).

Therefore, the objective of this paper is to demonstrate an effective strategy for constructing an optimal portfolio of weather-hedging instruments based on the forecast encompassing principle.

The forecast encompassing principle (Harvey, Leybourne, and Newbold) as applied to financial hedging (Sanders and Manfredo) means that if there are multiple ways to hedge a particular risk, and none of them are perfect, then the optimal hedging portfolio is likely to consist of different proportions of each hedging instrument. We specifically examine this problem in the context of hedging California nectarine yields with weather derivatives.

The remainder of the paper is presented as follows. First, minimum variance hedging in the context of forecast encompassing is discussed, and theoretical evidence of the hedging role of options is presented. Next, the methods and data used to specifically examine the hedging role of both linear and nonlinear weather derivatives in managing yield risks for an important California specialty crop, nectarines, are described. Results of the encompassing tests developed are presented, followed by a summary and discussion of results.

Minimum Variance Hedging, Forecast Encompassing, and Options

Hedgers using exchange traded futures contracts in hedging commodity price risk in essence trade the absolute price risk of the cash commodity for basis risk, where basis is defined as cash-futures price. In most hedging studies, ex-post hedging effectiveness is examined using a regression of cash price (or cash price changes) on futures price (or futures price changes) with the estimated coefficient on the futures price serving as the hedge ratio which minimizes basis risk (Leuthold, Junkus, Cordier; Witt, Schroeder, and Hayenga; Hull; Ferguson and Leistikow). The estimation of minimum variance hedge ratios is the standard procedure for determining the hedging effectiveness of a futures contract. The minimum variance hedging equation is typically specified as:

(1) $$\Delta CP_t = \alpha + \beta \, \Delta FP_t + e_{,t}$$

where ΔCP_t is the change in the cash price for a particular market, ΔFP_t is the futures price, α is the intercept term reflecting a systematic trend in cash prices, β is the minimum variance hedge ratio, and e_t represents the residual basis risk.[1] In this framework, ex-post hedging effectiveness is measured as the R^2 from this regression. Researchers, risk management practitioners, and designers of new futures contracts, use this framework to assess the hedging effectiveness of a particular futures contract relative to alternative hedging instruments.

When multiple futures contracts are available, Sanders and Manfredo suggest that useful information may be embedded in each of the available contracts, such that a hedge in a combination of the two contracts would actually reduce the residual basis risk relative to a hedge in only one of the contracts. Furthermore, a casual comparison of R^2 values does not mean that the suggested hedging superiority of one contract is statistically superior to the competing contract. Given this as motivation, Sanders and Manfredo illustrate and propose a new test for evaluating the ex-post hedging effectiveness of alternative futures contracts which utilizes the tests for forecast encompassing put forth by Harvey, Leybourne, and Newbold. Considering the

[1] Typically price changes are used. However, there is some controversy of whether price changes, price levels, or percent changes should be used. See Witt, Schroeder, and Hayenga for a discussion of this matter.

case where two competing futures contracts exist, the regression in equation (1) is estimated for both a preferred and competing futures contract.[2] In the case of the preferred contract, equation (1) is estimated as:

(2) $$\Delta CP_t = \alpha_0 + \beta_0 \Delta FP_t^0 + e_{0,t}$$

and, for the competing contract, equation (2) is estimated as

(3) $$\Delta CP_t = \alpha_1 + \beta_1 \Delta FP_t^1 + e_{1,t}$$

where FP^0_t is the price of the preferred futures contract, FP^1_t is the price of the competing futures contract, β_0 is the hedge ratio on the preferred contract, β_1 is the hedge ratio for the competing contract, $e_{0,t}$ is the residual basis risk for the preferred contract, and $e_{1,t}$ is the residual basis risk of the competing contract. For comparing the hedging performance of alternative futures contracts, Sanders and Manfredo (pg. 34 and 35) derive a test that is analogous to the forecast encompassing test of Harvey, Leybourne, and Newbold where:

(4) $$e_{0,t} = \phi + \lambda[(e_{0,t} - e_{1,t})] + v_t \,.$$

The null hypothesis that $\lambda=0$, is tested with a two-tailed t-test (Harvey, Leybourne, and Newbold). Therefore, a failure to reject the null hypothesis suggests that the preferred futures contract encompasses the competing contract[3] In other words, the competing futures contract provides no reduction in residual basis risk relative to the preferred. If the null hypothesis is rejected, then this suggests that positions could be taken in both the preferred and competing futures contracts that would provide a reduction in residual basis risk (a composite hedging position). The weight or proportion of the cash position to hedge in the preferred futures market is $1 - \lambda$, and the weight in the competing futures contract is λ. Considering this in the context of the hedging ratios estimated in equations (2) and (3), the new optimal hedge ratio for the preferred contract is $\beta_0(1-\lambda)$ and for the competing is $\beta_1\lambda$.[4,5]

Following Madalla, Sanders and Manfredo show that λ reflects the tradeoff between the residual basis risk of the competing and preferred futures contract such that:

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[2] The words "preferred" and "competing" are commonly used in the forecasting literature to distinguish between two or more forecasts that are being compared, and do not denote preference for one forecast (futures contract) over the other.

[3] Sanders and Manfredo show that equation (4) is similar to the J-test for testing non-nested hypothesis among competing model specifications.

[4] Arguably, a regression of the form $\Delta CP_t = \alpha_1 + \beta_1 \Delta FP_t^0 + \beta_2 \Delta FP_t^1 + e_t$ could be used instead of the encompassing test proposed in equation (4). However, Sanders and Manfredo discuss that the power of the test is reduced when the two regressors are collinear. Furthermore, Granger and Newbold (pg. 286) suggest that forecast evaluation tests be conducted where focus is on the error terms to avoid interpretative issues.

[5] This procedure can be used for any functional form, and easily handles conditional hedge ratios (Myers and Thompson).

(5) $$\lambda = \frac{\sigma_{e_0}^2 - \rho_{e_0 e_1}}{\sigma_{e_0}^2 + \sigma_{e_1}^2 - 2\,\rho_{e_0 e_1}\,\sigma_{e_0}\,\sigma_{e_1}}$$

where σ_{e_0} and σ_{e_1} are the standard deviation of the residual basis risk for the preferred and competing contracts respectively, and $\rho_{e_0 e_1}$ is the correlation between the basis risk of the two contracts. Thus, the λ which minimizes the basis risk reflects the ability of the competing futures contract to provide less absolute basis risk than the preferred, as well as less basis risk through diversification in a portfolio context. In other words, a positive λ suggests that a composite hedge can help reduce basis risk where the competing forecast provides a lower level of absolute basis risk ($\sigma_{e_0} > \sigma_{e_1}$), as well as the potential diversification effects provided by hedging a portion of the cash position in two different contracts ($\rho_{e_0 e_1}$ < 1).[6]

Hedging the variability of specialty crop yields caused by adverse weather conditions with a weather derivatives contract is obviously a different proposition than hedging a cash commodity position with an exchange traded futures contract. While there are many obvious differences, the primary difference arises in the definition and specification of the hedging relationship. In considering the pricing of weather derivatives for specialty crops, Richards, Manfredo, and Sanders as well as Fleege, et. al find that the historical relationship between yields and weather (CDD index) for various California specialty crops was nonlinear. For the case of nectarines in Fresno County, California, Richards, Manfredo, and Sanders found yields to be a concave quadratic function of a CDD index measured at the Fresno Air Terminal (FAT) as well as a linear time trend.

Broll, Chow, and Wong provide a theoretical model supporting the use of options as a hedging instrument when the relationship between spot and futures positions are nonlinear – a phenomenon they identify with exchange rates for several different countries. In the case of linear risk exposure, Broll, Chow, and Wong conclude that options on futures play no hedging role relative to futures contracts which possess linear payoffs. This assertion is similar to that of Lapan, Moschini, and Hanson in considering the competitive firm under output price uncertainty. However, in the case of nonlinear risk exposure, Broll, Chow and Wong do support the use of options, which have a nonlinear payoff structure, in combination with futures contracts. Thus, the combination of both linear and nonlinear positions addresses the convexity (concavity) of the risk exposure.

Methods and Data

The theoretical support for the use of combining hedging instruments with linear and nonlinear payoffs for hedging nonlinear risk positions (Broll, Chow, and Wang), is an appealing proposition. Hence, a composite hedge where positions are placed in weather derivative instruments possessing linear and nonlinear payoffs may reduce the technological basis risk that exists due to the known nonlinear relationship between specialty crop yields and weather

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[6] See Sanders and Manfredo (p. 35) for more detail.

(temperature). In examining this, two weather derivatives instruments are defined. First, a hedging instrument with a linear payoff function is defined as a swap on an underlying weather index. Therefore, this instrument essentially behaves identically to the underlying weather index. Second, a hedging instrument with nonlinear payoffs is defined as a straddle, which is the simultaneous purchase or sale of both a put and call option on an underlying weather index. As suggested by Richards, Manfredo, and Sanders, the relationship between nectarine yields and a weather index is nonlinear – yield is a quadratic (concave) function of a CDD index. Following the proposition of Broll, Chow, and Wang, yields can be hedged using either the linear instrument (swap), the nonlinear instrument (straddle), or a combination of both.

After defining these two weather derivative instruments, hedging regressions analogous to the traditional minimum variance hedge regression in (1), are estimated. In hedging yields, y_t, with a linear instrument, w_t, the relationship is defined as:

(6) $$y_t = \alpha_1 + \beta_1 w_t + e_{1,t}$$

where $e_{1,t}$ is the residual basis risk resulting from the hedge, and β_1 is the hedging weight or hedge ratio placed on the linear instrument (swap). When using a nonlinear hedging instrument (straddle), the hedging relationship is defined as:

(7) $$y_t = \alpha_2 + \beta_2 \Psi_t + e_{2,t}$$

where Ψ_t represents the value of the straddle position, β_2 is the hedging weight on the straddle position, and $e_{2,t}$ is the residual basis risk. In considering the known concavity of the relationship between nectarine yields and temperature, the payoff from the straddle position is specified as the negative of the absolute value between the underlying weather index and strike price such that:

(8) $$\Psi_t = -\left| w_t - strike \right| .$$

Assuming equations (6) and (7) are analogous to the cash / futures relationship represented in (1), and the resulting basis risk reflected by $e_{1,t}$ and $e_{2,t}$ respectively, the R^2 can be used as a measure of overall hedging effectiveness for each hedging relationship. However, given the findings of Broll, Chow, and Wang on the use of linear and nonlinear instruments in the presence of nonlinear risk exposure, as well as the use of forecast encompassing in assessing hedging effectiveness (Sanders and Manfredo), a composite hedge combining the instruments used in both equations (7) and (8) may be most appropriate for reducing residual basis risk relative to the individual hedging relationships. This notion is tested using the forecast encompassing test of Harvey, Leybourne, and Newbold described in equations (2) through (5).

The data used in estimating the hedging regressions and conducting the encompassing tests represent an important specialty crop in California – nectarines. Yield data are annual county average yields for Fresno County, California nectarines (tons per acre). These annual yield data span from 1982 to 2003 (21 observations). While yield data would ideally be available at the farm level, these county average data allow us to examine the basis risk that the "average" or "typical" nectarine farm in Fresno County would be exposed to. While there may be several reporting weather stations in or in relative proximity to a particular county or farm, only weather reported at the Fresno Air Terminal (FAT) is used to keep the analysis tractable, as well as focus the analysis on the portion of basis risk that is attributable to the technical relationship between nectarine yields and CDD. Cumulative CDD values are calculated as $CDD = \sum_{t=1}^{T} \max(0, w_t - 65)$. These cumulative CDDs are calculated for FAT during the critical growing period of May through July. Therefore, there is an ending cumulative CDD value to match each year of yield data (21 CDD observations). The weather (temperature) data used in developing these CDDs are obtained from the National Oceanic and Atmospheric Administration (NOAA) website.

Results

Table 1 presents summary statistics of the nectarine yield and Fresno cumulative CDD data used in the analysis. Average nectarine yields over the sample period were 9.08 tons per acre, with a maximum of 11.90 tons per acre, and a minimum of 6.90 tons per acre. The annual standard deviation was 1.14 tons per acre. Clearly, nectarine yields are quite volatile on an annual basis. The cumulative CDD values for FAT are also quite volatile, averaging 1084.52 with a standard deviation of 161.12. The minimum cumulative CDD value is 764.00 and maximum is 1388.00. Figure 1, however, is most informative as it shows the scatter plot of nectarine yields relative to CDD values. Clearly, the yield / weather relationship is nonlinear (yield is a concave function of CDD values).[7] As shown by Broll, Chow, and Wang, this relationship suggests that options positions, in conjunction with a position in a linear hedging instrument, may provide the best hedge.

In examining this notion, both equations (6) and (7) are estimated using the data described previously. In defining the straddle position defined in (8), a fixed strike price is chosen. This fixed strike price is chosen by estimating equation (7) for varying levels of the strike price, and then choosing a strike which maximizes the log likelihood function. Through this process, the optimal strike price used in defining the straddle in (8) is 1200, which is a level of CDD which provides the highest yield. This strike level can be confirmed visually from an examination of Figure 1. Table 2 presents the results from estimating the hedging regressions defined in (6) and (7). As shown by Sanders and Manfredo, the standard deviation of the residuals (σ_e) is a measure of basis risk, and the R^2 and significance of the estimated coefficients (β_1 and β_2) gives an indication of the overall strength of the hedging relationship. In both cases, the hedge ratios on the linear (swap) and nonlinear (straddle) instruments are significant at the 5% level. The R^2 from the nonlinear hedging model is slightly larger than that of the linear hedging model (0.217 versus 0.202). Following conventional wisdom, the higher R^2 of the nonlinear model would suggest the use of a straddle strategy in hedging nectarine yield risk in Fresno County. As well,

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[7] Richards, Manfredo, and Sanders estimate a yield / weather relationship for Fresno County Nectarines where the relationship is defined as $y_t = \alpha + \beta_1 w_t + \beta_2 w_t^2 + \beta_3 t + \varepsilon_t$ where y_t is yield, w_t is the cumulative CDD value, t is a time trend variable, and ε_t is a random disturbance term.

the standard deviation of the residual basis risk is also slightly lower for the nonlinear model (σ_{e2} = 1.005) than the linear model (σ_{e1} = 1.015). Both hedging regressions yielded low Durbin-Watson statistics, and the residuals exhibit non-normality based on the rejection of the null hypothesis of normal errors using the Jarque-Bera statistic.

The possibility of a composite hedge using both the linear and nonlinear weather derivative instruments is tested using the encompassing principle presented in equation (4). The linear hedging instrument is defined as the as the preferred contract, and the nonlinear hedging instrument defined as the competing contract such that:

(9) $$e_{1,t} = \phi + \lambda[(e_{1,t} - e_{2,t})] + v_t$$

where $e_{1,t}$ are the residuals from equation (6) and $e_{2,t}$ are the residuals from the nonlinear hedging relationship estimated in (7). If there is a failure to reject the null hypothesis of λ=0, then the linear hedging instrument (preferred) is said to encompass the nonlinear instrument (competing). That is, a composite hedging model could not be formed that would reduce the residual basis risk relative to the preferred. If this is the case, then all hedging should be conducted using the linear weather instrument. If the null hypothesis is rejected (λ does not equal zero) then this suggests that a composite hedge should be considered where a proportion of the hedge is placed in weather derivative contracts that have linear payoffs (swap) and nonlinear payoffs (straddle). Specifically, the weight placed on the preferred model is 1-λ, and the weight on the competing model is λ.

Results of the encompassing tests are presented in Table 3. A statistical pitfall of the encompassing test is that it can lack robustness in small samples when the residuals from the individual regressions ($e_{1,t}$ and $e_{2,t}$) are found to be non-normal (Harvey, Leybourne, and Newbold). Since there is indeed evidence of non-normality in the errors from both hedging regressions (Table 2), the Newey-West estimator is used to correct the covariance matrix. When the linear hedging model is designated as the preferred, the null hypothesis of λ=0 is rejected is rejected at the 5% level using a two-tailed t-test. This result suggests that a composite hedging model utilizing both a swap and straddle can be developed reducing the overall residual basis risk associated with the preferred model. A λ = 0.559, suggests that approximately 56% of the hedging position be placed in the straddle, and 44% be placed in the swap. Following Sanders and Manfredo, the new hedge ratio for the linear swap is 0.0014 [$\beta_1(1-\lambda)$], and 0.0029 [$\beta_2\lambda$] for the straddle.

Reversing the preferred and competing hedging models confirms the above result (Table 3). When the nonlinear model is designated as the preferred in the encompassing regression, the estimated λ is 0.44 as expected, but is not significant at the 5% level. This suggests that the straddle alone may serve as an effective hedge, and that the nonlinear straddle hedge encompasses the linear swap hedge. While encompassing cannot be rejected at the 5% level, it can be rejected at the 10% level. This, as well as the theoretical evidence presented by Broll, Wang, and Chow, suggests that there is indeed a role for options, especially when the risks are nonlinear in nature. This is clearly the case when hedging yield risks of specialty crops with weather derivatives where the typical yield / weather relationship has been found to be quadratic.

Summary and Conclusions

Weather derivatives provide growers of specialty crops the potential to manage yield risks associated with adverse or non-optimal weather phenomenon. Given that specialty crop growers have few market mechanisms to manage risks, insights gained through research on this unique derivative instrument enhances the probability that this financial market innovation will be successful. As is the case with any hedging tool, such as exchange traded futures and options, the behavior of the basis ultimately determines the final net-hedged outcome. This also holds when over-the-counter weather derivatives are used to hedge volumetric risks of specialty crops. Indeed, the definition of basis, and subsequently the consideration of basis risk, is inherently different for that of weather derivatives than the known cash-futures relationship that exists when using agricultural futures and options contracts. However, there are also similarities.

In this research, we argue that the estimated relationship between yields and weather is similar to that of the traditional optimal hedging regression of cash on futures price. Thus, a major source of basis risk when considering the use of weather derivatives is the technological relationship between yields and the underlying weather index used. As with the cash / futures relationship, basis risk can be represented by the residuals of the yield / weather relationship, and this relationship is likely to be nonlinear in nature.

We use the encompassing methodology put forth by Harvey, Leybourne, and Newbold, and extended to financial hedging by Sanders and Manfredo, for examining alternative futures hedges to evaluate the residual basis risk associated with hedging California nectarine yields with weather derivatives based on cumulative CDD. Both weather derivatives with linear payoffs (swaps) and weather derivatives with nonlinear payoffs (straddle) are considered individually, and in a composite framework. The results of the encompassing tests suggest that a composite hedge, which uses both linear and nonlinear weather derivatives, may be optimal. This empirical result is consistent with the theoretical results presented by Broll, Chow, and Wong that suggests options have a role in a hedging program when the relationship between the hedging instrument and the underlying is nonlinear.

The primary practical implication of these results is that basis risk in weather derivatives need not be an obstacle to weather derivatives trade in the future, because it is easily mitigated using the methodology outlined in this study. The methodology used relies on the historical relationship between the crop being hedged and weather, which is critical for a successful weather derivatives hedge. This methodology can also be extended to a multivariate framework (Harvey and Newbold), such that weather derivatives written on competing or nearby weather stations could also be considered in a composite. This multivariate approach may provide a way for researchers to simultaneously consider spatial basis risk with the technological basis risk resulting from the empirical yield / weather relationship. This idea remains a topic of current inquiry.

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Table 1. Summary Statistics for Annual Fresno County Nectarine Yields (tons/acre) & Cumulative CDD Values for Fresno Air Terminal (1982 – 2003)

	Yield (tons/acre)	**CDD (cumulative)***
Mean	9.08	1084.52
Standard Deviation	1.14	161.12
Minimum	6.90	764.00
Maximum	11.90	1388.00
Observations	21.00	21.00

*Cumulative CDD is defined as $CDD = \sum_{t=1}^{T} \max(0, w_t - 65\,F^0)$ during the critical May through July growing period.

Table 2. Empirical Hedge Ratios for Fresno County Nectarines Using Linear and Nonlinear Hedging Instruments[1]

Linear Hedging Model		Nonlinear Hedging Model	
$y_t = \alpha_1 + \beta_1 w_t + e_{1,t}$		$y_t = \alpha_2 + \beta_2 \Psi_t + e_{2,t}$	
α_1	5.647	α_2	9.951
t-ratio	3.566 *	t-ratio	22.533 *
β_1	0.0032	β_2	0.0052
t-ratio	2.190 *	t-ratio	2.293 *
R^2	0.202	R^2	0.217
Durbin-Watson	1.268	Durbin Watson	0.898
Jarque-Bera	11.157 *	Jarque-Bera	9.453 *
$\sigma_{(e1)}$	1.015	$\sigma_{(e2)}$	1.005
$\rho_{(e1,e2)}$	0.920		

[1] y_t is nectarine yield, w_t is the cumulative CDD value, Ψ_t represents the straddle position, β_1 and β_2 are the empirical hedge ratios, $\sigma(e_{1,t})$ and $\sigma(e_{2,t})$ are the standard deviation of the residuals or residual basis risk, and $\rho(e_{1,t},e_{2,t})$ is the correlation between the basis risk for the alternative hedging specifications.

* Significance at the 5% level.

Table 3. Encompassing Regressions

Encompassing Regression (Preferred = linear: $e_{1,t} = \phi + \lambda[(e_{1,t} - e_{2,t})] + v_t$)	
Estimated λ	0.559
t-ratio	2.296 [a,*]
Encompassing Regression (Preferred = nonlinear: $e_{2,t} = \phi + \lambda[(e_{2,t} - e_{1,t})] + v_t$)	
Estimated λ	0.440
t-ratio	1.805 [a]

[a.] Estimated using the Newey-West covariance estimation procedure.
[*] Significant at the 5% level.

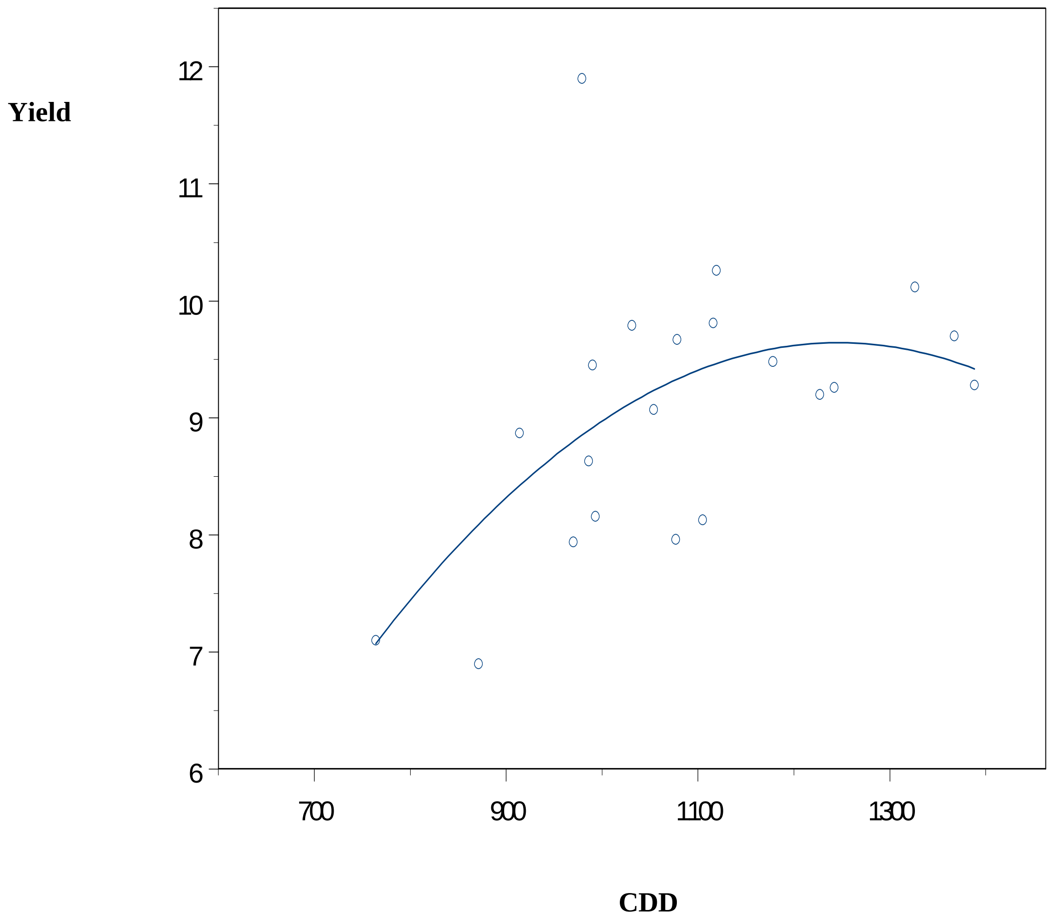

Figure 1. Fresno County Nectarine Yield vs. Cumulative CDD for Fresno Air Terminal (1982 – 2003)