An Introduction to Economic Models

Edward R. Morey: draft, September 13, 2018

Economic models are in some, but not all, ways much like fashion models; the good ones are stylized, useful, and attractive representations of reality.

Note that I did not say they are reality, in spite of what you saw in the Coors Light ad during the football game.

Simply put, economists build and test models of economic systems, or build and test models of a part of an economic system.

A scientist is someone who builds or tests models.

Before we define a model, let's consider its purpose.

What is the purpose of a model (theory)?

A model tries to correctly explain and predict the working of a **system**, and, in particular how things are and how they will change if something exogenous to the system changes.[1]

Note that “model” and “theory” are two different names for the same thing: the former is simply less ostentatious.[2]

The following are *systems*
The U.S. economy
The solar system
A hot dog sitting in some cold water on your stove
The human body
A household
The market for potatoes
The flow and distribution of water in the Mississippi delta
Wanda Sue is a system, so it everyone else.

For example: the system might be the market for cigarettes and the intent of the model is to explain and predict what will happen to the consumption of cigarettes if the price of cigarettes increases by one dollar.[3]

> In this case one is not trying to explain/model how the price of cigarettes is determined, but rather than how consumption of cigarettes is affected by the price of cigarettes. That is, the price influences the system one is trying to explain, but the price is not part of what one is trying to explain.

[1] Like what happened when Jordan moved to Wiggins.
[2] That said, I would rather date a model than a theory.
[3] Coloradoans voted (Nov 2016) on a ballot initiative that would have greatly increase the tax on cigarettes. One would need a model to predict the effect of the tax increase on cigarette consumption. (Note the initiative lost.)

In the last recession, the Federal Government gave a subsidy to first-time home buyers (now expired) to simulate the housing market.

Some economists built models to predict how this subsidy would affect the number of homes purchased, both in the short run and long run.

That is, models to predict how many homes would be purchased in a world where the subsidy is zero and a world where the subsidy is the amount specified by the government.

Some of those models predicted the subsidy would lead to an increase in home buying, while some of the other models predicted only that the subsidy would cause people to buy sooner rather than later.

The models predicted different things because they made different assumptions.

Building a model

One begins building a model by identifying the system of interest (the system you what to explain)

> A model cannot explain everything, only a subset of everything; usually a model explains only a small subset of everything.

A model describes the chosen system in terms of “variables” and the relationships between those variables. (This last sentence could be considered a quasi-definition of a model, an incomplete definition.)

Variables

Variables are simply thing that vary: your body temperature, the number of cigarettes the population of Boulder smokes per day, how many people get married each day, whether an individual will have sex tomorrow(yes or no variable), GDP, and the unemployment rate.

Representing variables and their levels

Scientists and mathematicians use different letters (e.g. x, y, and z) to represent different variables.

For example, in a model an economist might use c to denote the variable aggregate consumption in the U.S and c_t to represent the level of aggregate consumption in year t, For example c_{2007} would be the aggregate level of consumption in 2007

Or, in another model c might be the number of cigarettes an individual smokes in 24 hours. In which case c_i would be the number smoked by individual i, $i=1,2,3,\ldots..,N$.

In another model, $d_i=1$ if the condemned prisoner i is dead, and zero otherwise. In this model, dead would be considered a “success”, at least from the perspective of the State.

> Variables that can take only two values are called *dichotomous* or *dummy* variables: one only needs two numbers (0 and 1, or, for example, 1 and 2, or 1 and 37) to represent a variable that can take only two levels (alive or dead, true or false, yes or no).

Endogenous and exogenous variables

In models make a distinction between those variables whose levels you want to explain in your model, and those variables you want to include in your model, but not explain. The former are called *endogenous variables,* the latter *exogenous variables.*

In more detail: **you,** the model builder, **choose** what variables you want **your model** to explain. The variables whose levels you want to explain are call endogenous variables. The adjective *endogenous* means *inside* – what is determined inside your model.

The prefix “ex” mean “out, from, or away”
The prefix “en” means “in, into, into”
The adjective “exogenous” means the value of the variable is determined outside of the system
The adjective “endogenous” means the value of the variable is determined within the system

You include exogenous variables in a model because you assume they, together, will determine/explain the levels of the endogenous variables in your model.

Assumptions relate variables

After you have decided on the variables that will be in your model and which will be exogenous and which will be endogenous,

You then make assumptions about relationships between the variables in your model with the intent of explaining the levels of the endogenous variables in your model in terms of the levels of the exogenous variables in your model.

The exogenous variables in your model are the variables that you think determine the levels of the endogenous variables in your model.

In your model, you don't care how the levels of the exogenous variables are determined; you only care about how they influence the levels of the endogenous variables.

> Variables that are exogenous in one model might be endogenous in another model
>
> Variables that are endogenous in one model might be exogenous in another model.
>
> If it is your model, you can make whatever variables you want either exogenous or endogenous, you just cannot make a variable both exogenous and endogenous.

Examples of endogenous and exogenous variables in different models

You want to build a macroeconomic model to explain, in the U.S. economy, yearly GDP (gross domestic product), aggregate consumption, and the level of unemployment: you want the model to predict the levels of these three variables, so these will be the endogenous variables in your model.

> You assume that that the levels of these variables are determined by interest rates, the level of government expenditures and whether the President is a Republican or Democrat.
>
> For the purpose of this model, you are not trying to explain how interest rates are determined or how government expenditures are determined, or who gets elected President.
>
> In this model, GDP, aggregate consumption and the level of unemployment are endogenous variables. In this model interest rates, government expenditures and the political party of the President are exogenous variables.

Our next model will involve nose picking, so I am going to take a detour and read a poem about nose picking.

Poem by Paul Hughes 2008

The following is a poem, not a model.

A foolish boy named Jimmy Price

refused to take his mum’s advice

and kept on poking up his nose

his fingers, thumbs and, once, his toes

nose picking gave him endless joy

oh what a frightful, horrid, boy

his mother told him that his head

would cave right in and he’d be dead

but Jimmy knew that this was bluff

“it’s such an awful lot of guff

there’s really nothing wrong with snot

I’ll pick my nose and eat the lot”

he scraped and plucked his nostrils clean

it was a truly gruesome scene

ignoring every sign of pain

he rummaged ‘til he found his brain

which out he pulled without a thought

and that’s the end of my report

for Jimmy died right there and then

he never picked his nose again

Moral

It’s most unsatisfactory

to eat what is olfactory.

A model of relationship status (the endogenous variable) with nose picking being an exogenous variable

You want to build a model to explain only whether someone has a significant other, and, for your model, you are willing to assume one either does or does not have a significant other – there are no intermediate cases (e.g. my local friend whose girlfriend lives with her husband in California)

> Let s=1 if the individual has a significant other, and s=0 if they do not. So, s is the endogenous variable in this model, a dichotomous variable. So, for example s_i=0 if individual i does not have a significant other.

> You are not trying to explain one's income or nose-picking habits but assume they are important determinants of whether one has a significant other.[4] In this model, significant other is the only endogenous variable, and income and nose-picking habit are exogenous variables.

>> y_i could denote the individual i's income and n_i =1 if the individual is a nose-picker (n_i =0 if not)

> You might assume that the probability of having a significant other increases with one's income and, ceteris paribus, decreases if one picks their nose.[5] These might be two assumptions in your model.

The above is not a complete model; rather it is the skeleton/outline of a model—it is not complete.

A different model:

Instead of the last model, maybe you want to explain both whether an individual has a significant other and whether the individual is a nose picker, and are willing to assume both are determined by one's income. In this model, significant other and nose picking are both endogenous variables. Income is still exogenous.

You might assume that probability of significant other increases with income and probability of nose picking increases with income, but assume probability of a significant other decreases with nose picking. These might be assumptions in this model.

[4] Note that Elon Musk supposedly picks his nose.
[5] "Ceteris paribus" "means everything else constant." Or, you could assume the opposite, it's your model.

Build a model to explain how many days an individual will ski Vail this winter (my dissertation predicted ski trips).

So, number of days individual *i* skis Vail in a season is your endogenous variable, v_i is the number of days individual *i* skis Vail.

You might assume it depends on the price of a Vail lift ticket, that season's snowfall, and how far the individual lives from Vail.

In this model, you are not trying to model how Vail sets their lift-ticket prices, or explain how God (or global warming) decides how much it will snow, or explain why people choose to live where they live. In this model, number of ski days is the endogenous variable; price, snow fall, etc. are exogenous variables.

The state of the human body (dead or alive) would be of interest in a model designed to explain and predict the outcome of attempted executions.

Life status, dead or alive, would be the endogenous variable.

Volts administered might be an exogenous variable.

Or, one might model dead or alive in a population with some disease as a function of treatment type.

A model consists of three parts: variables and their definitions, assumptions relating those variables, and predictions

Synonyms for predictions are *hypotheses* and *if… then … statements*.

Variables and Definitions

One begins model building by choosing and defining the endogenous and exogenous variables in your model.

> For example, if you model is about potatoes, you need to define a potato. A Potato is ..
>
> The price of a potato is the wholesale price at the Chicago commodities exchange.
>
> A hot dog is …..

Assumptions

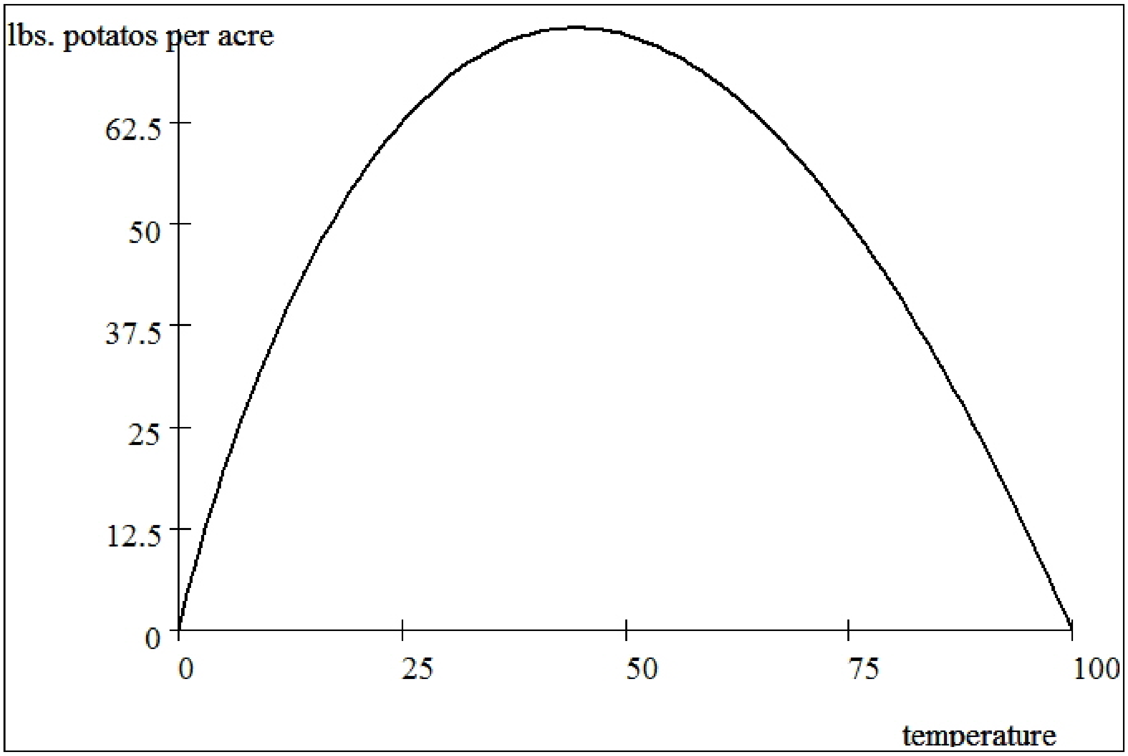
One specifies, by assumption, which variables are endogenous and which are exogenous.

> For example, one might assume the price and quantity sold of potatoes is what you want to explain, so these two variables are assumed endogenous variables.

> You might specify rainfall and temperature as exogenous variables (something influential that you don’t want to explain).

One then specifies, by assumption, relationships between variables.

For example, one might assume the relationship between rainfall and potato production is an inverted U (production is low if rainfall is low or high)

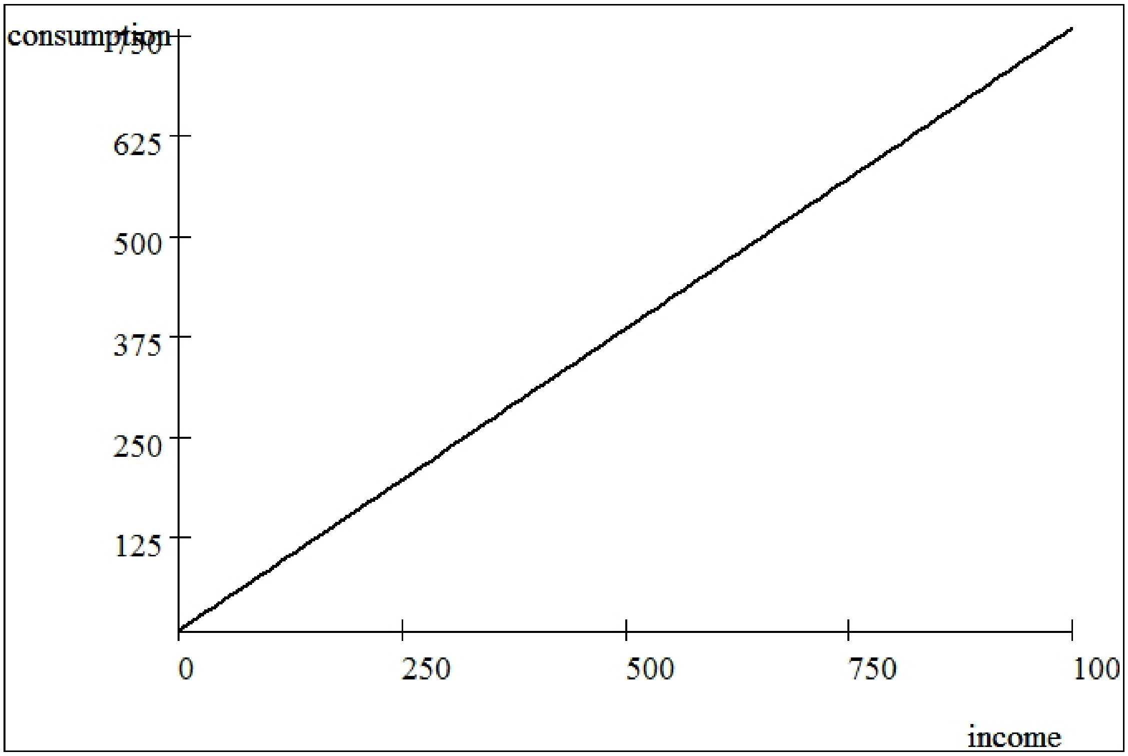


lbs. potatoes per acre as a function of temp.

This is the graph of an assumption. The specific assumption is lbs =100-(100-5t+.5t^{1.5}).

Or, in another theory, one might assume that aggregate consumption in the U.S. increases, linearly, when aggregate income increases.

Or, in notation, $C_t = a + bY_t$. Where $a, b>0$



$$consumption = 10 + .75(income)$$

Note that c=10+.75*(income) is a much more restrictive assumption than is c=a+b*(income).

A third example of a possible assumption (an assumption might or might not be true)

Boys pick their nose twice as much as girls.

Note that an assumption in one model might be a prediction in another model

Models have **more than one** assumption and the assumptions **cannot contradict** one another

Equilibrium is an important **assumption** is many models, and most economic models

Exercise for recitation (or home): Choose and define two or three variables that you might want to put in a model (whatever variables you want). Define, in words, each of your variables. Then choose a different letter to denote each of your variables.

Then specify two assumptions relating your variables. Specify each of your assumptions in words, mathematical notation, and with a graph.

Predictions

The predictions of a model follow **logically** from the assumptions and definitions.

Consider the following two assumptions:

All men cry

Donald is a man

What prediction follows?

Another model:

Consider the following five assumptions:

1. Sad men cry
2. Barak Obama is a man
3. Barak Obama is a Democrat
4. If the Tea Party exists, Democrats will be sad.
5. The Tea Party exists.

Assumptions 4 and 5 together imply that Democrats are sad.

This and assumption 3 imply that Barak is sad

This and 2 imply that Barak is a sad man.

This and 1 imply that Barak cries.

What are some other things the theory implies? Does not imply?

For example: It implies that Democratic women are sad, but it does not imply that they cry, maybe they cry, and maybe not. Not enough has been assumed to determine whether they cry.

The TA’s are making about multiple-choice questions where you will be given a set of assumptions and asked what these assumptions predict, or do not predict.

There are also questions like the above on old exams.

Assumption: The average person in the U.S. weighs 180 pounds.

Assumption: Individual *x* weighs more than the average person

Prediction

X weights more than 180 pounds

A model can have assumptions that are not true—assumptions simply cannot contradict one another

If you build a model you can define variables however you want. And you can assume whatever you want, as long as you do not contradict yourself.

For example, you cannot simultaneously assume the following three things:

A is greater than B

B is greater than C

C is greater than A.

(Make sure you can explain why any two of these assumptions contradict the third one)

If you were building a model to predict the shots of an expert pool player, you might assume in your model that expert pool players know advanced geometry. Such an assumption is not necessarily true, but the assumption might lead to a model that accurately predicts the pool shots of experts.

And **you must follow the rules of logic when deriving the predictions implied by your definitions and assumptions.**

What scientists do is build models, test models, or both

This is true of chemists, biologists, and even economists—yes, economists are scientists, or that is what economists believe.

In models, **what goes in (the assumptions) determines what comes out (the predictions)**.

Logic is the machine that links the two.

Theory is another word for **model**.

Economists build theories

How do we judge (test) our models?

We see how well they explain/predict the system of interest.

For example, imagine a model built to explain the driving habits of Americans: whether one owns a car, if so, what kind, and if one owns a car how many miles one drives per week.

> As an environmental economist interested in air pollution, such models have great importance for me.

Imagine this model consists of a bunch of definitions and assumptions and predicts that every time the price of gas increases by 1%, miles driven decreases by .4%

One can look at data to see if this is true.

If a model gets it all wrong, it is a Baaad model

That said, Baaad is a matter of degree.

For example, Newtonian Physics predicts a lot of stuff correctly but gets some stuff wrong.

It has been replaced by Einstein's Relativity Theory which predicts correctly what Newtonian Physics predicts, but, in addition, gets correct stuff that Newtonian Physics got wrong, or did not consider.

So Newtonian physics is a baad model, at least relative to Relativity theory.

How does one “fix”/modify a model/theory?

One changes the assumptions.

Consider the prevailing economic theory, in 1929, of how the economy works. The stock market crashed October 29, 1929 (Black Tuesday) at the beginning of the Great Depression, a long period of high unemployment (25%), and low income that ended only after immense government intervention to stimulate the economy (President Franklin Roosevelt’s “New Deal” and finally World War II).

Dorothea Lange's *Migrant Mother* depicts destitute pea pickers in California, centering on Florence Owens Thompson, age 32, a mother of seven children, in Nipomo, California, March 1936.

Back then economists believed that

"left along they [markets] were self-correcting and would return to an 'equilibrium' that efficiently utilized capital, workers and natural resources… this was the inviolate and core axiom of 'scientific economics' itself…

… A month after the Great Crash of 1929, the economists of Harvard, stated that a 'severe depression … is outside of the range of probability." (Richard Parker, John Kenneth Galbraith: his life, politics and economics, 2005, p.12)[6]

They could not have been more wrong.

A new theory emerged, Keynesianism, with the publication of John Maynard Keynes' "The General Theory of Employment, Interest and Money." Keynes made different assumptions, assumptions that lead to the prediction—impossible in the replaced Neoclassical theory—that the economy can stagnate (get stuck): be in an equilibrium with high unemployment and low income, an inefficient equilibrium.

[6] Galbraith (1908-1996), a Harvard economist, produced four dozen books and thousands of articles. When I was first studying economics, he was the most famous economist among non-economists. I highly recommend two of his books: "The Affluent Society" and "The New Industrial State." Neither has any math in it.

(If you are in Econ 4545 and reading these notes for background material, you can stop here.)

An example of a simple economic model

a simple production model for a one-person economy.

This model in the book has three parts: definitions, assumptions and predictions

The model has three variables:

> Amount of resources available, Tom Hanks' time devoted to production = T (meas. in hours)
>
> Number of coconuts gathered =C
>
> Number of fish caught = F

The model assumes C and F are endogenous variables – what the modeler wants to explain.

The model assumes T is exogenous (the model is not trying to explain how much Tom works)

It assumes only two goods can be produced: no production of cigarettes, booze, or naughty movies, only coconuts and fish.[7]

In addition, the model assumes time is needed to catch fish and to gather coconuts, and one cannot do both at the same time. (There is also no texting.)

It further assumes that fish caught per additional hour time spent fishing starts positive, but while remaining positive decreases as Tom allocates more hours to catching fish.

> Tom wisely starts by catching the fish that are easiest to catch (fish that are close by, hungry and stupid).

[7] Before Anthony Weiner I never thought about how one might direct, film, and be the only actor in a naughty movie.

Likewise, it assumes the number of coconuts gathered per hour starts positive, but while remaining positive decreases as Tom allocates more of his work hours to gathering coconuts.

Tom starts at the closest tree.

What does the model predict?

The model does **not** predict how many coconuts Tom will gather or how many fish he will catch; rather it predicts the combinations of coconuts and fish that are feasible, and how that will change as Tom works more or less.

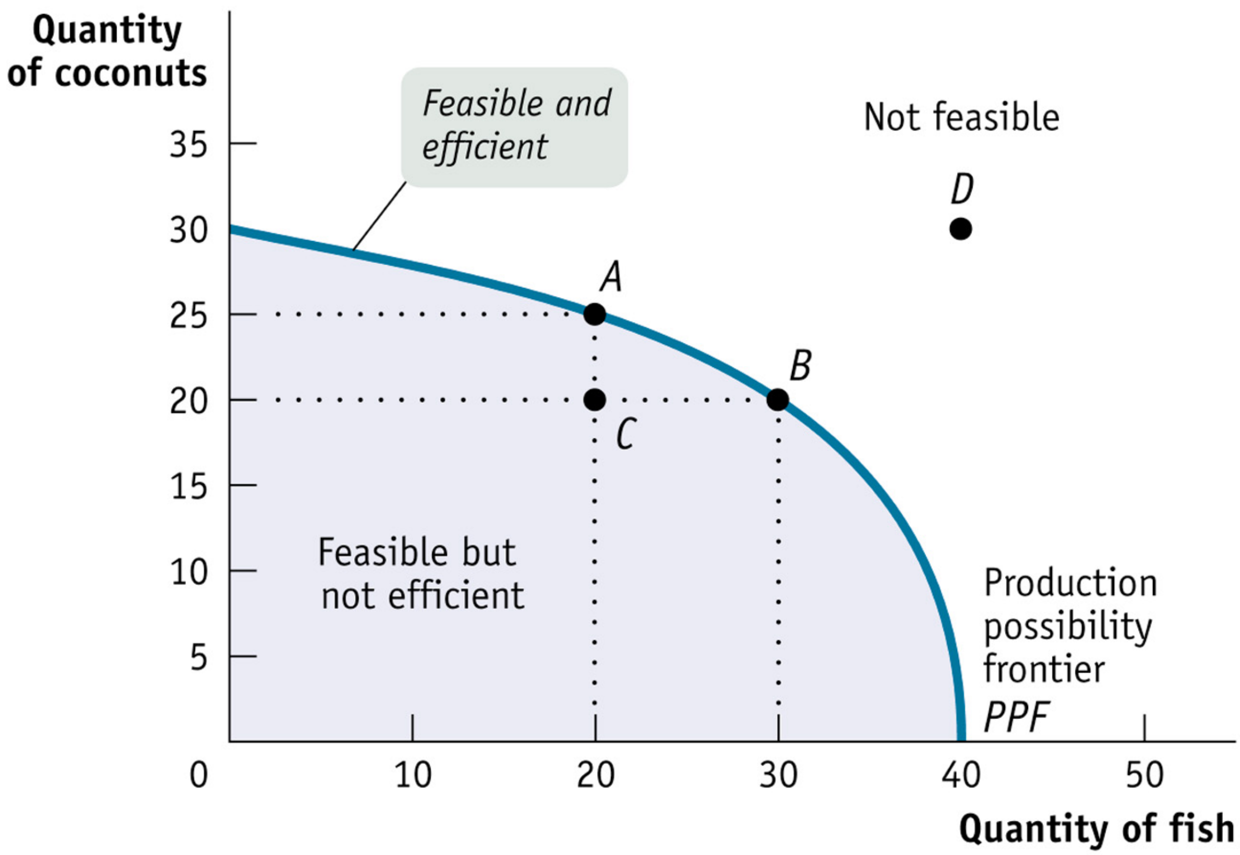
What is feasible in terms of coconut and fish production is represented with a set of points, called a production-possibilities set – all those combinations of *C* and *F* that are feasible.

The boundary of that set is called the production-possibilities frontier.

This graph is a visual representation of the information contained in the assumptions specified on the previous page, plus, sufficient assumptions to imply the numerical amounts.

The assumptions on the previous page together imply the basic shape, but not the specific numbers

Discuss the graph



(Note that the word “efficient” in the graph refers to efficiency in production, not necc. Overall efficiency)

Again, what does this theory predict?

Tom cannot produce outside of the shaded area

What else does it predict?

Does it predict how much will be produced if Tom does not work? “**If** Tom does not work **then**…..”

What does it predict will happen if Tom increase (or decreases) the amount he works?

What does it predict will happen if Tom continues to work the same amount but catches more fish? **Be careful with this question**. **It should be on the midterm.**

Show this with a graph.

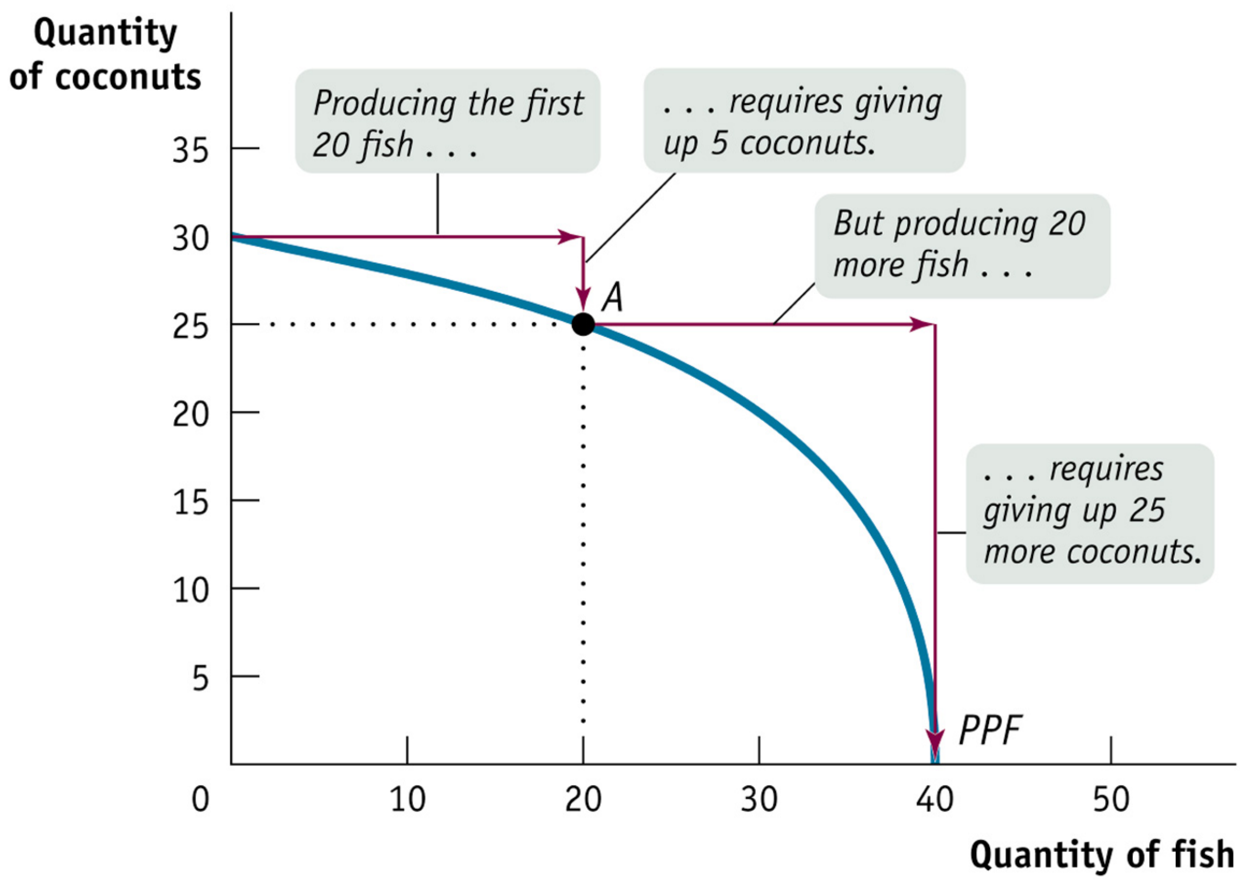
What happens if Tom decides to work more or less?

This simple model predicts even more,

Operating on the frontier, as Tom allocates more hours to catching fish, and fewer hours to gathering coconuts, the marginal cost of catching fish, in terms of forgone coconuts, increases.

An equivalent way of saying this is as Tom allocates more hours to gathering coconuts, and fewer hours to catching fish, the marginal cost of collecting coconuts in terms of forgone fish increases.

To catch another fish requires the sacrifice of some coconuts (the opportunity cost of another fish) and each additional fish costs more than the previous one in terms of un-gathered coconuts.



What would it mean if the PPF was a straight line?

In closing:

I have a little trouble with Krugman and Wells identifying the boundary of the production possibilities frontier as efficient.

Being on the frontier is efficient given how much Tom is working, but not necessarily overall efficient—he might be working too much or too little, so not working the efficient amount from his perspective.

Requiring Tom to work a certain amount of time might lead to an inefficient amount of work from Tom's perspective

It is efficient if Tom chose how much to work.

Efficiency in this world is achieved when Tom is doing the best he can given his constraints (abilities, time, and existing natural resources)

Tom might decide the efficient thing to do is to let the coconut rote into alcohol and drink himself to death, or simply spend all day everyday working on his tan.[8]

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[8] Eventually he will become a well-tanned corpse.