Was Sandmo Right? Experimental Evidence on Producer Attitudes to Price Risk and Uncertainty

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Introduction

How do producers adjust their production decisions in response to output price risk and uncertainty?

In his seminal article, Sandmo (1971) answered this question by showing that an (income) risk-averse producer would hedge against price risk by decreasing how much he produces relative to a situation of price certainty, holding mean price constant.

Introduction

In this paper, we use experimental methods to study how producers behave in the face of output price uncertainty.

Specifically, we study how individuals who are put in the role of firm managers make production decisions in the presence of output price risk (uncertainty of a known form) and ambiguity (uncertainty of an unknown form).

Introduction

In the output price risk treatment, we use a two-stage randomized design to first determine whether producers face a certain or an uncertain output price and then, conditional on facing an uncertain price, to determine how much uncertainty they face.

This allows studying the effect of output price risk at the extensive and intensive margins, i.e., the effect of output price risk relative to output price certainty, and the effect of more relative to less output price risk.

In this price risk treatment, we show subjects the distribution we draw prices from.

Introduction

In the output price ambiguity treatment, we use the same two-stage randomized design to first determine whether producers face a certain or an uncertain output price and then, conditional on facing an uncertain price, to determine how much uncertainty they face.

In this price ambiguity treatment, however, we do not show subjects the distribution we draw prices from. Rather, we only tell them the range of possible prices.

Introduction

Our experimental design allows testing:

1. Whether the move from a certain to a risky output price causes producers to hedge by decreasing how much they produce, as Sandmo (1971) famously predicted,
2. Conditional on facing a risky output price, whether increases in output price risk cause producers to decrease how much they produce even more, and
3. Whether the move from a certain to an ambiguous output price causes producers to hedge by decreasing how much they produce and, if so, whether their response to output price ambiguity differs from their response to output price risk.

Introduction

In order to make sure that we are studying how experimental subjects respond to price rather than income uncertainty, we control for their income risk preferences throughout by controlling for our subjects' response in the Holt-Laury (2002) lottery game.

Lastly, in order to eliminate potential order effects, we run two versions of each of our output price risk and ambiguity treatments, viz. one in which subjects play the output price uncertainty game first and the Holt-Laury income risk lottery second, and one in which subjects played the Holt-Laury income risk lottery first and the output price uncertainty game second.

Introduction

This work is related to other work I have done. In Bellemare, Barrett, and Just (2013), we extended the estimation of price risk aversion to several staples. Using data from rural Ethiopia, we showed one cannot ignore the covariances between prices, and we derived at measure of willingness to pay for price stabilization.

The problem with Bellemare, Barrett, and Just (2013), however, is that the analysis relied on observational data.

Introduction

Indeed, the matrix A of price risk aversion derived in Bellemare, Barrett, and Just (2013) is such that for all $i, j \in \{1, ..., K\}$

$$A_{ij} = -\frac{M_i}{p_j}[\beta_j(\eta_j - R) + \epsilon_{ij}], \tag{1}$$

where M_i is the marketable surplus of commodity i, p_j is the price of commodity j, β_j is the budget share of commodity j, η_j is the income-elasticity of M_j, R is the coefficient of relative risk aversion, and ϵ_{ij} is the price j-elasticity of M_i.

Introduction

This means that many coefficients have to be estimated. For starters, all the elasticities η_j and ϵ_{ij} have to be estimated from marketable surplus regressions. Then, the budget shares β_j have to be computed from the data. Lastly, R has to be elicited from respondents–or an assumption has to be made about what it looks like.

In other words, the estimation of price risk preferences requires a number of heroic assumptions about functional forms, and it has so far relied on noisy observational data and less-than-ideal identification strategies.

Introduction

In this paper, we go for the gold standard by taking the theory of price risk to the lab. Specifically, we study producer attitudes (we leave consumers to future research) to price uncertainty by looking at both price risk *and* price ambiguity (or Knightian uncertainty).

In doing so, we provide a clean test of the theory by testing Sandmo's (1971) prediction that price uncertainty makes risk-averse individuals hedge by producing less than under price certainty (i.e., whether there is price uncertainty), and by looking at what happens when price uncertainty increases (i.e., how much uncertainty there is).

Introduction

This is important for both agricultural and development economics. First, this is important to *agricultural economics* because many of the policy instruments used in agricultural policy consist of programs aimed at eliminating price uncertainty, and the provision of such programs mobilizes large sums of money that cannot be used for other policy purposes.

Second, this is important for *development economics* because in developing countries, agricultural production is almost always characterized by a failure of the insurance market. Knowing whether producers hedge because of price risk can help with the development of policy instruments that can help enhance food security.

Introduction

Our findings are surprising. First and foremost, we find that relative to the case where prices are known with certainty, the presence of price risk (i.e., uncertainty of a known distribution) leads to an increase in production. Then, within uncertain prices, an increase in price risk leads to a decrease in production.

Second, we find that relative to the case where prices are known with certainty, the presence of price ambiguity (i.e., uncertainty of an unknown distribution but of a known range) leads to a mixed findings. In one session, we see a decrease in production due to price ambiguity; in the other, we see an increase. We offer a few explanations for why this might be happening.

Introduction

Based on that preliminary evidence, we can thus answer the question posed in our title.

Was Sandmo right? Not really. Indeed, price risk–what Sandmo studied–leads people to produce more rather than less. It is only in cases of price ambiguity–and even then, not always–that people decrease their production decision in response to price uncertainty.

Outline

Experimental Design

We split the subjects into four sessions (two in December; two in March). The first session is the risk session, the second session is the ambiguity session.

In both cases, we follow a two-stage randomization strategy, as follows:

1. In one third of the rounds, subjects are presented with a certain price. In two thirds of the rounds, subjects are presented with an uncertain price.
2. Conditional on facing an uncertain price, we randomly select one of four random distributions, which are mean-preserving spreads of one another.

Experimental Design

The difference between the two sessions is that when the price is uncertain in the risk session, we show subjects which random distribution we sample from. In the ambiguity session, when the price is uncertain, we do not show subjects which random distribution we sample from–we only tell them the range of possible prices.

In each round, subjects have to choose how much to produce. All subjects are given charts showing them how their within-round profit varies by price according to the production level they choose. Profits mapped into a monetary reward function.

Experimental Design

This allows disentangling the effect of uncertainty relative to certainty (extensive price risk margin), and the effect of an increase in uncertainty (intensive price risk margin), which are the questions Sandmo was looking at.

Perhaps more interestingly, it also allows looking at the effect of price ambiguity on producer behavior. As far as we know, no one has looked at the impact of price ambiguity on behavior, either in theory or in practice.

Experimental Design

Note that in any given round, all subjects receive the same treatment. That is, there is no between-subject within-round variation–all of the variation in treatment here is between-round and within-subject. That is because of the lo-fi (i.e., pen and paper) nature of our experiment.

After asking subjects to make production choices in the face of price uncertainty, we elicit income risk aversion by conducting the Holt and Laury (2002) list experiment. We do this to ensure that our results are not driven by income risk or ambiguity preferences. This also mapped into a monetary reward function. In December, we played Holt-Laury second, after the price uncertainty game; in March, we played it first.

Experimental Subjects

The experiments were conducted at the Cornell Lab for Experimental Economics and Decision Research (LEEDR) in December 2014. We chose LEEDR because it does not allow deception, and some professional associations are considering a ban on experiments conducted in labs were deception is allowed.

LEEDR staff recruited 48 Cornell undergraduates as our subjects. In each session, we played 10 practice rounds, and a total of 20 actual rounds. For each session, this gives us a sample size of 480 subject-round observations. We also collected some demographic information (e.g., age, gender, race) on each subject.

Estimation Strategy

We estimate ordinary least squares regressions with random effects throughout. Random effects are the right thing to do with experimental data–the experimentally assigned variables are clearly orthogonal to everything else, and because random effects models are more efficient than fixed effects.

We also estimated everything using Poisson regressions with random effects (negative binomial regressions wouldn't converge), with identical results. I present the simpler specifications here.

Producer Responses to Price Risk

Table 1. Descriptive Statistics for the December Risk Session (n=480)

Variable	Mean	(Std. Dev.)	Min	Max
Output Level	9.92	(2.46)	4	19
Price	6.85	(1.11)	5	9
Uncertainty	0.70	(0.46)	0	1
Standard Deviation	0.97	(0.68)	0	1.58
Profit	2.86	(11.61)	-43.39	31.99
Holt-Laury Switch Point	6.70	(1.51)	4	10
Age	20.67	(0.94)	18	22
Female	0.42	(0.49)	0	1

Producer Responses to Price Risk

Table 2. Descriptive Statistics for the March Risk Session (n=480)

Variable	Mean	(Std. Dev.)	Min	Max
Output Level	10.11	(2.00)	4	19
Price	6.90	(1.05)	5	9
Uncertainty	0.65	(0.48)	0	1
Standard Deviation	0.85	(0.68)	0	1.58
Profit	3.43	(10.90)	-43.39	32.61
Holt-Laury Switch Point	7.46	(1.36)	5	10
Age	20.29	(1.14)	19	24
Female	0.70	(0.46)	0	1

Producer Responses to Price Risk

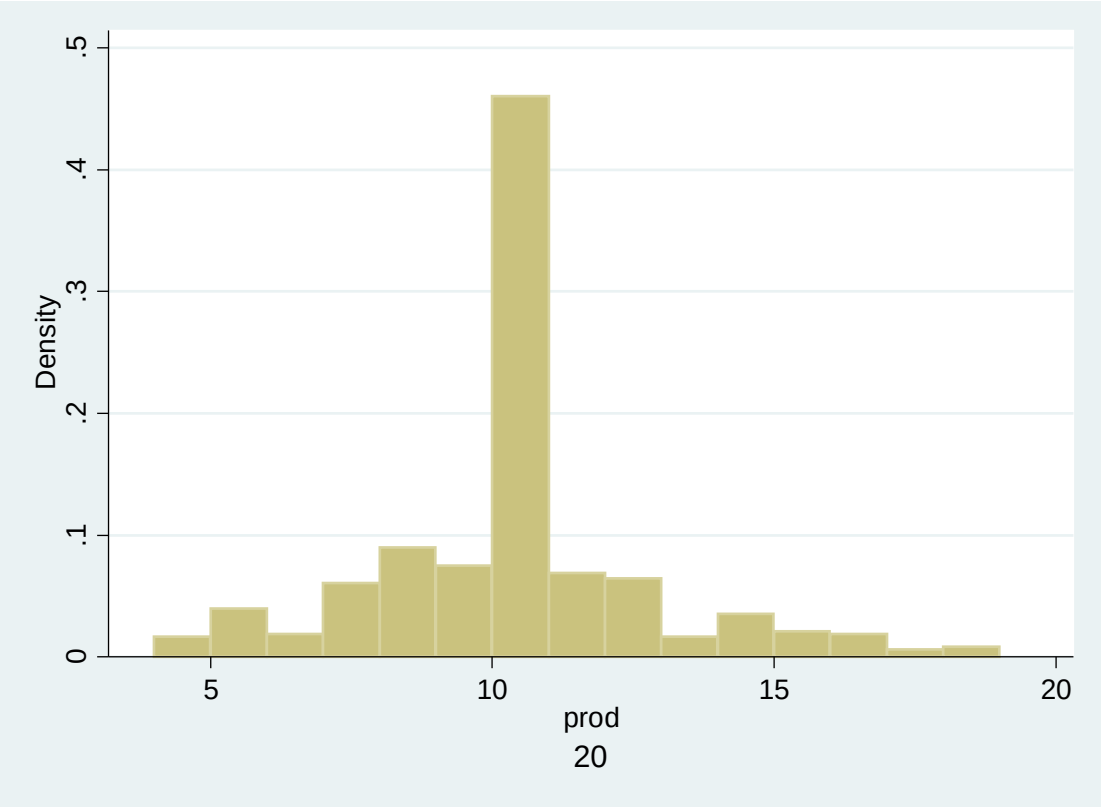


Figure: Histogram of Output Choice (December).

Producer Responses to Price Risk

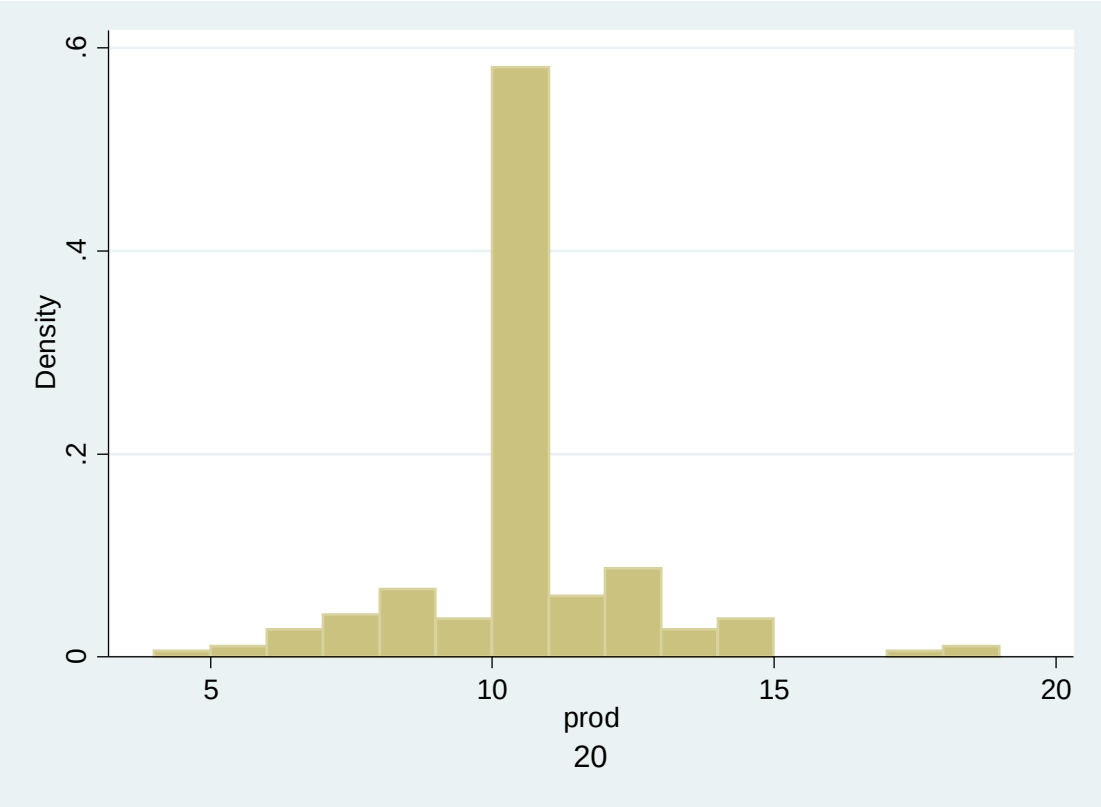


Figure: Histogram of Output Choice (March).

Producer Responses to Price Risk

Table 3. Random Effects Regression Results (December)

Variable	Coefficient	(Std. Err.)
Uncertainty	2.163***	(0.649)
Standard Deviation	-1.655***	(0.442)
Holt-Laury Switch Point	-0.366***	(0.147)
Round	0.003	(0.018)
Age	0.295	(0.268)
Female	-0.496	(0.530)
Constant	5.948	(5.265)
N	480	
Ethnicity Dummies	Yes	
R^2 Overall	0.10	
Wald $\chi^2(9)$	24.44	

Producer Responses to Price Risk

Table 4. Random Effects Regression Results (March)

Variable	Coefficient	(Std. Err.)
Uncertainty	1.873***	(0.486)
Standard Deviation	-1.170***	(0.362)
Holt-Laury Switch Point	-0.053	(0.140)
Round	-0.023	(0.019)
Age	0.232	(0.171)
Female	-0.973	(0.480)
Constant	6.671	(3.490)
N	460	
Ethnicity Dummies	Yes	
R^2 Overall	0.11	
Wald $\chi^2(9)$	26.83	

Producer Responses to Price Risk

Table 5. Random Effects Regression Results (Pooled)

Variable	Coefficient	(Std. Err.)
Uncertainty	2.041***	(0.400)
Standard Deviation	-1.491***	(0.277)
Holt-Laury Switch Point	-0.214**	(0.099)
Round	-0.002	(0.012)
Holt-Laury First	0.413	(0.318)
Age	0.252*	(0.148)
Female	-0.713**	(0.340)
Constant	6.066**	(2.955)
N	940	
Ethnicity Dummies	Yes	
R^2 Overall	0.09	
Wald $\chi^2(9)$	45.44	

Producer Responses to Price Risk

We get very interesting results: Sandmo's *only* sharp prediction was that price uncertainty would make people hedge by cutting back on how much they produce. We find the contrary.

Then, conditional on facing an uncertain price, producers decrease their output as the degree of uncertainty (i.e., the standard deviation of the price distribution) increases. On such mean-preserving spreads, Sandmo (who called them "stretches") made no sharp prediction

Finally, results control for income risk aversion. Here, there is a negative association between one's degree of income risk aversion and one's output choice, as one would expect.

Producer Responses to Price Risk

Moreover, there is a monotonic, decreasing response to price risk.

Table 6. Relationship between Output and Price Risk

Standard Deviation	Output Choice
0	10.00
0.80	10.83
1.17	10.20
1.45	9.90
1.58	9.61

Producer Responses to Price Risk

Price and profit in the previous round have no impact on output choice, either individually or together.

We also find that subjects tended to produce significantly more (less) when they experienced a loss (gain) in the previous round.

This is not inconsistent with Kahneman and Tversky's (1979), whose subjects were risk-loving over losses and risk-averse over gains.

Producer Responses to Price Ambiguity

Table 7. Descriptive Statistics for the December Ambiguity Session (n=460)

Variable	Mean	(Std. Dev.)	Min	Max
Output Level	9.58	(1.64)	3	18
Price	6.65	(1.02)	5	9
Uncertainty	0.60	(0.49)	0	1
Profit	1.21	(9.71)	-22.54	32.60
Holt-Laury Switch Point	6.91	(1.91)	4	10
Age	20.65	(0.92)	19	23
Female	0.61	(0.49)	0	1

Producer Responses to Price Ambiguity

Table 8. Descriptive Statistics for the March Ambiguity Session (n=460)

Variable	Mean	(Std. Dev.)	Min	Max
Output Level	11.20	(2.67)	4	20
Price	7.50	(1.19)	6	9
Uncertainty	0.90	(0.30)	0	1
Profit	10.03	(13.05)	-13.63	32.61
Holt-Laury Switch Point	7.08	(1.80)	4	10
Age	20.79	(1.69)	18	25
Female	0.58	(0.49)	0	1

Producer Responses to Price Ambiguity

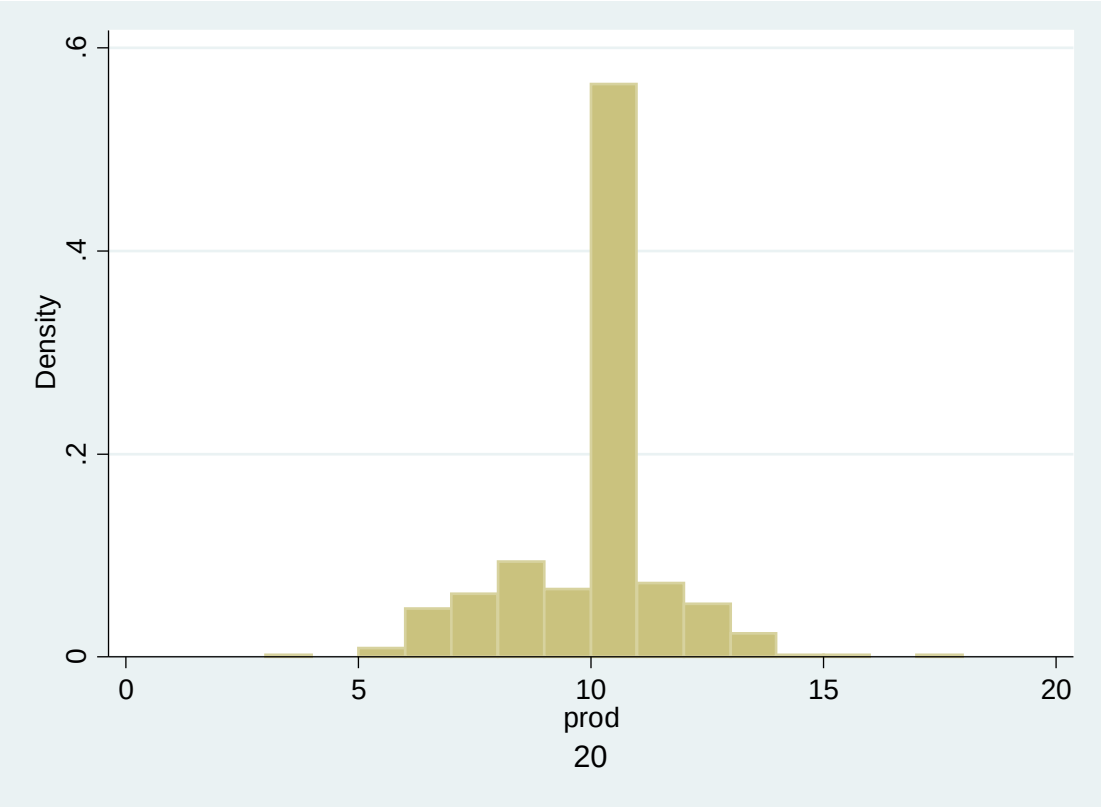


Figure: Histogram of Output Choice (December)

Producer Responses to Price Ambiguity

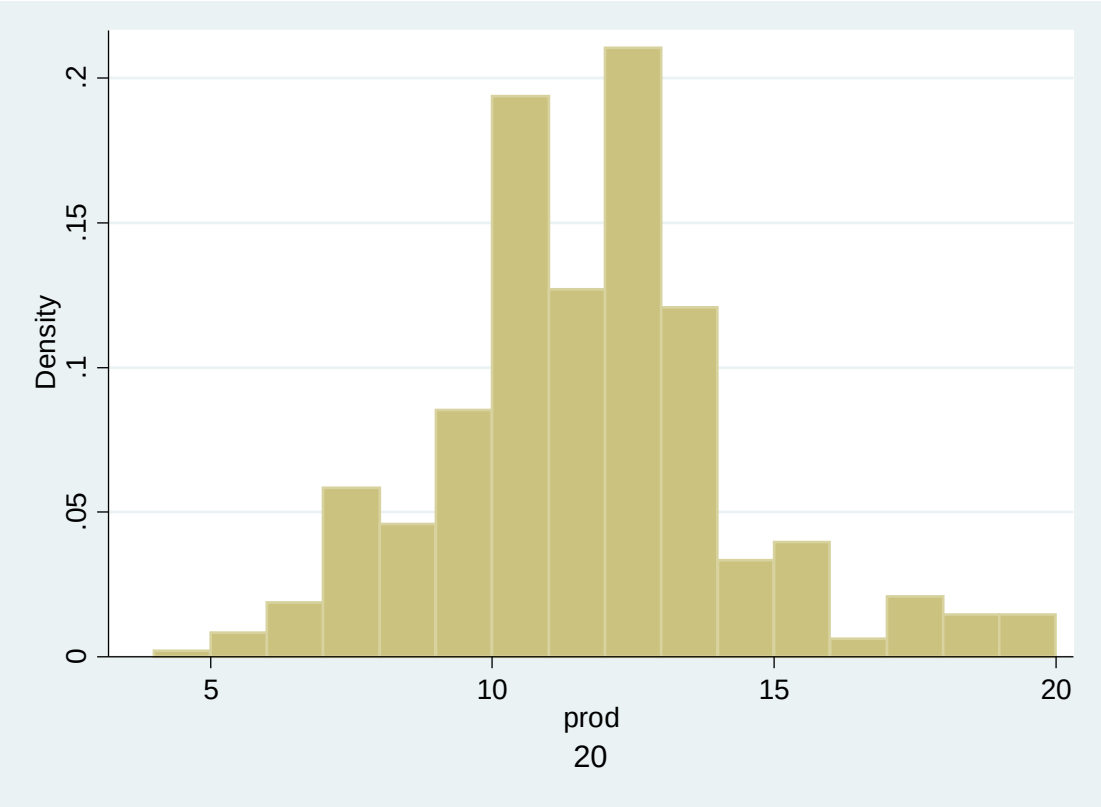


Figure: Histogram of Output Choice (March)

Producer Responses to Price Ambiguity

Table 9. Random Effects Regression Results (December)

Variable	**Coefficient**	**(Std. Err.)**
Uncertainty	-0.571***	(0.132)
Holt-Laury Switch Point	0.055	(0.121)
Round	-0.019*	(0.011)
Age	-0.182	(0.256)
Female	-0.660	(0.453)
Constant	14.344**	(5.624)
N	460	
Ethnicity Dummies	Yes	
R^2 Overall	0.10	
Wald $\chi^2(8)$	26.95	

Producer Responses to Price Ambiguity

Table 10. Random Effects Regression Results (March)

Variable	**Coefficient**	**(Std. Err.)**
Uncertainty	1.425***	(0.324)
Holt-Laury Switch Point	-0.535***	(0.160)
Round	0.052***	(0.017)
Age	-0.037	(0.149)
Female	-0.721	(0.539)
Constant	14.397	(3.124)
N	480	
Ethnicity Dummies	Yes	
R^2 Overall	0.28	
Wald $\chi^2(8)$	59.14	

Producer Responses to Price Ambiguity

Table 11. Random Effects Regression Results (Pooled)

Variable	Coefficient	(Std. Err.)
Uncertainty	0.027	(0.149)
Holt-Laury Switch Point	-0.222**	(0.102)
Round	0.014	(0.010)
Holt-Laury First	1.263***	(0.380)
Age	-0.087	(0.128)
Female	-0.855**	(0.377)
Constant	13.541***	(2.740)
N	940	
Ethnicity Dummies	Yes	
R^2 Overall	0.24	
Wald $\chi^2(9)$	49.87	

Producer Responses to Price Ambiguity

Here, we get mixed results: When people play the Holt-Laury income risk game second, price ambiguity makes them hedge against uncertainty by producing less than they otherwise would. When they play the Holt-Laury income risk game first, price ambiguity makes them speculate over uncertainty by producing *more* than they otherwise would.

Our results control for income risk aversion here as well. In this case, however, there is no association between one's degree of income risk aversion and one's output choice.

Producer Responses to Price Ambiguity

What could explain that asymmetry? In the paper, we speculate that playing the income risk (i.e., Holt-Laury) game first might "prime" our subjects to take on more risk than they otherwise would.

Another possible reason for the conflicting results is the high price draws during the March ambiguity session. Although the mean price drawn in December and March are not significantly different from $7 in both December and March sessions, we drew much higher prices in the March experiment, which may have (mis)led subjects to take on less (more) risk in December (March).

Producer Responses to Price Ambiguity

Consistent with this, price and profit in the previous round do have an impact on decisions in the current round. As price or profit in the previous round increases, subjects tend to produce more, in some kind of overconfidence effect. When both are included, neither are significant.

In stark contradiction with our risk findings, we find that subjects tended to produce significantly more (less) when they experienced a gain (loss) in the previous round–this is the opposite of what a prospect-theoretic framework would predict.

Summary and Conclusions

We study experimentally the behavior of producers in the face of price uncertainty–both price risk (i.e., known distribution of prices) and price ambiguity (i.e., unknown distribution of prices, with only the range of prices known).

Surprisingly, we find that price risk causes subjects to produce more. Conditional on there being price risk, increases in price risk cause subjects to produce less at the margin.

Summary and Conclusions

Moreover, and in line with expectations, we find that price ambiguity causes subjects to produce less, but only if people aren't forced to think about income risk-aversion first. When they are forced to think about income risk aversion first, then ambiguity causes them to produce *more*.

Between the risk and ambiguity treatments, we find significant but contradictory effects of whether subjects have experienced a gain or a loss in the round immediately preceding the current round.

All results control for income risk aversion by incorporating the result of the Holt and Laury (2002) list experiment.

Summary and Conclusions

If you take our results at face value, what should you conclude? First off, you could conclude that when comparing uncertain with certain prices, knowing the shape of the price distribution causes producers to take on more risk–producers speculate over price risk by producing more than when they face certain prices. There is a threshold amount of uncertainty, however, where output crosses the certainty level of output from above.

For the same comparison, however, not knowing the shape of the price distribution causes producers to take on more or less risk, depending on whether they are primed by having to think about income risk first by having to play the Holt-Laury game first.

Summary and Conclusions

Our results suggest an interesting policy implication for those of us with an interest in food security: If people do produce less because of price ambiguity, the provision of price forecasting information to farmers in contexts where there is no insurance against price risk might lead to improvements in food security.

The benefits of a more abundant supply of cheaper food for food consumers would have to be weighed against the costs of more price risk for food producers–but note that those food producers would appear to willingly take on more risk.

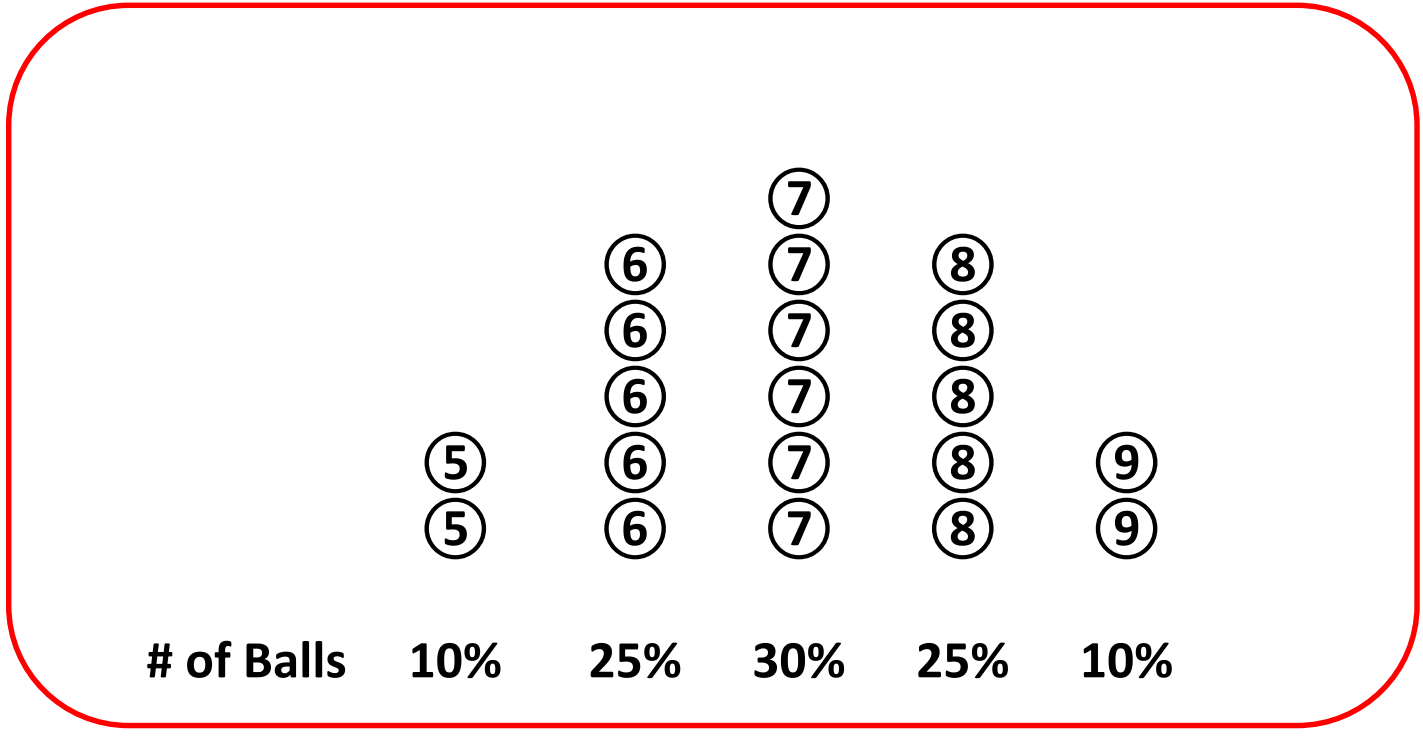
Summary and Conclusions

Our results also suggest that the theory of producer behavior in the face of price uncertainty needs rethinking. Sandmo's (1971) only sharp prediction was that the move from certain to (known) risky prices would cause producers to hedge against price risk by producing less. Given these preliminary data, we roundly reject that hypothesis.

Given the popularity of price supports and other insurance programs for farmers, maybe it is the case that agricultural producers are price ambiguity-averse rather than price risk-averse. If so, we should develop a theoretical framework to think through what this means.

Setting 3

- There are 20 balls in the bag marked with prices \$5, \$6, \$7, \$8, and \$9. The number of balls marked with each price are shown in the following picture.



- Write down your choice of input (0-20) on the answer sheet.

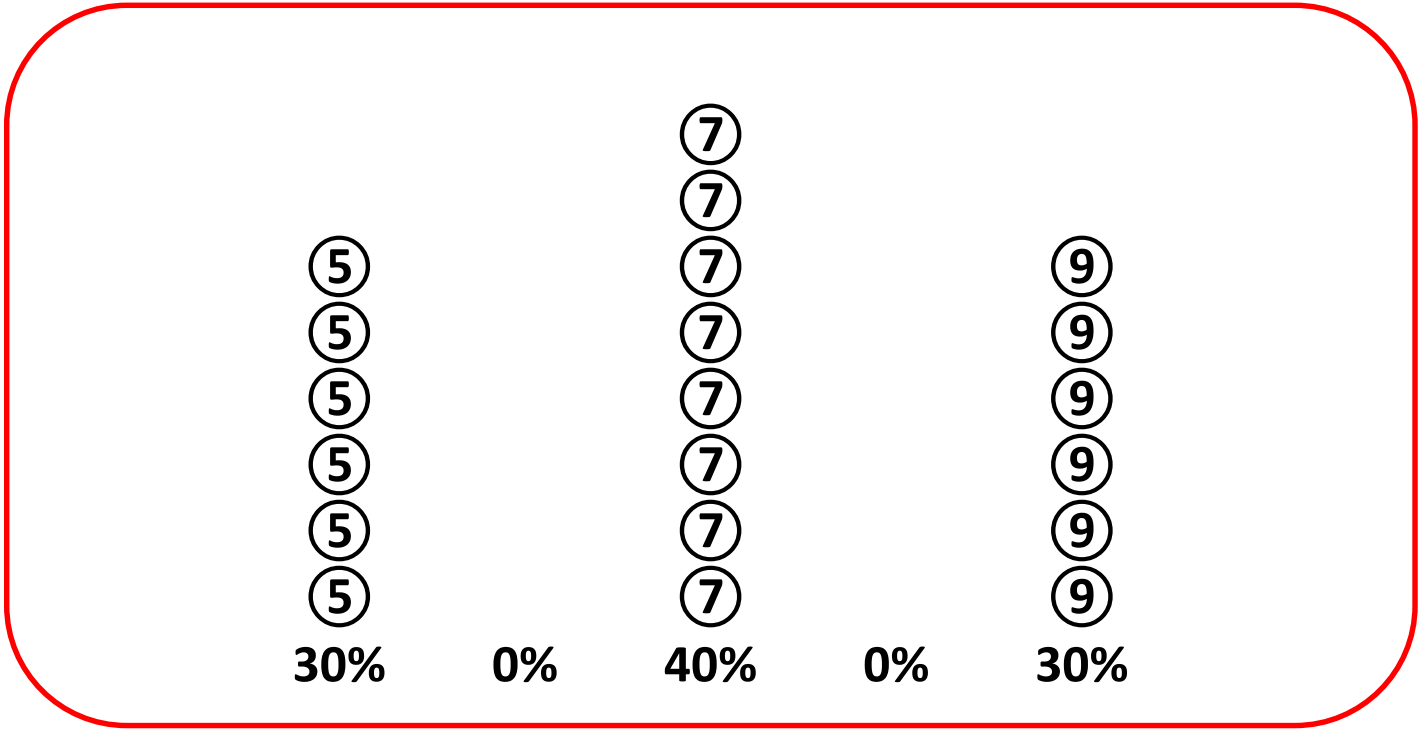
Setting 4

- There are 20 balls in the bag marked with prices $5, $6, $7, $8, and $9. The number of balls marked with each price are shown in the following picture.

- Write down your choice of input (0-20) on the answer sheet.

Setting 5

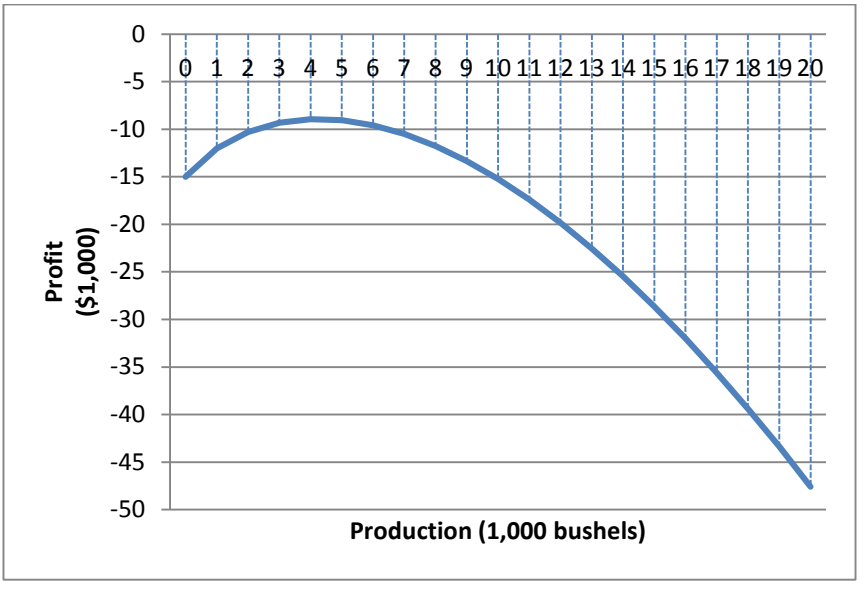
- There are 20 balls in the bag marked with prices \$5, \$6, \$7, \$8, and \$9. The number of balls marked with each price are shown in the following picture.



- Write down your choice of input (0-20) on the answer sheet.

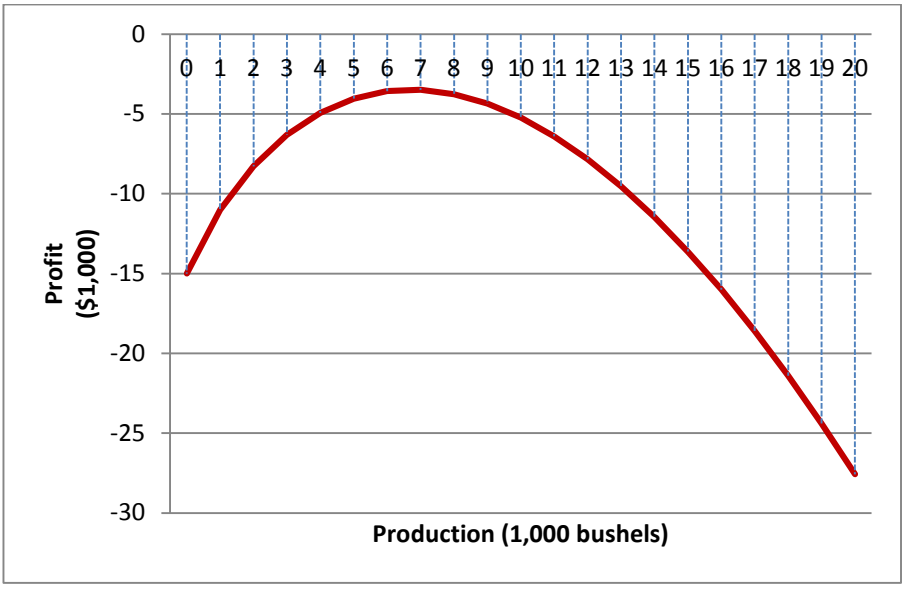
1. Wheat production, cost, and profit when price of wheat is **$5/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X (1)$^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	5	15	-15.00
1	5	17	-12.00
2	5	20	-10.28
3	5	24	-9.31
4	5	29	-8.93
5	5	34	-9.04
6	5	40	-9.57
7	5	45	-10.49
8	5	52	-11.76
9	5	58	-13.35
10	5	65	-15.24
11	5	72	-17.41
12	5	80	-19.85
13	5	88	-22.54
14	5	95	-25.47
15	5	104	-28.63
16	5	112	-32.01
17	5	121	-35.60
18	5	129	-39.40
19	5	138	-43.39
20	5	148	-47.58



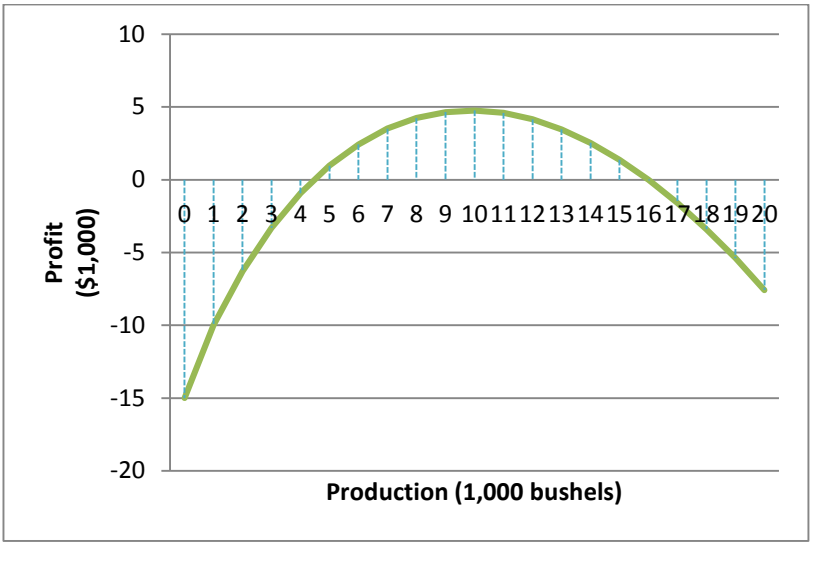
2. Wheat production, cost, and profit when price of wheat is $6/bushel.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X $(1)^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	6	15	-15.00
1	6	17	-11.00
2	6	20	-8.28
3	6	24	-6.31
4	6	29	-4.93
5	6	34	-4.04
6	6	40	-3.57
7	6	45	-3.49
8	6	52	-3.76
9	6	58	-4.35
10	6	65	-5.24
11	6	72	-6.41
12	6	80	-7.85
13	6	88	-9.54
14	6	95	-11.47
15	6	104	-13.63
16	6	112	-16.01
17	6	121	-18.60
18	6	129	-21.40
19	6	138	-24.39
20	6	148	-27.58



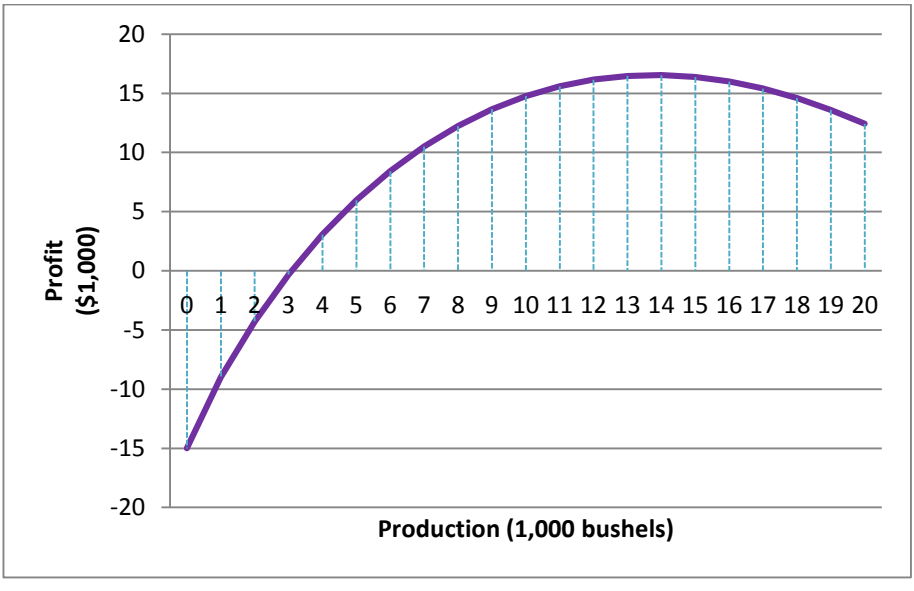
3. Wheat production, cost, and profit when price of wheat is **$7/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X $(1)^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	7	15	-15.00
1	7	17	-10.00
2	7	20	-6.28
3	7	24	-3.31
4	7	29	-0.93
5	7	34	0.96
6	7	40	2.43
7	7	45	3.51
8	7	52	4.24
9	7	58	4.65
10	7	65	4.76
11	7	72	4.59
12	7	80	4.15
13	7	88	3.46
14	7	95	2.53
15	7	104	1.37
16	7	112	-0.01
17	7	121	-1.60
18	7	129	-3.40
19	7	138	-5.39
20	7	148	-7.58



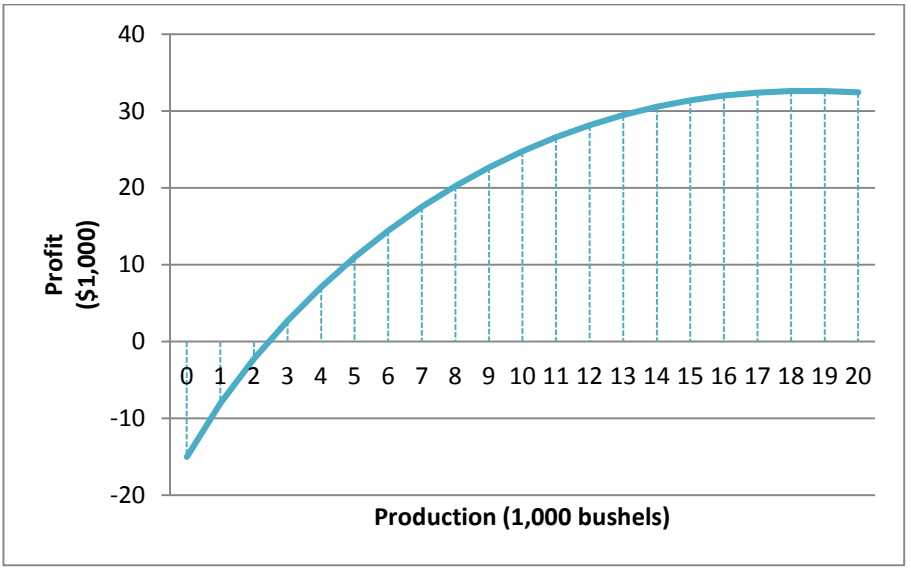
4. Wheat production, cost, and profit when price of wheat is **$8/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X $(1)^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	8	15	-15.00
1	8	17	-9.00
2	8	20	-4.28
3	8	24	-0.31
4	8	29	3.07
5	8	34	5.96
6	8	40	8.43
7	8	45	10.51
8	8	52	12.24
9	8	58	13.65
10	8	65	14.76
11	8	72	15.59
12	8	80	16.15
13	8	88	16.46
14	8	95	16.53
15	8	104	16.37
16	8	112	15.99
17	8	121	15.40
18	8	129	14.60
19	8	138	13.61
20	8	148	12.42



5. Wheat production, cost, and profit when price of wheat is **$9/bushel**.

(1) Wheat Production (1,000 bushels)	(2) Price ($/bushel)	(3) Cost = 2 X $(1)^{1.4}$+15 ($ 1,000)	(4) Profit = (1)X(2)-(3) ($1,000)
0	9	15.00	-15.00
1	9	17.00	-8.00
2	9	20.28	-2.28
3	9	24.31	2.69
4	9	28.93	7.07
5	9	34.04	10.96
6	9	39.57	14.43
7	9	45.49	17.51
8	9	51.76	20.24
9	9	58.35	22.65
10	9	65.24	24.76
11	9	72.41	26.59
12	9	79.85	28.15
13	9	87.54	29.46
14	9	95.47	30.53
15	9	103.63	31.37
16	9	112.01	31.99
17	9	120.60	32.40
18	9	129.40	32.60
19	9	138.39	32.61
20	9	147.58	32.42



6. Profits when price of wheat is **$5/bushel-$9/bushel**.

Wheat Production	Profit				
	P = $5	P = $6	P = $7	P = $8	P = $9
0	-15.00	-15.00	-15.00	-15.00	-15.00
1	-12.00	-11.00	-10.00	-9.00	-8.00
2	-10.28	-8.28	-6.28	-4.28	-2.28
3	-9.31	-6.31	-3.31	-0.31	2.69
4	-8.93	-4.93	-0.93	3.07	7.07
5	-9.04	-4.04	0.96	5.96	10.96
6	-9.57	-3.57	2.43	8.43	14.43
7	-10.49	-3.49	3.51	10.51	17.51
8	-11.76	-3.76	4.24	12.24	20.24
9	-13.35	-4.35	4.65	13.65	22.65
10	-15.24	-5.24	4.76	14.76	24.76
11	-17.41	-6.41	4.59	15.59	26.59
12	-19.85	-7.85	4.15	16.15	28.15
13	-22.54	-9.54	3.46	16.46	29.46
14	-25.47	-11.47	2.53	16.53	30.53
15	-28.63	-13.63	1.37	16.37	31.37
16	-32.01	-16.01	-0.01	15.99	31.99
17	-35.60	-18.60	-1.60	15.40	32.40
18	-39.40	-21.40	-3.40	14.60	32.60
19	-43.39	-24.39	-5.39	13.61	32.61
20	-47.58	-27.58	-7.58	12.42	32.42