Industrial Design at the Service of Teaching Economics:

3D-Printed Prototypes and Materialized Demonstrations of Utility and Production Functions

(An Innovative, Pedagogical Tool to Teach Microeconomics)

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An Intro and A Quick Look at Literature:

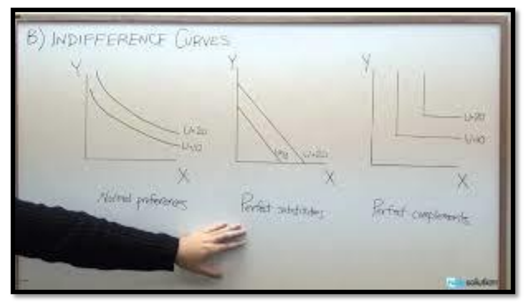
- Nilson (2007): "We **humans** have always been **visual animals**", but perhaps we have not relied much on our eyes in the past few millennia, during which oral cultures, then literate ones, have proliferated.
- Over the past several decades, we have seen **an emergence of a more visual culture**, one in which knowledge and information are increasingly conveyed in visual forms, and are decreasingly communicated in text (Fischman, 2001; Hartman, 2006).
- **Raised on television, movies, video games, and the Internet**, today's young people are leading this culture shift.
- According to Hodgins (2000), "**visualization will be at the heart of knowledge and understanding** in the coming decades.
- He also believes that "as visualization technologies evolve, we can expect to see the 'spoken and written word' - our dominant modes of sharing today - eclipsed in many instances by 3-dimensional, highly interactive, and compelling models, simulations, and augmented realities."
- A large body of research documents that **visualizations of all kinds are powerful teaching and learning tools** and that they specifically **facilitate comprehension and retention** in multiple, complex ways.

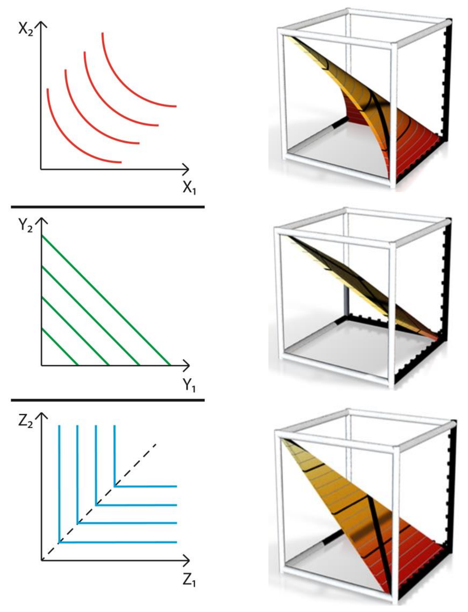
Abstract:

- Many economics students, even at the graduate level, have **difficulty in deeply understanding** the **complex nature of utility and production functions.**
- Admittedly, dealing with this intrinsic complexity has always been **difficult** in the classroom **for both instructors** in teaching as well as **students** in learning.
- As these functions are somehow **fundamental building blocks** of economics as a science, it is crucial for economic students to completely learn the nature and essence of these functions.
- Therefore, **effectively teaching** and completely learning the essence, nature, forms, and properties of these functions are crucial for economics students to thrive academically and professionally in the discipline.
- **A novel, innovative way** to teach utility functions is to use "**materialized demonstrations**" of utility and production functions, enabling students to actually "observe" what instructors usually try to describe verbally or at best graphically.
- This way, students can actually "**see**" and even "**touch**" the functions, and get a hands-on experience with utility and production functions. These innovative pedagogical tools can highly enhance the quality of teaching and level of learning.

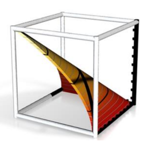
Prototypes for Three Main Types of Preferences:

- Relative Substitutes
- Perfect Substitutes
- Perfect Complements





Cobb-Douglas Utility/Production Function



Preferences to be Explained: *Relative substitutes*

Mathematical Formula: $U(x,y) = x^{0.5}y^{0.5}$

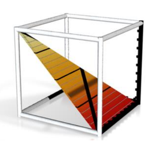
Description:
This instructional tool has been designed to help economics instructors visually teach the geometric and mathematical properties of the Cobb-Douglas utility/production function in the three-dimensional space. It will help economics students readily learn the gist of the Cobb-Douglas utility/production function.

Main Applications:

This instructional tool helps economics instructors visually and easily explain:

- The geometry of relative substitution, including mathematical and geometric properties of the Cobb-Douglas utility/production functions as well as those of their associated indifference curves and iso-quants
- Concavity of the Cobb-Douglas utility/production functions
- Convexity of preferences/iso-quants
- Quasi-concavity vs. concavity
- 3D representation of indifference curves and iso-quants in the 3D space
- The Infiniteness of the number of indifference curves and iso-quants
- The distinction between utility-commodity (or output-input) space and commodity-commodity (or input-input) space by exhibiting two different perspectives of the object
- etc.

Leontief Utility/Production Function



Preferences to be Explained: *Perfect complements*

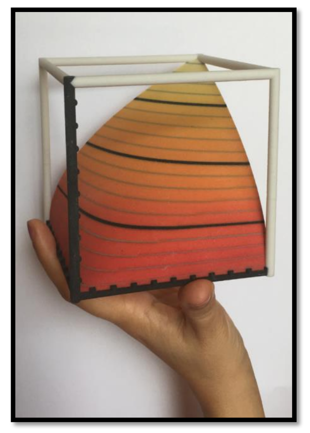
Mathematical Formula: $U(x,y) = min\{x,y\}$

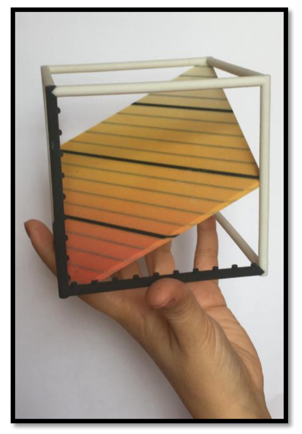
Description:
This instructional tool has been created to help economics instructors visually teach the geometric and mathematical properties of the Leontief utility/production function in the three-dimensional space. It will help students easily get the gist of the Leontief utility/production function.

Main Applications:

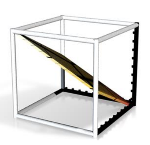
This instructional tool helps economics instructors visually and easily explain:

- The geometry of perfect complements, including mathematical and geometric properties of the Leontief utility and production function as well as mathematical and geometric properties of perfect-complement indifference curves and iso-quants
- Concavity of the Leontief utility/production functions
- Introducing an extreme case of convexity of preferences/iso-quants
- 3D representation of L-shaped indifference curves and iso-quants in the 3D space
- etc.





Linear Utility/Production Function



Preferences to be Explained: *Perfect substitutes*

Mathematical Formula: $U(x,y) = 0.5x + 0.5y$

Description:
This instructional tool has been created to help economics instructors visually teach the geometric and mathematical properties of a linear utility/production function in the three-dimensional space. It will help students easily get the gist of a linear utility/production function.

Main Applications:

This instructional tool helps economics instructors visually and easily explain:

- The geometry of perfect substitutes, including mathematical and geometric properties of a linear utility/production function as well as mathematical and geometric properties of perfect-substitute indifference curves and iso-quants
- Concavity of linear utility/production function
- Introducing an extreme case of convexity of preferences/iso-quants
- 3D representation of linear indifference curves and iso-quants in the 3D space
- Corner solutions
- etc.

Cobb-Douglas Utility/Production Function with a Budget Constraint

Preferences to be Explained: *Relative substitutes*

Mathematical Formula: $U(x,y) = x^{0.5}y^{0.5}$ *s.t.* $x + y = 7$

Description:
This instructional tool has been designed to help economics instructors visually teach the geometric and mathematical properties of the Cobb-Douglas utility/production function in the three-dimensional space. It will help economics students readily learn the gist of the Cobb-Douglas utility/production function. Additionally, it enables economics instructors to elaborate the geometry and math of a constrained maximization process in the three-dimensional space.

Main Applications:

This instructional tool helps economics instructors visually and easily explain:

- The geometry of relative substitution, including mathematical and geometric properties of the Cobb-Douglas utility/production function as well as those of their associated indifference curves and iso-quants
- Concavity of the Cobb-Douglas utility/production function
- Convexity of preferences/iso-quants
- Quasi-concavity vs. concavity
- 3D representation of indifference curves and iso-quants in the 3D space
- The Infiniteness of the number of indifference curves and iso-quants
- The distinction between utility-commodity (or output-input) space and commodity-commodity (or input-input) space by exhibiting two different perspectives of the object
- Budget constraint, line and set
- The geometry and math of constrained maximization
- Tangent indifference curve or iso-quant
- etc.

Four Conventional Ways to Teach Utility Functions:

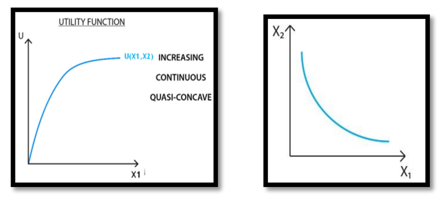
- Text

A utility function $u: X \rightarrow \mathbb{R}$ **represents** a preference relation $\precsim$ on X iff for every $x, y \in X$. $u(x) \leq u(y)$ implies $x \precsim y$. If u represents $\precsim$, then this implies $\precsim$ is complete and transitive, and hence rational.

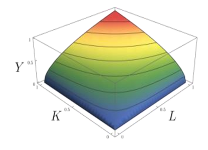
- Mathematical Functional Forms (3D hard to imagine)

$$U(x_1,x_2) = x_1^a x_2^b$$
$$U(x_1,x_2) = ax_1 + bx_2$$
$$U(x_1,x_2) = \min(x_1,x_2)$$

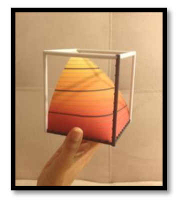
- Multiple 2D Diagrams (to illustrate different dimensions)



- A Single 3D Functions On a 2D Paper/Board



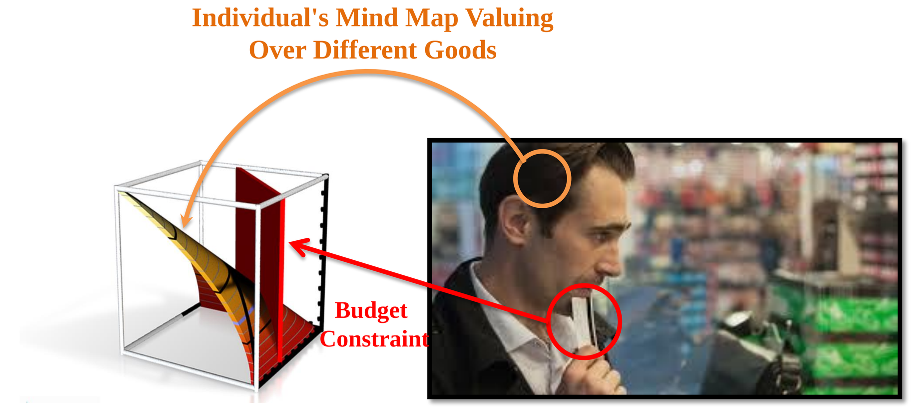
- **Actual 3D Models of Functions!!!**



Different applications of these innovative instructional tools:

- Demonstrating various types of utility and production functions that exhibit desired mathematical, technical, and theoretical properties
- Introducing three major types of utility and production functions, two polar cases, namely perfect substitutes and perfect complements, and an intermediate one, i.e. Cobb-Douglas utility and production function
- Clarifying the concept of isoquants, indifference map, and the existence of infinite number of indifference curves
- Illustrating the convexity of indifference curves and the diminishing marginal rate of substitution
- Exhibiting the (quasi-)concavity of utility and production function
- Clarifying the distinction between quasi-concavity and concavity
- Illustrating the relationship between indifference curves and a utility function
- Demonstrating the concepts of budget constraint, budget line, and budget set
- Interpreting the concept of constrained maximization in a geometric fashion

One Cool Way to Teach Constrained Utility Maximization!



Not just Micro, but also Macro!

- A Recently Published Textbook: ***Modern Macroeconomics***
- By Sanjay Chugh, MIT Press
- The first chapter of the textbook is devoted to visually explain utility functions.