Experimental Test of the Giffen Good

The Giffen good is the unicorn of economics. It is an anomaly, a perverse result if observed in nature. And yet its image is like a cloaked figure slipping into the fog. We are never quite sure if we have seen it or not.

The Giffen good has received a lot of attention in the literature and every textbook discusses it to some degree. However, the best paper so far describes some experimental work done by Battalio, Kagel and Kogut.[1] They set out to empirically uncloak the mysterious visage.

The Giffen good is a name given to a positive price effect. The price effect is the slope of the ordinary demand curve. It is the change in consumption that occurs when the price of a good changes holding all other prices and income constant. Normally, the price effect is negative. Indeed, we can say that in everyday experience the price effect is always negative. Demand curves always slope down. On this basis, the Giffen good is just a name given to a theoretical possibility that is product of vapid excesses of logical tinkering.

If we draw the picture of a budget constraint and indifference curve tangent to it, it is clearly possible to allow the price of one good to fall and consumption of that good to fall as well. We could depict such an event without falling prey to errors in construction of indifference curves (i.e., that they cannot cross). And if we can draw it, it is a theoretical possibility.

This raises the malodorous question of "Just what is the Law of Demand?" If the price effect can be positive meaning that demand curves can slope upward, where is the "Law" in the Law of Demand?

As we have already seen, the Law of Demand is really a statement about relative price changes or income compensated price changes. The Law of Demand says that if the price of one good goes up relative to another, then consumption of that good will decline relative to the other. The summary statement of the Law of Demand is embodied in the Slutsky equation that says the substitution effect, which must be negative, is equal to the price effect plus the consumption-weighted income effect. That is, if the price of a good goes up, but we compensate the consumer for this event so that the consumer could continue to consume as much of the good as before, this will be the equivalent of a relative price change. In this event, the consumer is predicted to *always* consume less of the good.

Thus, the ordinary demand curve, albeit a yeoman workhorse of empirical economics, is not the true Law of Demand, though we can employ it to depict the true Law. And even if the ordinary demand curve were positively sloped, by the Slutsky equation we can explore this perversity.

Again, the Slutsky equation says that the substitution effect equals the price effect plus the weighted income effect, and the substitution effect, by the Law of Demand, must be negative. Hence, if the price effect is positive, then it is immediately obvious that the income effect in this case must be negative. The point is, Giffen goods must be inferior goods: Not all inferior goods are Giffen, but all Giffen goods must be inferior.

B K & K begin their search for a Giffen good in exactly this way. They picked out six of their best rats, good and true. They put these guys in a Skinner box for three hours per day during which time the rats could consume the liquids quinine water and root beer and dry food. The rest of the day, the rats stayed in their holding cages where they had dry food but no liquids. Thus all

[1] Battalio, Kagel, Kogut. "Experimental Confirmation of the Existence of a Giffen Good," *AER*, Sept 91, 961-978.

of the liquid consumption came in the Skinner box and was comprised of quinine water and root beer.

Quinine water is a solution of water and the bitter extract of a root.[2] Quinine has been historically used as a cure for malaria. Because of the large number of people that were exposed to this disease during WWII, quinine became the form of a popular liquor drink called Gin & Tonic.[3] You can buy tonic water at the store. It is a mixture of sugar water and a trace of quinine for flavor. The quinine water offered the rats did not have sugar.

The Skinner box has two dispensers for liquid each effected by a lever. Pressing the lever once gives a serving of liquid. The quantity of liquid that comes out can be varied. The standard serving is .05cc. The rats were given a fixed number of presses for each Skinner box session. This is like their income. The amount of the two liquids that they received for each press was different. One press yielded .05cc of root beer, but .1cc of quinine water. In the baseline experiment, total presses were set at 110.

With a budget of 110 presses and serving sizes of .1cc and .05cc for quinine and root beer respectively, the rats could enjoy either 11cc of quinine water or 5.5cc of root beer each day or any combination in between. This is the budget constraint. The experimenters talk about price as the number of .05cc servings per press. Hence, the price of root beer is 1; while the price of quinine water in this baseline trial is ½.

Let's examine the behavior of Rat 543, a noble fellow. Table 1 shows 543's behavior. In trial (a), which I label with lower case letters because they don't in order to minimize confusion, 543 chose to consume 3.9cc of quinine, as reported in their table 1. This implies that ol' 543 also consumed 3.55cc of root beer.

The next step was to lower income. Since all Giffen goods must be inferior goods, our researchers first sought to determine if quinine was an inferior good for rats. An inferior good is one for which consumption rises as income falls. The researchers lowered income. The rule that they used to lower income was this. They set the number of presses allowed during each Skinner box session in trial (b) equal to the total consumption of liquid in trial (a) divided by .1. By this, they allowed each rats to consume exactly the same amount of liquid in trial (b) as was consumed in trial (a) if it consumed only quinine.[4]

Faced with this budget, ol' 543 chose 5.9cc of quinine and only .8cc of root beer. This shows that quinine water for 543 is inferior. The lower income in presses increased consumption of quinine. Notice that root beer was normal: lower income caused consumption to fall. Both goods cannot be inferior. Not all the rats treated quinine as inferior. In fact, two out of the six treated both goods as normal.

Now, the scientists had the stage set for a trial that might reveal the existence of a Giffen good. The next trial held income at the lower level but decreased the price of quinine. Quinine water fell to 1/3; that is, .15cc of quinine water was dispensed with each press. For the four rats who had exhibited negative income effects, if the lower price induced lower consumption, the researchers could claim that quinine water is a Giffen good.

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[2] A bitter, colorless, amorphous powder or crystalline alkaloid, $C_{20}H_{24}N_2O_2 \cdot 3H_2O$, derived from certain cinchona barks and used in medicine to treat malaria.

[3] Purely speculation.

[4] This method is not completely mad. Given that the income in trial (a) was set so that the rats were not under nourished in terms of liquid, the lower income in the second trial would not threaten harm to the animals.

This did indeed happen for three of the four rats. In particular, 543 reduced its consumption of quinine from 5.9cc to 4.7cc when the price of quinine water fell.

Legitimately, the researchers should test to make sure that the behavior pattern of the rats conforms to the Slutsky equation. Again, the price effect plus the weighted income effect must be negative. When the Slutsky is expressed in linear terms, the weight on income is the baseline consumption level. It is often easiest to implement the Slutsky equation when it is expressed in elasticity terms. The Slutsky equation says that ordinary price elasticity plus income elasticity times budget share must equal the compensated price elasticity, which must be negative. Elasticities can be calculated in either arc or point fashion. The baseline for evaluation of the Slutsky condition should be trial (b).

Table 2 shows the evaluation of the Slutsky condition for the three rats who exhibited Giffen responses. The results are not wholly satisfying. Evaluating the Slutsky condition in linear or point elasticity terms, the condition is not satisfied for two out of the three rats. In arc elasticity terms, it is satisfied for all three.

There are a number of other problematic aspects of this experiment. First there is always the question of whether the rats figured out the problem. But this is particularly troublesome here. The researchers performed some test/re-test experiments to see if the rats behaved consistently. Some did and some didn't. Of the three Giffen rats, only 532 was most consistent as depicted in their Figure 2.

The researchers also tried a direct test of the negative substitution effect. They did this by rotating the budget constraint through the "original consumption bundle." It is not clearly which bundle they mean here. The most interesting way to run the experiment would be to rotate the budget through the consumption bundle in trial (b) by lowering the price to its value in trial (c). They definitely didn't do this. Regrettably, their direct test of the negative substitution effect for the three Giffen rats failed in one case (532) (before they applied the torture) and was insignificant in the other two.

In spite of these inconsistencies, these research stands as the lone case of unmasking a Giffen good. In addition, it is a good description of the experimental methodology.

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Table 1: The Trials of Rat 543

Trials	Income	Price				Quantity Consumed					
		Quinine		Root Beer		Quinine			Root Beer		
		cc/press	*presses/cup*	*cc/press*	*presses/cup*	*cc's*	*cups*	*bud. shr.*	*cc's*	*cups*	*bud. shr.*
a	110	.1cc	1/2	.05cc	1	3.90	78	35%	3.55	71.0	65%
b	75	.1cc	1/2	.05cc	1	5.90	118	79%	0.80	16.0	21%
c	75	.15cc	1/3	.05cc	1	4.70	94	42%	2.18	43.7	58%

Notes: Cup size equals .05 cc. Income is the total number of presses allowed each session.

Table 2: Slutsky Check on Giffen Rats

		Experimental Results						Evaluation of the Slutsky Condition		
Rat	Trial	Income	Price	Consumption Choices (cc's)	Consumption in Cups	Budget Share		Linear Effects	Point Elasiticity	Arc Elasticity
543	(a)	110	0.5	3.9	78	35%	*Income Effect*	-1.12	-0.72	-1.06
	(b)	75	0.5	5.86	117.2	78%	*Price Effect*	134.37	0.57	0.53
	(c)	75	0.333	4.74	94.8	42%	*Subst. Effect*	3.11	0.01	-0.07
532	(a)	110	0.5	5.02	100.4	46%	*Income Effect*	-1.81	-0.94	-1.35
	(b)	80	0.5	7.74	154.8	97%	*Price Effect*	104.38	0.34	0.30
	(c)	80	0.333	6.87	137.4	57%	*Subst. Effect*	-176.32	-0.57	-0.66
542	(a)	110	0.5	3.04	60.8	28%	*Income Effect*	-2.07	-1.04	-1.85
	(b)	71	0.5	7.08	141.6	100%	*Price Effect*	323.94	1.14	1.18
	(c)	71	0.333	4.38	87.6	41%	*Subst. Effect*	30.57	0.11	0.00

Notes: Trial are labeled as discussed in Table 1 for Rat 543. Income is total presses allowed during three hour session. Price is expressed in presses per cup of .05 cc size. Price for quinine water is shown. Root beer price was 1 for all experiments. Consumption is quinine. Trial (b) is the baseline for the weights used in the Slutsky equation. Slutsky equation is Subst. Eff. = Pr. Eff. + Consumption*Inc. Eff. In elasticity form: Subst. Elas. = Pr. Elas. + Inc. Elas. * Budget Shr.

Tables 1 & 2 from Battalio, Kagel, Kogut (1991)

TABLE 1-QUININE INCOME ELASTICITIES FOR INITIAL INCOME CHANGES (MEAN DATA FOR LAST FIVE DAYS IN PERIOD)

	Subject					
Variable	531	532	533	541	542	543
Total presses available, high income	110	110	110	110	110	110
Quinine consumption [a]	4.80	5.02	5.36	7.52	3.04	3.90
	(0.434)	(0.246)	(0.093)	(0.637)	(0.147)	(0.416)
Total presses available, low income	59	80	62	60	71	75
Quinine consumption'	4.92	7.74	5.12	5.80	7.08	5.86
	(0.222)	(0.103)	(0.588)	(0.152)	(0.020)	(0.371)
Change in quinine consumption'	+0.12	+2.72**	-0.24	-1.72*	+4.04**	+ 1.96*
Income elasticity	-0.04	-1.35	+0.08	+0.44	-1.85	-1.06

'Quantity measured in cc; standard errors of means in parentheses. *Significantly different from zero at the 0.10 level (two-tailed test); **Significantly different from zero at the 0.01 level (two-tailed test).

TABLE 2-QUININE CONSUMPTION FOR INITIAL PRICE CHANGES (MEAN DATA FOR LAST FIVE DAYS IN PERIOD)

	Subject					
Variable	531	532	533	541	542	543
Income elasticity	-0.04	-1.35	+0.08	+0.44	-1.85	-1.06
High price	1/2	1/2	1/2	1/2	1/2	1/2
Quinine consumption'	4.92	7.74	5.12	5.80	7.08	5.86
	(0.222)	(0.103)	(0.588)	(0.152)	(0.020)	(0.371)
Low price	1/3	1/3	1/3	1/3	1/3	1/3
Quinine consumption'	4.95	6.87	6.54	7.89	4.38	4.74
	(0.394)	(0.438)	(0.387)	(0.485)	(0.537)	(0.215)
Change in quinine consumption'	0.03	-0.87	1.44	2.09	-2.70	-1.12
t statistic	0.07	-1.93	2.02	4.11	-5.02	-2.61
Significance level [b]	0.95	0.12	0.08	*0.01*	*< 0.01*	0.04
Giffen?	no	yes	no	no	yes	yes

'Quantity measured in cc; standard errors of means in parentheses. [b] Two-tailed test for difference in means.

More on Giffen Rats

Figure 1 shows the possible outcomes of a price experiment. An initial budget is presented to the subject. From this initial budget the consumer makes a choice, call it *z*. The subject is then presented a new budget A-E which is created by decreasing the price of quinine water. The question is, How will the consumer respond? Listed in the figure are the possibilities. Normally we expect that when price declines, consumption will increase. Hence, the normal response range will be somewhere to the right of point C.

However, the consumer might choose in the range of B-C. Here the consumer reacts to a price decrease with a consumption decrease, but even so the consumer is still acting rationally. It is only if the consumer chooses in the range of A-B that we can say the consumer is acting irrationally, and the Law of Demand fails the empirical test.

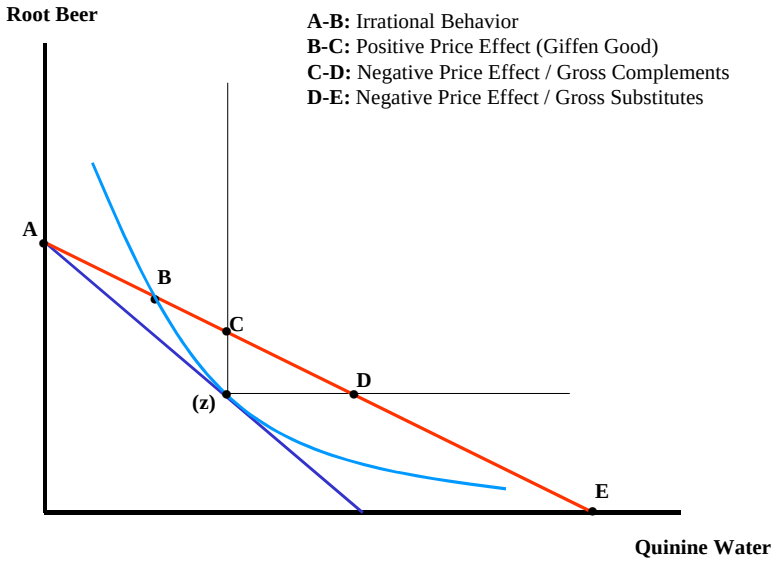

Figure 1

Figure 2 shows the experiments the way that BB&K performed them. They ran an initial experiment at a high income. Then they lowered income. From this lower income they ran a price experiment which had the outcome possibilities noted in Figure 1.

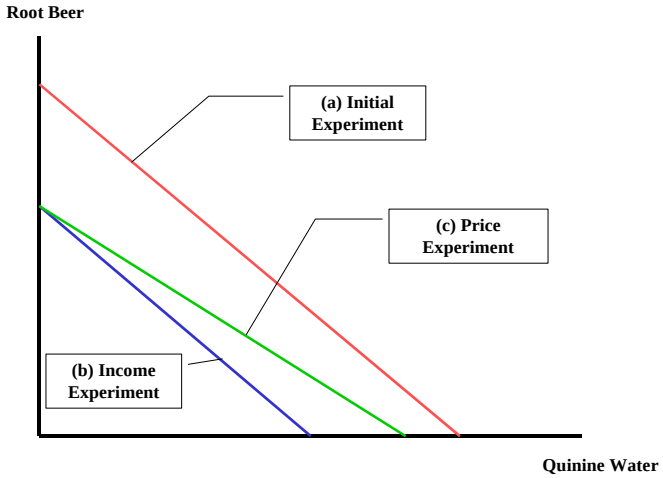

Figure 2

It is interesting to consider the outcome of their research for the rats that did not behave in a perverse way. Consider subject 541. Shown below are the experimental results that the researchers report in their tables 1 and 2. For this rat, quinine is a normal good in both price and income. This rat exhibits a negative price effect and a positive income effect. In effect, its behavior can be characterized by linear demand curves which are downward sloping. Figure 3 shows the demand curves taken from the data.[5] The function is

$$Q = 10.1 - .63\,P + .03\,M$$

where Q is consumption, P is price, and M is income.

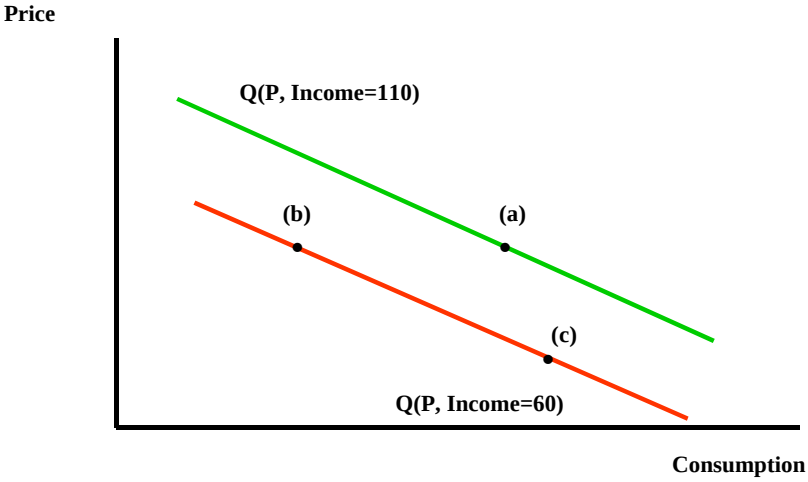

Figure 3

[5] Note that the way the researchers ran the experiment requires that we restate price. They experiment by changing serving size per press. This is units / $. Price is $ / unit. Hence we must invert the experimental pricing formula to get price in order to calculate the price effect. That is, .05 cc /press is 20 presses / cc, etc.

While subject 541 exhibits normal demand curves, this is not the case for subject 543. The behavior of this rat has been address above. The behavior can be graphed as shown in Figure 4.

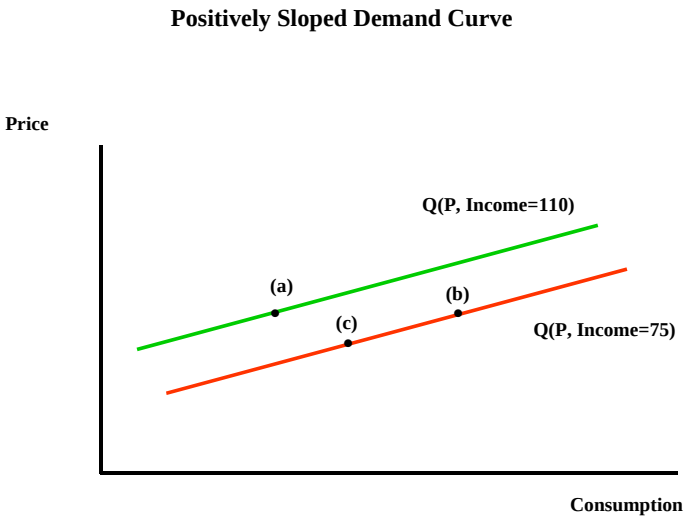

Figure 4

The behavior of the rat is consistent with the definition of a Giffen good. That is, the rat exhibits a positive price effect and a negative income effect. However, this alone does not mean that the rat is behaving rationally. Recall the discussion in reference to Figure 1. The question posed by the theory of consumer behavior and the law of demand is whether the economic agent is maximizing utility by choosing among the consumption bundles available, ones that yield the highest level of utility. This proposition can be graphed in reference to the behavior of subject 543 in Figure 5.

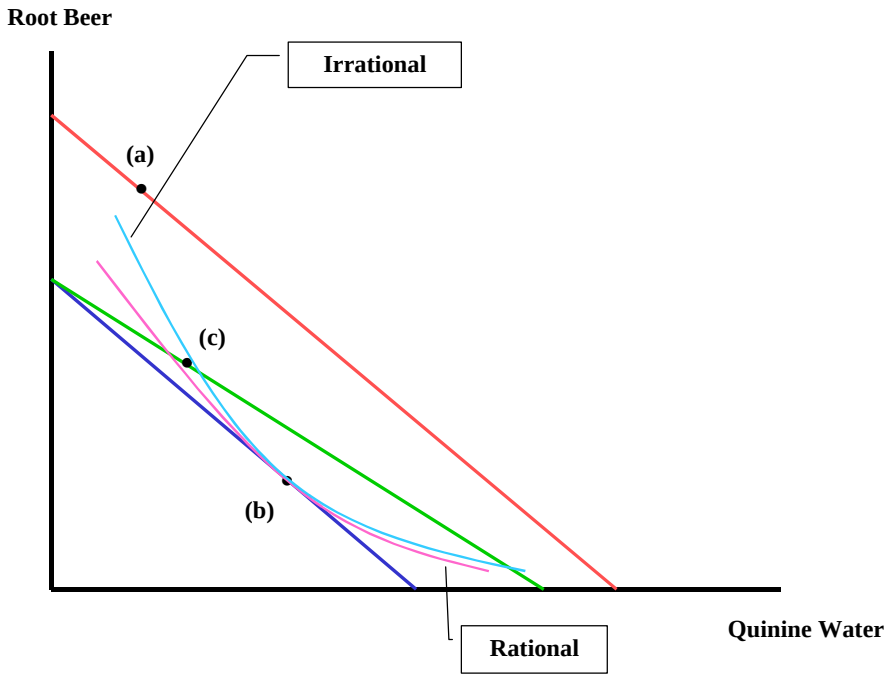

Figure 5

The experimental evidence is plotted in consumption space. The rat exhibits a negative income effect, (a) to (b); and a positive price effect, (b) to (c). However, is the rat behaving rationally? It might be. If the indifference curve that caused the rat to choose point (b) lies below point (c), then the rat is rational. However, if the indifference curve tangent to point (b) lies above point (c) then the rat is irrational.

Obviously, the problem is that we cannot observe indifference curves. The solution to this dilemma is the Slutsky Equation.

Slutsky Equation

The Slutsky equation is the law of demand. The Slutsky equation tells us how to measure the slope of the indifference curve in terms of the observable price and income effects. Indifference curves are not directly observable, but their slopes are in an indirect way.

The Slutsky equation says this:

Price Effect + Income Effect weighted by Consumption = Substitution Effect

where the substitution effect is the slope of the indifference curve and must be negative. By this, we can judge whether subject 543 is acting rationally.

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		cc/press	*presses/cup*	*cc/press*	*presses/cup*	*cc's*	*cups*	*bud. shr.*	*cc's*	*cups*	*bud. shr.*
a	110	.1cc	1/2	.05cc	1	7.52	150	68%	1.74	34.8	32%
b	60	.1cc	1/2	.05cc	1	5.80	116	97%	0.10	2.0	3%
c	60	.15cc	1/3	.05cc	1	7.89	158	88%	0.37	7.4	12%

Notes: Cup size equals .05 cc. Income is the total number of presses allowed each session.