

Lecture 4 - Theory of Choice and Individual Demand

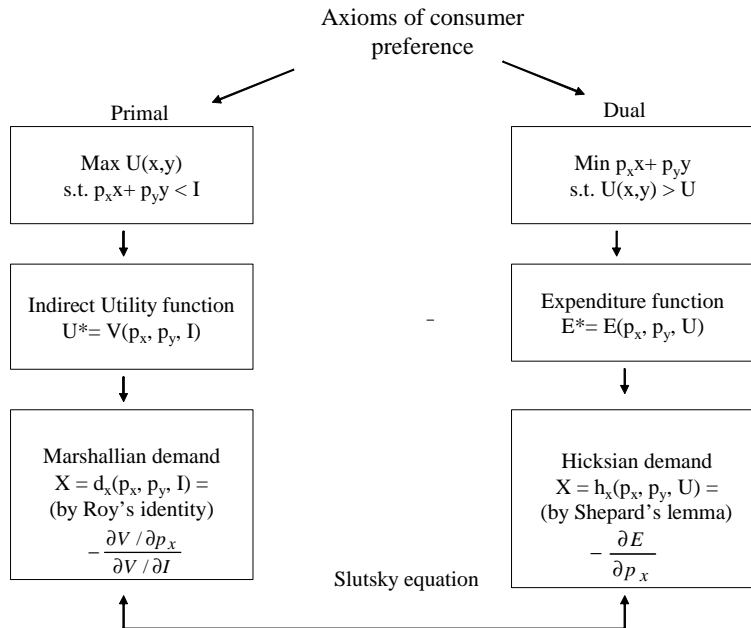
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Agenda

1. Utility maximization
2. Indirect Utility function
3. Application: Gift giving – Waldfogel paper
4. Expenditure function
5. Relationship between Expenditure function and Indirect utility function
6. Demand functions
7. Application: Food stamps – Whitmore paper
8. Income and substitution effects
9. Normal and inferior goods
10. Compensated and uncompensated demand (Hicksian, Marshallian)
11. Application: Giffen goods – Jensen and Miller paper

Roadmap:



1 Theory of consumer choice

1.1 Utility maximization subject to budget constraint

Ingredients:

- Utility function (preferences)
- Budget constraint
- Price vector

Consumer's problem

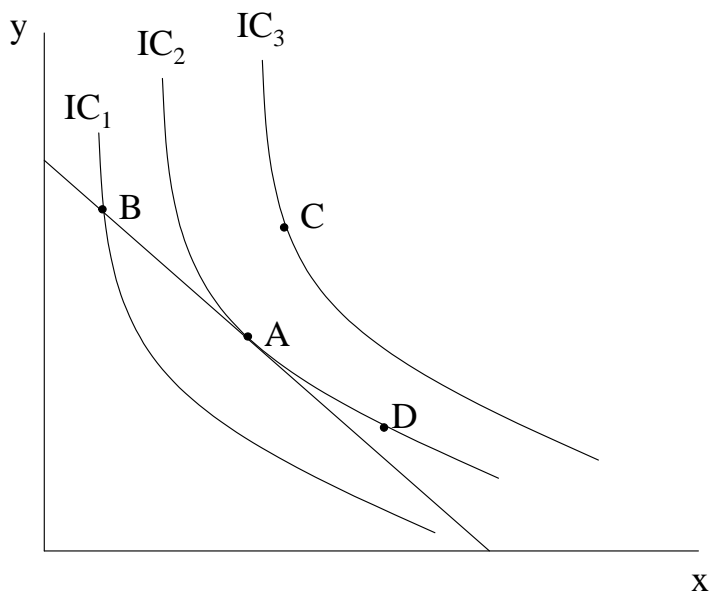
Maximize utility subject to budget constraint

Characteristics of solution:

- Budget exhaustion (non-satiation)
- For most solutions: psychic tradeoff = monetary payoff
- Psychic tradeoff is MRS
- Monetary tradeoff is the price ratio

From a visual point of view utility maximization corresponds to the following point:

(Note that the slope of the budget set is equal to $-\frac{p_x}{p_y}$)



What's wrong with some of these points?

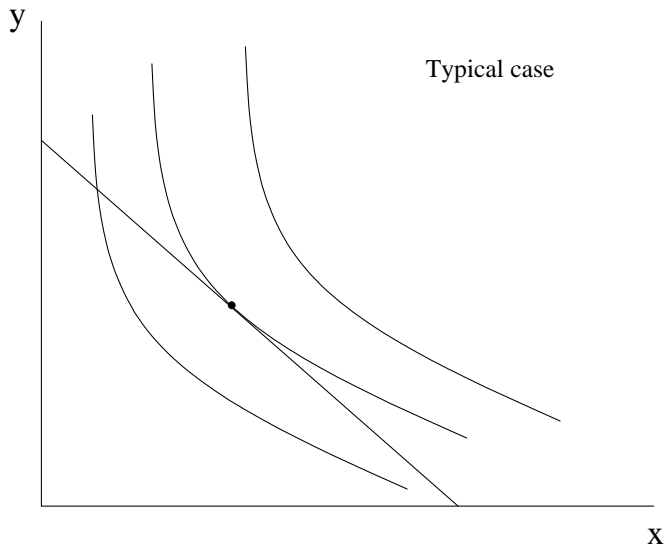
We can see that $A \succ B$, $A \succ D$, $C \succ A$. Why should one choose A ?

The slope of the indifference curves is given by the MRS

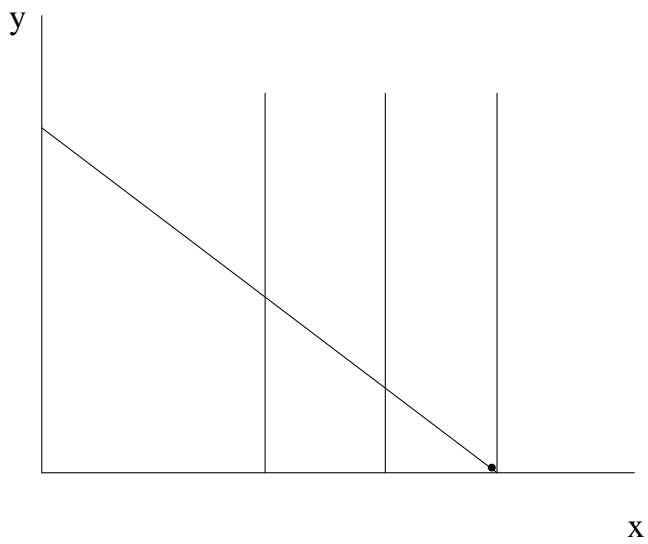
1.1.1 Interior and corner solutions [Optional]

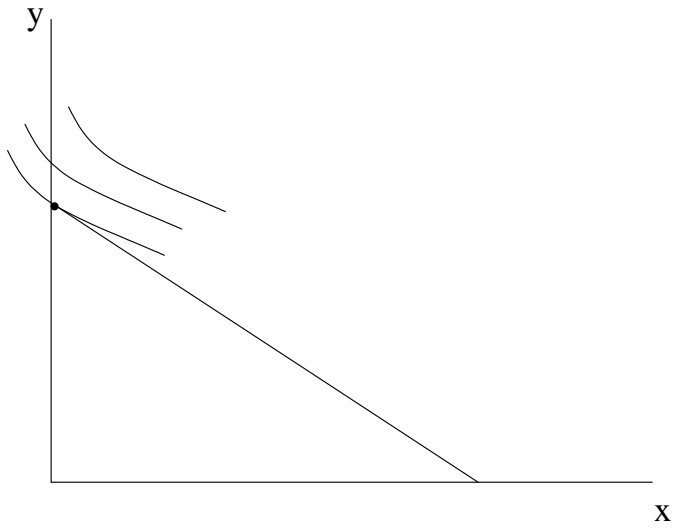
There are two types of solution to this problem.

1. Interior solution
2. Corner solution



The one below is an example of a corner solution. In this specific example the shape of the indifference curves means that the consumer is indifferent to the consumption of good y . Utility increases only with consumption of x .

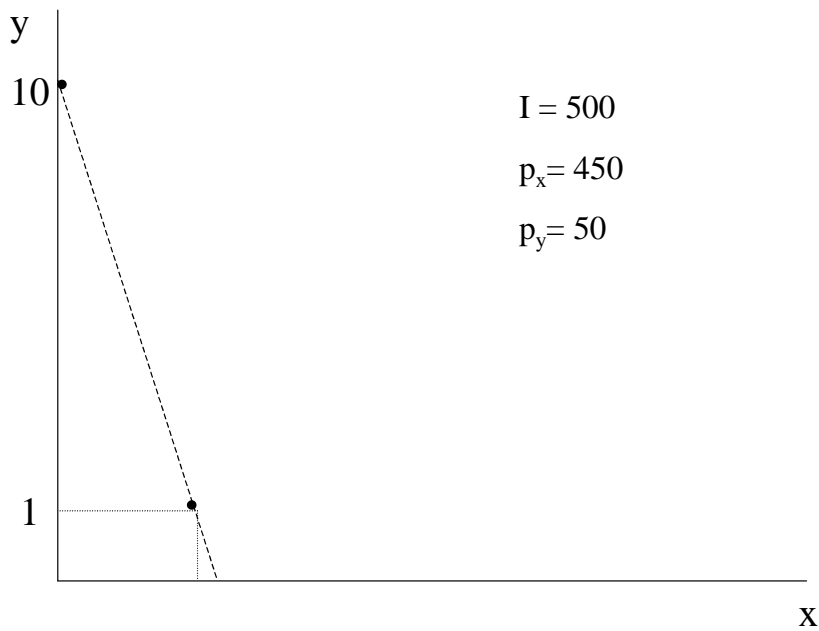




In the graph above preference for y is sufficiently strong relative to x that the psychic tradeoff is always lower than the monetary tradeoff.

This must be the case for many products that we don't buy.

Another type of "corner" solution results from indivisibility.



Why can't we draw this budget set, i.e. connect dots?

This is because only 2 points can be drawn. This is a sort of "integer constraint". We normally abstract from indivisibility.

Going back to the general case, how do we know a solution exists for consumer, i. e. how do we know the consumer can choose?

We know because of the completeness axiom. Every bundle is on some indifference curve and can therefore be ranked: $A \succ B, A \succ B, B \succ A$.

1.1.2 Mathematical solution to the Consumer's Problem

Mathematics:

$$\begin{aligned} & \max_{x,y} U(x,y) \\ \text{s.t. } & p_x x + p_y y \leq I \\ & L = U(x,y) + \lambda(I - p_x x - p_y y) \\ 1. & \frac{\partial L}{\partial x} = U_x - \lambda p_x = 0 \\ 2. & \frac{\partial L}{\partial y} = U_y - \lambda p_y = 0 \\ 3. & \frac{\partial L}{\partial \lambda} = I - p_x x - p_y y = 0 \end{aligned}$$

Rearranging 1. and 2.

$$\frac{U_x}{U_y} = \frac{p_x}{p_y}$$

This means that the psychic tradeoff is equal to the monetary tradeoff between the two goods.

3. states that budget is exhausted (non-satiation).

Also notice that:

$$\begin{aligned} \frac{U_x}{p_x} &= \lambda \\ \frac{U_y}{p_y} &= \lambda \end{aligned}$$

What is the meaning of λ ?

1.1.3 Interpretation of λ , the Lagrange multiplier

At the solution of the Consumer's problem (more specifically, an interior solution), the following conditions will hold:

$$\frac{\partial U / \partial x_1}{p_1} = \frac{\partial U / \partial x_2}{p_2} = \dots = \frac{\partial U / \partial x_n}{p_n} = \lambda$$

This expression says that at the utility-maximizing point, the next dollar spent on each good yields the same marginal utility.

So what is $\frac{\partial U}{\partial I}$? Return to Lagrangian:

$$\begin{aligned} L &= U(x, y) + \lambda(I - p_x x - p_y y) \\ \frac{\partial L}{\partial x} &= U_x - \lambda p_x = 0 \\ \frac{\partial L}{\partial y} &= U_y - \lambda p_y = 0 \\ \frac{\partial L}{\partial \lambda} &= I - p_x x - p_y y = 0 \\ \frac{\partial L}{\partial I} &= \left(U_x \frac{\partial x}{\partial I} - \lambda p_x \frac{\partial x}{\partial I} \right) + \left(U_y \frac{\partial y}{\partial I} - \lambda p_y \frac{\partial y}{\partial I} \right) + \lambda \end{aligned}$$

By substituting $\lambda = \frac{U_x}{p_x}$ and $\lambda = \frac{U_y}{p_y}$ both expressions in parenthesis are zero.

We conclude that:

$$\frac{\partial L}{\partial I} = \lambda$$

λ equals the “shadow price” of the budget constraint, i.e. it expresses the quantity of utils that could be obtained with the next dollar of consumption.

This shadow price is not uniquely defined. It is defined only up to a monotonic transformation.

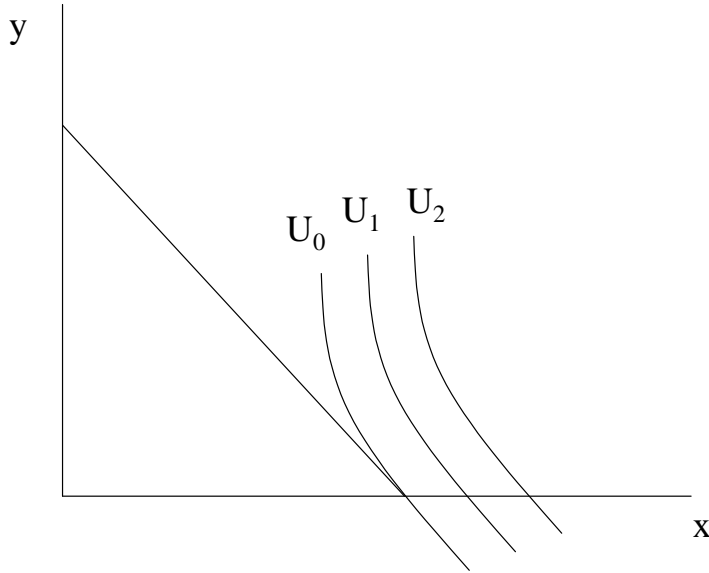
What does the shadow price mean? It’s essentially the ‘utility value’ of relaxing the budget constraint by one unit (e.g., one dollar). [Q: What’s the sign of $\partial^2 U / \partial I^2$, and why?]

We could also have determined that $\partial L / \partial I = \lambda$ without calculations by applying the envelope theorem. At the utility maximizing solution to this problem, x^* and y^* are already optimized and so an infinitesimal change in I does not alter these choices. Hence, the effect of I on U depends only on its direct effect on the budget constraint and does not depend on its indirect effect (due to reoptimization) on the choices of x and y . This ‘envelope’ result is only true in a small neighborhood around the solution to the original problem.

Corner Solution: unusual case

When at a corner solution, consumer buys zero of some good and spends the entire budget on the rest.

What problem does this create for the Lagrangian?



The problem is that a point of tangency doesn't exist for positive values of y .

Hence we also need to impose “non-negativity constraints”: $x \geq 0, y \geq 0$.

This will not be important for problems in this class, but it's easy to add these constraints to the maximization problem.

1.1.4 An Example Problem

Consider the following example problem:

$$U(x, y) = \frac{1}{4} \ln x + \frac{3}{4} \ln y$$

Notice that this utility function satisfies all axioms:

1. Completeness, transitivity, continuity [these are pretty obvious]
2. Non-satiation: $U_x = \frac{1}{4x} > 0$ for all $x > 0$. $U_y = \frac{3}{4y} > 0$ for all $y > 0$. In other words, utility rises continually with greater consumption of either good, though the rate at which it rises declines (diminishing marginal utility of consumption).
3. Diminishing marginal rate of substitution:

Along an indifference curve of this utility function: $\bar{U} = \frac{1}{4} \ln x_0 + \frac{3}{4} \ln y_0$.

Totally differentiate: $0 = \frac{1}{4x_0} dx + \frac{3}{4y_0} dy$.

Which provides the marginal rate of substitution $-\frac{dy}{dx}|_{\bar{U}} = \frac{U_x}{U_y} = \frac{4y_0}{12x_0}$.

The marginal rate of substitution of y for x is increasing in the amount of y consumed and decreasing in the amount of x consumed; holding utility constant, the more y the consumer has, the more y he would give up for one additional unit of x .

Example values:

$$p_x = 1$$

$$p_y = 2$$

$$I = 12$$

Write the Lagrangian for this utility function given prices and income:

$$\begin{aligned} & \max_{x,y} U(x,y) \\ \text{s.t. } & p_x x + p_y y \leq I \\ & L = \frac{1}{4} \ln x + \frac{3}{4} \ln y + \lambda(12 - x - 2y) \\ 1. & \quad \frac{\partial L}{\partial x} = \frac{1}{4x} - \lambda = 0 \\ 2. & \quad \frac{\partial L}{\partial y} = \frac{3}{4y} - 2\lambda = 0 \\ 3. & \quad \frac{\partial L}{\partial \lambda} = 12 - x - 2y = 0 \end{aligned}$$

Rearranging (1) and (2), we have:

$$\begin{aligned} \frac{U_x}{U_y} &= \frac{p_x}{p_y} \\ \frac{1/4x}{3/4y} &= \frac{1}{2} \end{aligned}$$

The interpretation of this expression is that the MRS (psychic trade-off) is equal to the market trade-off (price-ratio).

What's $\frac{\partial L}{\partial I}$? As before, this is equal to λ , which from (1) and (2) is equal to:

$$\lambda = \frac{1}{4x^*} = \frac{3}{8y^*}.$$

The next dollar of income could buy one additional x , which has marginal utility $\frac{1}{4x^*}$ or it could buy $\frac{1}{2}$ additional y 's, which provide marginal utility $\frac{3}{4y^*}$ (so, the marginal utility increment is $\frac{1}{2} \cdot \frac{3}{4y^*}$). It's important that $\partial L / \partial I = \lambda$ is defined in terms of the optimally chosen x^*, y^* . Unless we are at these optima, the envelope theorem does not apply. So, $\partial L / \partial I$ would also depend on the cross-partial terms: $(U_x \frac{\partial x}{\partial I} - \lambda p_x \frac{\partial x}{\partial I}) + (U_y \frac{\partial y}{\partial I} - \lambda p_y \frac{\partial y}{\partial I})$.

1.1.5 Lagrangian with Non-negativity Constraints [Optional]

$$\begin{aligned}
 & \max U(x, y) \\
 \text{s.t. } & p_x x + p_y y \leq I \\
 & y \geq 0 \\
 & L = U(x, y) + \lambda(I - p_x x - p_y y) + \gamma(y - s^2) \\
 1. \quad & \frac{\partial L}{\partial x} = U_x - \lambda p_x = 0 \\
 2. \quad & \frac{\partial L}{\partial y} = U_y - \lambda p_y + \gamma = 0 \\
 3. \quad & \frac{\partial L}{\partial s} = -2s\gamma = 0
 \end{aligned}$$

Point 3. implies that $\gamma = 0$, $s = 0$, or both.

1. $s = 0$, $\gamma \neq 0$ (since $\gamma \geq 0$ then it must be the case that $\gamma > 0$)

(a)

$$\begin{aligned}
 U_y - \lambda p_y + \gamma &= 0 \longrightarrow U_y - \lambda p_y < 0 \\
 \frac{U_y}{p_y} &< \lambda \\
 \frac{U_x}{p_x} &= \lambda
 \end{aligned}$$

Combining the last two expressions:

$$\frac{U_x}{U_y} > \frac{p_x}{p_y}$$

This consumer would like to consume even more x and less y , but she cannot.

2. $s \neq 0$, $\gamma = 0$

$$\begin{aligned}
 U_y - \lambda p_y + \gamma &= 0 \longrightarrow U_y - \lambda p_y = 0 \\
 \frac{U_y}{p_y} &= \frac{U_x}{p_x} = \lambda
 \end{aligned}$$

Standard FOC, here the non-negativity constraint is not binding.

3. $s = 0$, $\gamma = 0$

Same FOC as before:

$$\frac{p_x}{p_y} = \frac{U_x}{U_y}$$

Here the non-negativity constraint is satisfied with equality so it doesn't distort consumption.

1.2 Indirect Utility Function

For any:

- Budget constraint
- Utility function
- Set of prices

We obtain a set of optimally chosen quantities.

$$\begin{aligned}x_1^* &= x_1(p_1, p_2, \dots, p_n, I) \\ &\dots \\ x_n^* &= x_n(p_1, p_2, \dots, p_n, I)\end{aligned}$$

So when we say

$$\max U(x_1, \dots, x_n) \text{ s.t. } PX^* \leq I$$

we get as a result:

$$\begin{aligned}\max U(x_1^*(p_1, \dots, p_n, I), \dots, x_n^*(p_1, \dots, p_n, I)) \\ \Rightarrow U^*(p_1, \dots, p_n, I) \equiv V(p_1, \dots, p_n, I)\end{aligned}$$

which we call the “Indirect Utility Function”. This is the value of maximized utility under given prices and income.

So remember the distinction:

Direct utility: utility from consumption of x_1, \dots, x_n

Indirect utility: utility obtained when facing p_1, \dots, p_n, I

Example:

$$\begin{aligned}\max U(x, y) &= x^{.5}y^{.5} \\ \text{s.t. } p_x x + p_y y &\leq I \\ L &= x^{.5}y^{.5} + \lambda(I - p_x x - p_y y) \\ \frac{\partial L}{\partial x} &= .5x^{-.5}y^{.5} - \lambda p_x = 0 \\ \frac{\partial L}{\partial y} &= .5x^{.5}y^{-.5} - \lambda p_y = 0 \\ \frac{\partial L}{\partial \lambda} &= I - p_x x - p_y y = 0\end{aligned}$$

We obtain the following:

$$\lambda = \frac{.5x^{-.5}y^{.5}}{p_x} = \frac{.5x^{.5}y^{-.5}}{p_y},$$

which simplifies to:

$$x = \frac{p_y y}{p_x}.$$

Substituting into the budget constraint gives us:

$$\begin{aligned} I - p_x \frac{p_y y}{p_x} - p_y y &= 0 \\ p_y y &= \frac{1}{2}I, \quad p_y y = \frac{1}{2}I \end{aligned}$$

$$x^* = \frac{I}{2p_x}, \quad y^* = \frac{I}{2p_y}$$

Half of the budget goes to each good.

Let's derive the indirect utility function in this case:

$$U\left(\frac{I}{2p_x}, \frac{I}{2p_y}\right) = \left(\frac{I}{2p_x}\right)^{.5} \left(\frac{I}{2p_y}\right)^{.5}$$

Why bother calculating the indirect utility function? It saves us time. Instead of recalculating the utility level for every set of prices and budget constraints, we can plug in prices and income to get consumer utility. This comes in handy when working with individual demand functions. Demand functions give the quantity of goods purchased by a given consumer as a function of prices and income (or utility).

1.3 The Carte Blanche Principle

One immediate implication of consumer theory is that consumers make optimal choices for themselves given prices, constraints, and income. [Generally, the only constraint is that they can't spend more their income, but we'll see examples where there are additional constraints.]

This observation gives rise to the Carte Blanche principle: consumers are always weakly better off receiving a cash transfer than an in-kind transfer of identical monetary value. [Weakly better off in that they may be indifferent between the two.]

With cash, consumers have Carte Blanche to purchase whatever bundle or goods are services they can afford – including the good or service that alternatively could have been transferred to them in-kind.

Prominent examples of in-kind transfers given to U.S. citizens include Food Stamps, housing vouchers, health insurance (Medicaid), subsidized educational loans, child care services, job training, etc. [An exhaustive list would be long indeed.]

Economic theory suggests that, relative to the equivalent cash transfer, these in-kind transfers serve as *constraints* on consumer choice.

If consumers are rational, constraints on choice cannot be beneficial.

For example, consider a consumer who has income $I = 100$ and faces the choice of two goods, food and housing, at prices p_f, p_h , each priced at 1 per unit.

The consumer's problem is

$$\begin{aligned} & \max_{f,h} U(f, h) \\ \text{s.t. } & f + h \leq 100 \end{aligned}$$

The government decides to provide a housing subsidy of 50. This means that the consumer can now purchase up to 150 units of housing but no more than 100 units of food. The consumer's problem is:

$$\begin{aligned} & \max_{f,h} U(f, h) \\ \text{s.t. } & f + h \leq 150 \\ & h \geq 50. \end{aligned}$$

Alternatively, if the government had provided 50 dollars in cash instead, the problem would be:

$$\begin{aligned} & \max_{f,h} U(f, h) \\ \text{s.t. } & f + h \leq 150. \end{aligned}$$

The government's transfer therefore has two components:

1. An expansion of the budget set from I to $I' = I + 50$.
2. The imposition of the constraint that $h \geq 50$.

The canonical economist's question is: why do both (1) and (2) when you can just do (1) and potentially improve consumer welfare at no additional cost to the government?

1.3.1 A Simple Example: The Deadweight Loss of Christmas

Joel Waldfogel's 1993 *American Economic Review* paper provides a stylized (and controversial) example of the application of the Carte Blanche principle.

Waldfogel observes that gift-giving is equivalent to an in-kind transfer and hence should be less efficient for consumer welfare than simply giving cash.

In January, 1993, he surveyed approximately 150 Yale undergraduates about their holiday gifts received in 1992:

1. What were the gifts worth in cash value
2. How much the students be willing to pay for them if they didn't already have them

Image removed due to copyright considerations.
See Figure 1: Gift-Giving and Deadweight Loss.

3. How much would the students be willing to accept in cash in lieu of the gifts. (Usually higher than willingness to pay – an economic anomaly.)

For each gift, Waldfogel calculates the gift's 'yield' $Y_j = V_j/P_j$.

As theory (and intuition) would predict, the yield was, on average, well below one. That is, in-kind gift giving 'destroys' value relative to the cost-equivalent cash gift.

Figure I of Waldfogel illustrates the idea transparently:

The budget line aa' is the original budget set.

The line bb' is the budget set for an in-kind transfer.

U_1 is the highest feasible indifference achievable for this consumer with budget set bb' . This is achieved with consumption bundle II .

The intersection of U_2 and bb' , labeled III , is the consumption bundle with the in-kind gift. The amount of G is selected by the gift-giver rather than the recipient.

Although III lies on bb' , it is not on the highest achievable indifference curve achievable with budget set bb' .

Line cc' is the actual budget set the consumer would require to attain utility U_2 if his choice set were not constrained by the gift giver.

The 'deadweight loss' of gift-giving relative to the equivalent cash transfer in this example is equal to $(b' - c')/p_g$.

Several interesting observations from the article:

1. Value ‘destruction’ is greater for distant relatives, e.g., grandparents.
2. Value ‘preservation’ is near-perfect for friends
3. Groups that tend to ‘destroy’ the most value are the most likely to give cash instead

It’s useful to be able to interpret the basic regression result given on the top of page 1332:

$$\ln(\text{value}_i) = \underset{(0.44)}{-0.314} + \underset{(0.08)}{0.964} \ln(\text{price}_i) .$$

The things in parentheses are standard errors. Since 0.964 is much larger than 2×0.08 , the relationship between value and price is statistically significant.

The derivative of value with respect to price is (recall that $\partial/\partial x$ of $\ln x$ is $\partial x/x$):

$$\frac{\partial \text{value}_i}{\partial \text{price}_i} = \frac{\partial \text{value}_i}{\text{value}_i} \cdot \frac{\text{price}_i}{\partial \text{price}_i} = 0.964.$$

That is, a 1 percent rise in price translates into a 0.964 percent rise in value.

But, there is a major discrepancy between the level of value and price. Rewriting the equation and exponentiating:

$$\begin{aligned} \ln(\text{value}_i) &= -\ln(\exp(0.314)) + 0.964 \ln(\text{price}_i) \\ &= \ln\left(\frac{\text{price}_i^{0.964}}{\exp(0.314)}\right) \end{aligned}$$

Exponentiating both sides:

$$\begin{aligned} \text{value}_i &= \frac{\text{price}_i^{0.964}}{\exp(0.314)} \\ &= \frac{\text{price}_i^{0.964}}{1.37} \\ &= .73 \times \text{price}_i^{0.964} \end{aligned}$$

So, for a \$100 gift, the approximate recipient valuation is about \$62.

You can see why it’s handy to use natural logarithms to express these relationships. They readily allow for proportional effects. The regression equation above says that the value of a gift is approximately equal to 96% of its price minus 31 percent.

The Waldfogel article generated a suprising amount of controversy, even among economists, most of whom probably subscribe to the Carte Blanche principle.

To many readers, this article seems to exemplify the well-worn gripe about economists, “They know the price of everything and the value of nothing.” What is Waldfogel missing?

1.4 The Expenditure Function

We are next going to look at a potentially richer (and better) application of consumer theory: the value of Food Stamps.

Before that, we need some more machinery.

So far, we've analyzed problems where income was held constant and prices changes. This gave us the Indirect Utility Function.

Now, we want to analyze problems where utility is held constant and expenditures change. This gives us the Expenditure Function.

These two problems are closely related – in fact, they are ‘*duals*.’

Most economic problems have a *dual problem*, which means an inverse problem.

For example, the dual of choosing output in order to maximize profits is minimizing costs at a given output level: cost minimization is the dual of profit maximization.

Similarly, the dual of maximizing utility subject to a budget constraint is minimizing expenditures subject to a utility constraint.

1.4.1 Expenditure function

Consumer's problem: maximize utility subject to a budget constraint.

Dual: minimizing expenditure subject to a utility constraint (i.e. a level of utility you must achieve)

This dual problem yields the “expenditure function”: the minimum expenditure required to attain a given utility level.

Setup of the dual

1. Start with:

$$\begin{aligned} & \max U(x, y) \\ \text{s.t. } & p_x x + p_y y \leq I \end{aligned}$$

2. Solve for $x^*, y^* \Rightarrow v^* = U(x^*, y^*)$ given p_x, p_y, I .

$$V^* = V(p_x, p_y, I)$$

V is the indirect utility function.

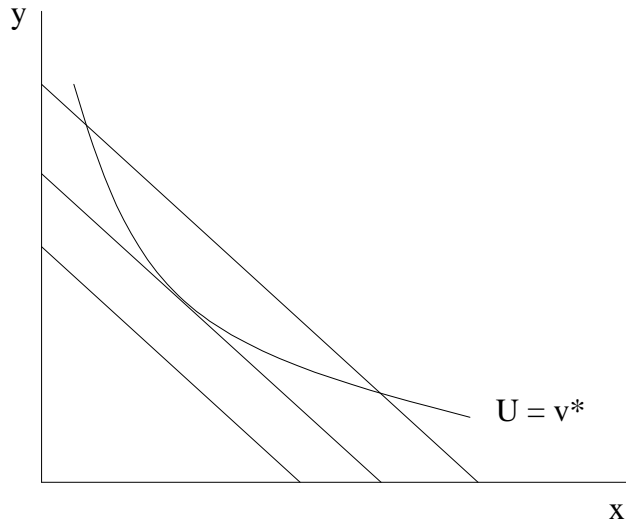
3. Now solve the following problem:

$$\begin{aligned} & \min p_x x + p_y y \\ \text{s.t. } & U(x, y) \geq v^* \end{aligned}$$

gives $E^* = p_x x^* + p_y y^*$ for $U(x^*, y^*) = v^*$.

$$E^* = E(p_x, p_y, V^*)$$

1.4.2 Graphical representation of dual problem



The dual problem consists in choosing the lowest budget set tangent to a given indifference curve.

Example:

$$\begin{aligned} \min E &= p_x x + p_y y \\ \text{s.t. } x^{.5} y^{.5} &\geq U_p \end{aligned}$$

where U_p comes from the primal problem.

$$L = p_x x + p_y y + \lambda (U_p - x^{.5} y^{.5})$$

$$\begin{aligned} \frac{\partial L}{\partial x} &= p_x - \lambda .5 x^{-.5} y^{.5} = 0 \\ \frac{\partial L}{\partial y} &= p_y - \lambda .5 x^{.5} y^{-.5} = 0 \\ \frac{\partial L}{\partial \lambda} &= U_p - x^{.5} y^{.5} = 0 \end{aligned}$$

The first two of these equations simplify to:

$$x = \frac{p_y y}{p_x}$$

We substitute into the constraint $U_p = x^{.5}y^{.5}$ to get

$$\begin{aligned} U_p &= \left(\frac{p_y y}{p_x}\right)^{.5} y^{.5} \\ x^* &= \left(\frac{p_y}{p_x}\right)^{.5} U_p, \quad y^* = \left(\frac{p_x}{p_y}\right)^{.5} U_p \\ E^* &= p_x \left(\frac{p_y}{p_x}\right)^{.5} U_p + p_y \left(\frac{p_x}{p_y}\right)^{.5} U_p \\ &= 2p_x^{.5} p_y^{.5} U_p \end{aligned}$$

How do solutions to Dual and Primal compare?

1.4.3 Relation between Expenditure function and Indirect Utility function

Let's look at the relation between expenditure function and indirect utility function.

$$\begin{aligned} V(p_x, p_y, I_0) &= U_0 \\ E(p_x, p_y, U_0) &= I_0 \\ V(p_x, p_y, E(p_x, p_y, U_0)) &= U_0 \\ E(p_x, p_y, V(p_x, p_y, I_0)) &= I_0 \end{aligned}$$

Expenditure function and Indirect Utility function are *inverses* one of the other.

Let's verify this in the example we saw above.

Recall that primal gave us factor demands x_p^* , y_p^* as a function of prices and income (not utility).

Dual gave us expenditures (budget requirement) as a function of utility and prices.

$$x_p^* = \frac{I}{2p_x}, \quad y_p^* = \frac{I}{2p_y}, \quad U^* = \left(\frac{I}{2p_x}\right)^{.5} \left(\frac{I}{2p_y}\right)^{.5}$$

Now plug these into expenditure function:

$$E^* = 2U_p p_x^{.5} p_y^{.5} = \left(\frac{I}{2p_x}\right)^{.5} \left(\frac{I}{2p_y}\right)^{.5} p_x^{.5} p_y^{.5} = I$$

Finally notice that the multipliers are such that the multiplier in the dual problem is the inverse of the multiplier in the primal problem.

$$\begin{aligned} \lambda_P &= \frac{U_x}{p_x} = \frac{U_y}{p_y} \\ \lambda_D &= \frac{p_x}{U_x} = \frac{p_y}{U_y} \end{aligned}$$

1.5 Demand Functions

Now, let's use the Indirect Utility function and the Expenditure function to get Demand functions.

To now, we've been solving for:

- Utility as a function of prices and budget
- Expenditure as a function of prices and utility

Implicitly we have already found demand schedules.

A demand schedule is immediately implied by an individual utility function.

For any utility function, we can solve for the quantity demanded of each good as a function of its price with the price of all other goods held constant and *either* income held constant *or* utility held constant.

1.5.1 Marshallian demand ('Uncompensated' demand)

In our previous example where:

$$U(x, y) = x^5 y^5$$

we derived:

$$\begin{aligned}x(p_x, p_y, I) &= .5 \frac{I}{p_x} \\y(p_x, p_y, I) &= .5 \frac{I}{p_y}\end{aligned}$$

In general we will write these demand functions (for individuals) as:

$$\begin{aligned}x_1^* &= d_1(p_1, p_2, \dots, p_n, I) \\x_2^* &= d_2(p_1, p_2, \dots, p_n, I) \\&\dots \\x_n^* &= d_n(p_1, p_2, \dots, p_n, I)\end{aligned}$$

We call this "Marshallian" demand after Alfred Marshall who first drew demand curves.

1.5.2 Hicksian demand ('Compensated' demand)

Similarly we derived that:

$$x(p_x, p_y, U) = \left(\frac{p_y}{p_x}\right)^{.5} U_p$$

$$y(p_x, p_y, U) = \left(\frac{p_x}{p_y}\right)^{.5} U_p$$

In general we will write these demand functions (for individual) as:

$$x_{1,c}^* = h_1(p_1, p_2, \dots, p_n, U)$$

$$x_{2,c}^* = h_2(p_1, p_2, \dots, p_n, U)$$

$$\dots$$

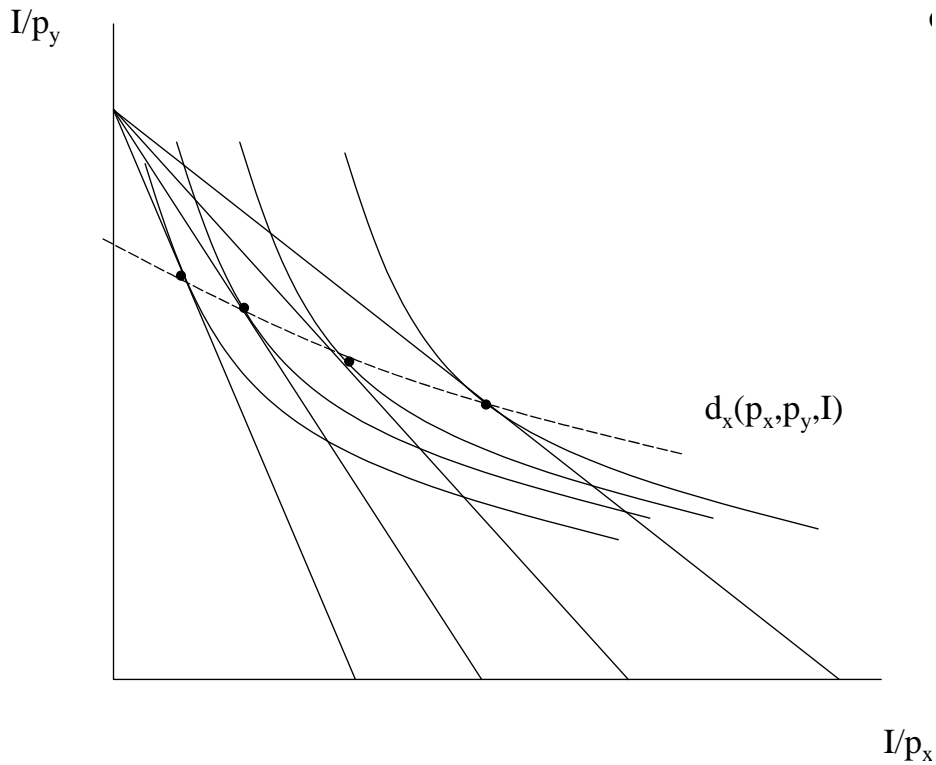
$$x_{n,c}^* = h_n(p_1, p_2, \dots, p_n, U)$$

This is called “Hicksian” or compensated demand after John Hicks.

This demand function takes utility as an argument, not income. This turns out to be an important distinction.

1.5.3 Graphical derivation of demand curves

A demand curve for x as a function of p_x



So a demand function is a set of tangency points between indifference curves and budget set holding I and p_y (all other prices) constant.

What type of demand curve is this?

Marshallian ($d_x(p_x, p_y, I)$). Utility is not held constant, but income is.

Now, we have the tools to analyze the Food Stamp program.