1 Macroeconomics: Modeling the Behavior of Aggregate Variables

Chapter 1 Contents

A. Topics and Tools

In this chapter, we sketch the basic outlines of macroeconomic analysis: What do we study in macroeconomics and how do we go about it? This chapter is less about specific topics and analytical tools than it is a survey of the topics and tools that we'll use throughout the course. It contains details about the macroeconomic variables we will study and about how macro models attempt to describe theories about the relationships among them.

The students in this class likely have widely varying exposure to macroeconomics, from a brief sampling of a few macro concepts to a full course at the intermediate level. Those who have a more extensive background may omit sections of this chapter with which they are very familiar.

B. Methods and Objectives of Macroeconomic Analysis

Macroeconomics is the study of the relationships among aggregate economic variables. We are interested in such questions as: Why do some economies grow faster than others? Why are economies subject to recessions and booms? What determines the rates of price and wage inflation?

These kinds of questions often involve issues of macroeconomic policy: What are the effects of government budget deficits? How does Federal Reserve monetary policy affect the economy? What can policymakers do to increase economic growth? Can monetary or fiscal policies help stabilize business-cycle fluctuations?

An important but elusive goal of macroeconomics is accurate forecasting of economic conditions. Although economic forecasting may well be a billion-dollar-a-year industry, forecasters are far better at predicting each other's forecasts than at anticipating economic fluctuations with any degree of precision. Experience suggests that in most cases the pundits who predicted the last recession correctly are not very likely to get the next one right.

The failure to achieve finely tuned forecasts is not surprising. Modern economies are huge entities of unfathomable complexity. The behavior of the U.S. economy depends on the decisions of more than 100 million households about how much to buy, how much to work, and how to use their resources. Equally important are millions of business firms—from small to gigantic—deciding how much to produce, what prices to charge, how many workers to hire, and how much plant and equipment to buy and use.

Economists attempt to transcend this complexity with simple, abstract models of the macroeconomy. A good model can mirror salient aspects of the economic activity it attempts to describe, but it is simple enough that the key mechanisms that make it work can be easily understood. By observing how the simple model operates we hope to gain flashes of insight about the workings of the incomprehensibly vast macroeconomy.

Of course, no simple model can pretend to describe all aspects of an economy, to apply to all macroeconomies, or to be relevant to any macroeconomy under all possible conditions. Simple models are made from simplistic assumptions. For some applications, those assumptions may be innocuous; for others they are likely to be misleading. We must be careful in applying our models, using the useful insights they provide about the situations for which they are appropriate, but not stretching them too far.

What macroeconomists do

Macroeconomics consists broadly of two modes of analysis. Theoretical macroeconomists create models to describe important aspects of macroeconomic behavior and demonstrate the models' properties by solving the mathematical systems that describe them. Empirical macroeconomics uses aggregate (or sometimes disaggregated) data to test the conclusions of theoretical models.

A new strand of macroeconomic theory often begins with the emergence of an event or phenomenon in the real world that is not consistent with existing theories. Economists search for a new theory to explain the new event. Once a theoretical model has been proposed, empirical scholars swarm over it like an army of ants, testing in many ways whether the theory's implications match actual macroeconomic observations. The answer is invariably ambiguous: there are so many different (but plausibly valid) ways of testing any model that most new theories will be supported by some pieces of evidence and refuted by others.

The results of these empirical tests give us clues about the ways in which the model succeeds in providing insight into macroeconomic behavior and the ways in which it falls short. This then leads to extensions and modifications of the original theory, attempting to reconcile it with those empirical facts that conflicted with the original model's conclusions. These revised theories will then be subjected to empirical scrutiny until, perhaps, a consensus emerges about what (if anything) the model can teach us about the economy. Given the inevitable conflicting evidence, there is always room for disagreement about a model's relevance, which often leads to spicy debates among macroeconomists.

Because the empirical testing of major macroeconomic theories consists of scores of individual studies that often reach conflicting conclusions, the student of empirical macroeconomics faces a daunting challenge. Reading individual empirical studies is essential to appreciate the methods used to test hypotheses. However, it is impossible to understand the breadth of evidence on a widely studied question without reading a half-dozen or more separate papers. The approach that we will take in this class will be to look in detail at a few key studies, then to survey the broader literature to get an idea of the degree of consensus or disagreement in results. Several coursebook chapters are devoted to discussion of empirical evidence using this format.

C. Models in Macroeconomics: Variables and Equations

"All models are false, but some are useful." – George Box

Introducing models

As noted above, the macroeconomy is a system of tremendous complexity. Hundreds of millions of individual people and firms make daily decisions about working, producing, investing, buying, and selling. These decisions are affected by countless factors (many of them unobservable and some not measurable) including abilities, preferences, incomes, prices, laws, technology, and the weather. To understand a modern macroeconomy in all its detail is clearly beyond the power of the human mind, even when aided by powerful computers.

As do other scientists, economists try to understand important features of the macroeconomy by building ***models*** to answer particular questions. Because they must be simple enough to work with, all models necessarily omit most of the details of the interactions among economic agents. A good model for any particular question is one that captures the interactions that bear most importantly on that question, while omitting those that are less relevant. Since different questions address different aspects of the economy, a model that is good for analyzing one question may be very poor for looking at others. For example, a model in which the labor market is perfectly competitive might provide a reasonable framework for looking at long-run wage behavior, but because it assumes full employment it would not yield useful insights about movements in the unemployment rate. There is no universally ***correct model*** of the macroeconomy, only models that have proved to be useful in answering specific sets of questions in specific settings.

Some scientific models have tangible representations, such as a globe in geography or a molecular model in chemistry. Economic models do not have such a physical representation. Rather they are abstract mathematical models composed of ***variables*** linked together by ***equations***.

Economic variables

The variables of economic models are measurable magnitudes that are outcomes of or inputs to economic decisions. Familiar examples include the number of hours worked, the amount of income earned, the amount of milk purchased, the price of a pound of kumquats, or the interest rate on a loan. Many of these variables can be observed at different levels of ***aggregation***. For example, an income variable could be the income of one person or household, or the aggregate income of all of the people in a city, state, or nation. Price variables can be specific to one commodity such as a 2012 Ford Focus with air-conditioning and automatic transmission, or an index of the prices of many commodities such as an automobile-price index or a price index for all consumer goods purchased in the United States.

In macroeconomics, we shall most often be interested in the behavior of economy-wide aggregates, including gross domestic product, economy-wide price indexes, and total employment. However, because decisions in market economies are made by individual households and firms, most of the theories underlying our models must be built at the microeconomic level then aggregated to form a macroeconomic model. This aggregation is usually accomplished by making extreme simplifying assumptions, such as assuming that all consumers are alike or that differences among individual consumer goods are irrelevant.

The purpose of an economic model is to describe how the values of some of its variables are determined, and especially how they are affected by changes in the values of other variables. The variables whose determination is described by the model are called ***endogenous variables***. Variables whose values are assumed to be determined outside the model are ***exogenous variables***. Because they are determined outside, *exogenous variables are assumed to be unaffected by changes in other variables in the model*. For example, the price and production of corn would be endogenous variables in a national model of agricultural markets, while variables measuring the weather would be exogenous. (It is reasonable to suppose that the other variables of the corn market do not affect the weather, at least immediately.) In macroeconomic models, aggregate output, the general price level, interest rates, and the unemployment rate are usually endogenous variables. Variables set by government policymakers and those determined in other countries are often assumed to be exogenous.

The "final product" of a macroeconomic modeling exercise is a description of the joint behavior of the model's exogenous and endogenous variables that is implied by the assumptions of the model. In this case, "joint behavior" could include a property such as "the nominal interest rate tends to be high when monetary policy is tight."

The exogenous variables are assumed to affect the endogenous variables but not vice versa, so this relationship has a causal interpretation: a change in an exogenous variable causes a change in the endogenous variables. (If we assume that monetary policy is exogenous and interest rates are endogenous, then we might conclude "tight monetary policy causes high interest rates.") This usually takes the form of a quantitative statement such as "a one-unit increase in exogenous variable X (holding all the other exogenous variables constant) in period t would lead to an increase in endogenous variable Y of 1.6 units."

The simple example above is appropriate for a ***static model*** in which time does not enter in an important way and we can think of the changes in X and Y as once-and-for-all events. However, all important models in modern macroeconomics are ***dynamic models***, where rather than examining changes in the levels of variables we consider changes in their time paths. In a dynamic model, the final solution is a statement more like "a one-unit permanent increase in X starting in period t (holding the paths of all other exogenous variables constant) would increase in endogenous variable Y by 1.6 units in period t, 2.2 units in period $t + 1$, …, and 3.4 units in the steady state of the new growth path."

In order to arrive at this final solution of our model, we must solve the model's equations. In simple models, we can use algebra to calculate a solution; more complex models can only be solved by numerical simulation methods. The process of solving economic models is discussed below.

Economic equations

A model's assumptions about individual and market behavior are represented by its ***structural equations***. Each equation expresses a relationship among some of the model's variables. For example, a demand equation might express the economic assumption that the quantity of a good demanded is related in a given way to its price, the prices of related goods, and aggregate income.

Endogenous variables are ones whose behavior is described by the model. Mathematically, their values are determined by the equations of the model. A model's "solution" consists of a set of mathematical equations that express each of the endogenous variables as a function solely of exogenous variables. This is an extremely important definition: you will be called upon to solve macro models in many homework sets during the course. You have not solved the model until you have an equation for each important endogenous variable *that does not involve any other endogenous variables*.[1] These equations are often called ***reduced-form*** equations. Each reduced-form equation tells how the equilibrium value of one endogenous variable depends on the values of the set of exogenous variables.

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[1] One of the most common mistakes that students make in solving macroeconomic models is to leave endogenous variables on the right-hand side of an alleged solution. The model is not solved until you have expressed the endogenous variable *solely* as a function of exogenous variables.

Analyzing the elements of a familiar microeconomic model

A simple example from introductory microeconomics may help clarify the nature of exogenous and endogenous variables, equations, and solving for the reduced form. Suppose that the demand for corn is assumed to be

$$c_c = \alpha_0 + \alpha_1 p_c + \alpha_2 y, \tag{1}$$

where c_c is consumption of corn, p_c is the price of corn, and y is aggregate income. Equation (1) expresses the economic assumption that the quantity of corn demanded is a linear function of the two variables appearing on the right-hand side (and no others). In order to draw conclusions from the model, we usually add assumptions about the signs of some of the coefficients in the equation. In equation (1) we might assume that $\alpha_1 < 0$, which reflects a downward-sloping demand curve, and that $\alpha_2 > 0$, which says that corn is a normal good: demand rises when income goes up.

The second equation of our model is a supply curve describing production of corn, which we denote by q_c. We could assume that the supply curve for corn can be represented by

$$q_c = \beta_0 + \beta_1 p_c + \beta_2 R, \tag{2}$$

where R is rainfall in major corn-producing states during the growing season. The additional assumption $\beta_1 > 0$ means that the supply curve slopes upward, while $\beta_2 > 0$ implies that production increases with more rainfall.

We complete our model with an assumption about how consumption is related to production. The simplest assumption is that they are equal, which is an assumption of ***market clearing***:

$$q_c = c_c \tag{3}$$

More sophisticated models could allow for stocks of corn inventories to absorb differences between production and consumption, but we will keep things simple in this example.

Equations (1), (2), and (3) express the assumptions of the model about demand, supply, and market clearing. We must also specify which variables are to be considered endogenous and which are assumed exogenous. In order for the model to have a single, unique solution, there must usually be the same number of equations as endogenous variables. The three variables that would typically be assumed endogenous in the corn-market model would be c_c, p_c, and q_c.

This leaves R and y as exogenous variables. Exogeneity assumptions are critical to the specification of a model. Is it reasonable to assume that income and rainfall are exogenous? Can we assume that a change in any of the other variables of the model (endogenous or exogenous) would not affect income or rainfall? It seems safe to assume that rainfall is exogenous because it is unlikely that changes in corn production, corn consumption, prices, or incomes would affect the weather in Nebraska. The exogeneity of income is a little less clear cut, but since the corn market is only a very small part of the economy, it is unlikely that aggregate GDP would be affected very much by changes to the model's other variables. Thus, our exogeneity assumptions seem reasonable here. (Later in this section we will consider the implications of an incorrect assumption of exogeneity.)

The purpose of a model is to examine how changes in the variables are related. In particular, since the model is supposed to represent the process by which the endogenous variables are determined, we are interested in knowing how each endogenous variable would be affected by a change in one or more of the exogenous variables. We do this by solving the model's equations to find reduced-form expressions for each endogenous variable as a function only of exogenous variables. In this example, we seek equations representing corn consumption, production, and price as a function only of rainfall and income.

In this simple model, we can find a reduced-form equation for p_c with simple algebra. First, we use equation (3) to set the right-hand sides of equations (1) and (2) equal: $\alpha_0 + \alpha_1 p_c + \alpha_2 y = \beta_0 + \beta_1 p_c + \beta_2 R$. Isolating the two p_c terms on the same side and dividing yields

$$p_c = \frac{\alpha_0 - \beta_0}{\beta_1 - \alpha_1} - \frac{\beta_2}{\beta_1 - \alpha_1} R + \frac{\alpha_2}{\beta_1 - \alpha_1} y. \tag{4}$$

Equation (4) is a reduced-form equation for p_c because the only other variables appearing in the equation are the exogenous variables R and y.

Since (4) is a *linear* reduced form for p_c, the coefficients in front of the R and y terms measure the effect of a one-unit increase in R or y on p_c.[2] Thus, a one-unit increase in R causes p_c to change by $-\beta_2 / (\beta_1 - \alpha_1)$. Earlier, we assumed that $\alpha_1 < 0$ and

[2]Two comments are important here. First, if this were not a reduced-form equation, then it would not be correct to use the coefficients of the exogenous variables to measure their effects on the endogenous variables. This is because when an exogenous variable changes, all of the endogenous variables in the model usually change. In (4), a change in R does not change y, thus the only change in p_c cause by a change in R is the effect measured by the coefficient on R. If another endogenous variable were on the right-hand side, then it would also be changing and p_c would change by the sum of the two effects. Second, only when the model is linear can the effect of the exogenous variable on the endogenous variable be read off directly as a coefficient. In nonlinear models, it is necessary to differentiate the reduced-form equation with respect to an exogenous variable to evaluate the effect.

$\beta_1 > 0$, so the denominator consists of a negative number subtracted from a positive number and is surely positive. We also assumed that $\beta_2 > 0$, so the numerator is positive until the negative sign in front makes the whole expression negative. Since we can establish that the coefficient measuring $\Delta p_c / \Delta R$ is negative, we have shown that under the assumptions of our model, an increase in rainfall will lower the equilibrium price of corn (by shifting the supply curve outward). A similar analysis can be used to show that $\Delta p_c / \Delta y$ is positive, so we conclude that an increase in income raises the price of corn.

Equation (4) tells us how p_c is affected by R and y, but what about the effects of R and y on c and q? Since $c = q$ at all times, $\Delta c/\Delta R$ and $\Delta c/\Delta y$ are the same as $\Delta q/\Delta R$ and $\Delta q/\Delta y$. The effects of the exogenous variables on p_c can be found by substituting equation (4) into either equation (1) or equation (2) and simplifying. The resulting equation is a reduced-form equation for q (or c). If you do this, you will find that, as expected, either an increase in rainfall or an increase in income raises the quantity produced and consumed.

The importance of the exogeneity assumptions

Choosing which variables are to be endogenous and which are to be exogenous is an important part of the specification of a model. If a variable is (incorrectly) assumed to be exogenous when it is actually influenced in important ways by other variables in the model, then false conclusions may result from comparative-static analyses. To illustrate the importance of the exogenous/endogenous specification, suppose that aggregate income is actually an endogenous variable in the corn-market model: income is strongly affected by changes in corn price and quantity. If that is the case, then equation (4) has an endogenous variable on the right-hand side and it is not a true reduced form. If we were to interpret the coefficient on R as the complete effect of a change in rainfall on the price of corn, we would make an error since the change in rainfall would (through its effect on the corn market) cause income to change, creating a secondary effect on the corn price.

In fact, without an additional equation, we could not solve to model at all. In terms of simple linear algebra, we have three equations but four (endogenous) unknown variables. To solve the model with y endogenous we would have to add an equation describing how y responds to p, q, and c.

This example shows that it is very important to identify correctly the variables that are endogenous and exogenous. Important, but not easy! It is often difficult to discern which variables in a model can safely be assumed to be exogenous since virtually all macroeconomic variables are affected, at least to some degree, by changes in most other variables. If a crucial error is made the model's predictions are likely to be wrong.

Static and dynamic models

The simple microeconomic model we analyzed above is an example of a ***static model***, because time did not play an important part in the model. The economic relationships described by equations (1), (2), and (3) all relate the levels of variables at the same moment in time; the variables at a particular time t are not in any way related to variables at other moments of time.

While static models are comparatively easy to analyze and can sometimes provide insights about economic equilibrium, most economic decisions are essentially ***dynamic***, since today's decisions affect tomorrow's choices and the decisions we made yesterday decisions affect our choices today. For example, the amounts that we earned, saved, and consumed in past years have a large effect on our ability to consume today and in the future. Expectations of future variables are often equally important; expected future earnings are one of the main determinants of present consumption and saving. Because these dynamic effects are important, most modern macroeconomic models are dynamic.

Dynamic models are more complicated to analyze than static models. In static models, we solve for the level of each endogenous variable as a function of the (current) levels of the exogenous variables, as in reduced-form equation (4). In dynamic models, the equilibrium conditions at every moment in time are related to the values of the model's variables at every other moment. This means that we must generally solve for the entire *time-path* of the endogenous variables as a function of the *time-paths* of the exogenous variables. The mathematical methods for doing this are more sophisticated than those for static models and sometimes must be accomplished by numerical simulation rather than analytical solution.

In dynamic models, we distinguish a third category of variables that is partly endogenous and partly exogenous—***predetermined variables***. These are variables for which *today's* values are determined exclusively by past events and external factors, but whose *future* values are affected by the other variables of the model. For example, the current amount of physical capital (plant and equipment) existing in an industry is predetermined. Its current value depends only on *past* investment decisions. Thus it is exogenous with respect to other current variables, but it is not fully exogenous because its value will change *in the future* in response to current variables such as the rate of investment.

We will study examples of two kinds of dynamic models. In ***discrete-time models***, time is broken into periods of finite length—such as months, quarters, or years. All variables are assumed to have the same value at every moment within the period and to jump discretely to new values at the moment that one period ends and the next period begins. In ***continuous-time models***, variables move smoothly through time; their values can change from one instant to the next.

It is not obvious which kind of model should be preferred. A discrete-time model requires us to make some artificial assumptions about when changes in stocks occur. For example, since investment occurs continuously (at a constant rate) through the period, the capital stock at the end of the period is larger than at the beginning. Should we use the beginning-of-period capital stock or the end-of-period capital stock as an input to current-period production? Beginning-of-period stock could be justified by the fact that only this capital was available during the *entire* period. However, if a unit of capital was installed early in the period, then it may be a mistake to assume that it cannot be used until the beginning of the next period.

Continuous-time models avoid this arbitrary timing decision because each increment of capital can be treated as usable at the instant it is installed. However, continuous-time models have anomalies of their own. Suppose that there is an instantaneous change in a stock variable X such as a fire that destroys some capital or a tax that is collected on a bank deposit. At the instant of the change, the corresponding flow variable $\dot{X} \equiv dX/dt$ is infinitely positive or negative. This can be awkward for models in which both the stock and flow variables are related to other variables. Moreover, macroeconomic data are collected in discrete-intervals, either by averaging flows over time (as in GDP measurement) or by collecting snapshots at fixed dates (as with the consumer price index and the unemployment rate).

We will use both kinds of models in our theoretical analysis depending on which is more convenient. In empirical work, discrete-time analysis is the norm.

Deterministic and stochastic models

The simple corn-market model we examined above is a ***deterministic*** model because there is no randomness or uncertainty present. We often insert ***random variables***, whose values at any point in time are determined randomly by a given rule (which is described by a probability distribution), into the economic relationships of our model to represent the unpredictable effects of unmeasured variables.

Models that include random variables—called ***stochastic models***—are useful for three reasons. First, when we fit our models to actual economic data, a simple deterministic model will never fit the data exactly. The discrepancy between the actual values of the endogenous variables and the "fitted" values predicted by the deterministic model is an error term, which is usually modeled as a random variable. Thus, in econometrics we use stochastic models with a random error term to model fluctuations in the endogenous variables that result from causes other than those included explicitly in the model.

Second, many modern macroeconomic models attach great importance to the expectations of agents about current and future economic variables and to agents' forecast errors. Since knowledgeable agents could quickly figure out the structure of a simple deterministic model and make perfectly accurate predictions, unpredictable random terms are often added to the model to ensure that even knowledgeable agents make errors in forecasting.

Finally, modern macroeconomists typically view fluctuations in the economy as resulting from unpredictable shocks. These shocks can be viewed as a special kind of exogenous variable where we may know the probability distribution from which their values are drawn, but we cannot anticipate the actual value. Dynamic, stochastic macroeconomic models examine the effects of shocks of various kinds (treated as random variables) on the endogenous variables of the model over time.

Most of the models we will study, especially in the first part of the course, are deterministic. Only when we need to study the effects of economic shocks explicitly will we use stochastic models.

D. Mathematics in Macroeconomics

Although modern economics is a highly mathematical discipline, this has not always been the case. Macroeconomics focuses is on key relationships among a few key aggregate variables. These relationships may be described in several ways. Before the 1940s, economists largely relied on ***verbal*** descriptions. While these descriptions may seem like they would be the easiest to understand, verbal descriptions of complex models can be very difficult to follow. It is hard to describe the complex interrelationships among a set of variables using words.

In most undergraduate courses, ***graphical*** presentation is the dominant way of expressing economic concepts. You have all learned the basic competitive model using supply and demand curves, as well as cost and revenue curves, indifference curves, budget lines, and other elements from the economist's geometric toolbox. Even at the most advanced levels of economic analysis, we often rely on graphs for a simple summary of the mathematics underlying a problem.

However, the most precise way to analyze an economic model is usually through formal ***mathematical analysis***, using equations to represent the relationships we are studying. This allows us to use the full set of mathematician's tools in solving our models. We can often get where we need to go with basic algebra, as in the linear version of the basic corn supply-demand model that we discussed above. We usually need to use methods of calculus and higher-level math to solve more difficult problems. Macroeconomic analysis often requires mathematical tools drawn from the fields of dynamic analysis and statistical theory.

We shall often spend a considerable fraction of our class time "doing math" and you will devote many hours to working on mathematically oriented problem sets. However, you should never lose sight of the fact that it is the economic concepts, not the mathematical techniques, that are the most important points you need to understand. For us, the math is a means (often the only feasible means) to an end, not an end in itself. It is a language that we use to express economic relationships and a tool that we use to analyze economic models.

This coursebook includes brief reviews of the mathematical tools that we shall use in our study of macroeconomics. Rather than grouping them all together in a mathematical introduction or appendix, they will be covered as they are used in our analysis. Chapter 3 includes a brief calculus review and a discussion of some functional forms that are especially useful in macroeconomics: exponential, logarithmic, and Cobb-Douglass. Later chapters introduce other concepts, such as dynamic programming and elements of probability theory, as they are needed.

E. Forests and Trees: The Relationship between Macroeconomic and Microeconomic Models

The complementary roles of microeconomics and macroeconomics

You've all probably heard the expression that someone "couldn't see the forest for the trees." This simple saying can be used to understand the motivation for studying macroeconomics. While microeconomists have made great progress in understanding the behavior of the individual "trees" (households and firms) and perhaps "groves" (industries) of the economy, aggregating simple microeconomic models about individual behavior has not been a totally successful strategy for modeling the behavior of the macroeconomic "forest." Just as arborists specialize in the study of individual trees whereas foresters study forests as a whole, so microeconomists and macroeconomists work on studying the economy at different levels of aggregation. By combining what we learn on both levels, we can achieve a better understanding of how the economy behaves.

To continue with the arboreal analogy, an arborist, working on a micro level, might study the growth of individual trees, examining the effects of changes in temperature and of the amount of light and water that are available. She might be perfectly satisfied to take the size and position of other surrounding trees as given (exogenous) and work in what an economist would call "partial equilibrium." However, from a forest-wide standpoint, the amount of light and water available to each tree is endogenous—it depends on the proximity and size of all the other trees—so the growth of each tree is linked to its neighbors in a complex system of "general equilibrium." Because there are so many factors that affect the relative location and growth of individual trees, and because each tree is interrelated in a complex way with its neighbors, predicting the growth of an entire forest by adding up the detailed tree-by-tree growth predictions is likely to require huge amounts of computation. Moreover, a small error in the model of individual tree growth could be magnified many times if it is applied to each tree in the forest, so the aggregate predictions of the detailed model may not be very accurate.

Because the forest/tree interaction is so complex, we might consider an alternative strategy: building simple models at the forest level. Such models would not attempt to examine individual trees or use the arborist's detailed knowledge, but instead would look for relationships between *forest* growth and such aggregate variables as hours of sunshine, average soil quality, and annual rainfall.[3] Although this approach ignores a lot of detailed information that we know about the individual trees, it might yield a better prediction of forest behavior.

In practice, economists (and biologists) use both micro-based and macro-level approaches to modeling. The emphasis placed on micro and macro approaches has varied over time. Before John Maynard Keynes, the first true macroeconomist, most analysis was strictly micro-based. Writing during the Great Depression, Keynes developed a model that emphasized the interrelationships of macro variables, justified by simplistic characterizations of individual behavior. The Keynesian model achieved broad acceptance in the decades following World War II.

In the 1970s, many of the predictions of the basic Keynesian model went awry. A new wave of "neoclassical" macroeconomists were quick to point out that the failures of the Keynesian model could be attributed to inconsistencies between the behavior represented in its aggregate equations and the behavioral assumptions that microeconomists usually make about individual behavior. This focused the attention of macroeconomists more strongly on the "microfoundations" of their models. The challenge of modern macroeconomics is figuring out how to use what we know about the micro-level behavior of individuals to explain the behavior we observe among macro-level variables. Since the 1970s, most macroeconomic models have been built on clearly specified assumptions of utility maximization, profit maximization, and perfect or imperfect competition.

The advantage of building macroeconomic models from microfoundations is that we can begin to understand the relationship between macroeconomic outcomes and the individual decisions of the agents in the economy. Macroeconomic forecasting is sometimes done (successfully) using econometric models that often do little more than extrapolate the economy's recent path into the future. While this leads to short-term predictions that are often reasonable and sometimes accurate, these models don't help us understand how the macroeconomy might respond to unforeseen (and especially to unprecedented) events. Macroeconomic forecasters had great difficulty

[3] Note that micro-level studies of individual tree behavior would be central in figuring out which macro-level variables are likely to be important for forest growth.

adjusting their predictions to shocks such as the 1973 oil embargo, the 1987 stock-market crash, the 2001 terrorist attacks, or the 2008 meltdown in the financial system because the past data on which they base their forecasts have no similar events from which observations can be drawn. In the words of Nobel-laureate Robert Lucas, who was one of the leaders of the neoclassical movement in macroeconomics,

> [I]f one wants to know how behavior is likely to change under some change in policy, it is necessary to model the way people make choices. If you see me driving north on Clark Street, you will have good (though not perfect) predictive success by guessing that I will still be going north on the same street a few minutes later. But if you want to predict how I will respond if Clark Street is closed off, you have to have some idea of where I am going and what my alternative routes are—of the nature of my decision problem. [Snowdon, Vane, and Wynarczyk (1994, 221)]

In order to make a reasonable prediction when something new happens, we must distinguish between relationships that can be assumed to be unchanged after the shock and those that will be altered. In Lucas's example, the observed behavior of driving on Clark Street is the result of the application of a decision criterion (for example, choosing the fastest route from home to office) to a set of feasible alternatives (the map of available routes). One may reasonably assume that his choice criterion would not be affected by a road closure (he still wants to get home as fast as possible), but such a closure might eliminate some previously feasible alternatives. If we model Lucas's decision explicitly in terms of objectives and constraints, we can probably make a good prediction of how he will react to the closure of Clark Street. If we simply predict his "demand function" for a route on the basis of past behavior, we cannot.

This is a strong argument for building macroeconomic models that incorporate details of microeconomic decision-making. However, tractability imposes limits on our ability to aggregate micro models to a macro level. Only very simple microeconomic models can be aggregated into a model can be solved or simulated. For example, most macroeconomic models embody the simplifying but highly unrealistic assumption that all agents (households/firms) are identical. We also often assume that the markets in which they trade are characterized either by perfect competition or a simple variation on the perfectly competitive model.

These micro-based models, which dominate the academic study of macroeconomics, teach us a lot about the kinds of macroeconomic outcomes that are consistent with specific sets of assumptions about individual behavior. However, the practice of macroeconomics by forecasters and policymakers continues to be influenced strongly by simple macro-level models such as the IS/LM and AS/AD framework. Since major shocks tend to be infrequent, such models often give quick, easy, and reasonably accurate answers to many important questions, despite their lack of grounding in basic principles.

Objectives of macroeconomic modeling

Most of our model-building this semester will study recent attempts to build bridges between underlying micro-level structures and macro-level relationships among variables. The goal of this exercise is to create models that satisfy two basic criteria:

- *Models should be based on reasonable microeconomic behavior.* Households should maximize utility; firms should maximize profits. If markets are not competitive, then the imperfections should be carefully described and justified.

- *Models' predictions about the behavior of macroeconomic variables should correspond to those we observe in modern economies.* If employment varies strongly and positively with production over the business cycle in most real-world economies, then our models should mirror this property.

The most prevalent modeling strategy in macroeconomics is called the *representative-agent model*. In such models, we make assumptions about the objectives and constraints of one agent (individual, household, or firm) and analyze how this agent would form a decision rule to maximize his or her objective, subject to the constraints. We then consider how the corresponding aggregate variables would behave if the economy consisted of a large (often essentially infinite) number of agents who all behaved just like the representative agent.

The assumption that everyone is alike is extremely convenient for relating individual to aggregate behavior. However, there are many circumstances in which differences among agents are central to economic interaction. For example, if everyone begins with the same endowment of commodities and has the same preferences, then there is no reason why anyone would trade and markets would not be needed. In situations such as these, we must either make some artificial assumptions to allow analysis with the representative agent model to go forward, or else we must model an economy with diverse agents explicitly.[4]

[4] Haltiwanger (1997) provides a survey of some pitfalls of representative-agent analysis.

F. Social Welfare and Macro Variables as Policy Targets

Macroeconomics includes both ***positive*** analysis—describing the collective behavior of macroeconomic variables—and ***normative*** analysis—attempting to determine which among several alternative states of the macroeconomy is most desirable. To establish a solid basis for normative analysis, we must go beyond the level of "I think the economy would be better off if X happened," on which everyone's opinion could be different, to a more broadly-based assessment of the desirability of alternative states of the economy. This means we must establish at least the broad outlines of a ***social objective function***, which describes socially desirable goals for the economy.[5]

Utility and the social objective function

In microeconomics, the basis for analyzing whether an individual gains or loses from a change in economic conditions is ***utility***. Each individual is assumed to be able to rank alternative economic states according to a utility function, which guides his or her choices of how much of various goods and services to buy, how much labor and other resources to sell, how much to save and spend, etc. It seems reasonable to suppose that people know what they like and dislike and considerable insight into economic behavior has been gained using the assumption that an individual or household behaves as though it has such a utility ranking. However, the existence of utility functions for each individual in a society is not sufficient to allow the definition of a social objective function that establishes a unique set of preferences for society as a whole.

The first problem in trying to move from individual utility to social welfare is how to observe the utility of individuals. If that were possible, then the effects on each individual's well-being of a change in the economy could be established. It would be convenient for macroeconomists if everyone had tiny "utilometers" implanted in the sides of their heads, so that their level of satisfaction under prevailing conditions could be observed. Since utilometers do not exist, it is practically impossible to obtain useful information on individual utility.[6]

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[5]This terminology evolved from attempts to define a mathematical function of observable macroeconomic variables that would measure social well-being. As discussed below, it is impossible to devise such a function that is in all ways acceptable. However, simple social objective functions depending on a few key variables (such as unemployment and inflation rates) are often used to evaluate the desirability of alternative policy choices in theoretical macro models.

[6] This traditional, neoclassical view of utility theory is under challenge from the evolving school of "behavioral economists." For an excellent discussion of the progress being made in measuring utility directly through surveys of individual happiness, see Frey (2008). In particu-

Even if individual utility could be observed, insurmountable problems would still prevent the successful measurement of aggregate social welfare because of the ***Arrow Impossibility Theorem***, named after Nobel-laureate Kenneth Arrow, who first demonstrated it. The basic problem is that it is impossible to compare the utility measures of different individuals. Suppose that we knew that a given policy change would increase A's utility by 14 utils and decrease B's utility by 18 utils. In order to determine whether the policy change is desirable, we must compare A's gain in utility to B's loss. Since there are no well-defined units in which utility can be compared, it would generally not be possible to construct a social objective function by simply adding up each individual's utility. Only changes that make *every* individual better off (or at least no worse off) and ones that make *every* individual worse off (or at least no better off) can be clearly established as good or bad.[7]

Does the Arrow Impossibility Theorem mean that the concept of a social objective function is useless? No, it only means that individual utility functions cannot be aggregated without specifying some mechanism for weighing the preferences of individuals against one another. This process of social evaluation and collective decision-making is analogous to the making of political decisions. In totalitarian systems, collective decisions may be made by a single individual, so only her utility matters for social decision-making. In effect, the dictator's utility receives all the weight and everyone else's utility is given no weight. In a pure democracy in which each individual votes in his or her own self-interest, a policy would be adopted (deemed socially improving) if more than half of the individuals affected by the policy are made better off. This is a little like giving everyone equal weight, except that it fails to take into account the intensity with which each individual's utility is affected by the policy—it only counts pluses and minuses rather than adding up actual numbers. The interdisciplinary field of economics and political science called ***public-choice theory*** considers these kinds of issues, as well as the implications of alternative political schemes for dealing with them.

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lar, Chapter 3 discusses the evidence on the connection between income and happiness. The "Easterlin paradox" refers to the widely observed fact that people do not seem to be permanently happier after an increase in their incomes. However, see Stevenson and Wolfers (2008) for a recent re-examination of this question.

[7]This is the criterion of *Pareto-ranking*, which is used extensively in the field of welfare economics. Situation X is Pareto-superior to Y if at least one person has higher utility under X than under Y and no one has lower utility under X than under Y. A situation to which there are no policy changes that are Pareto-superior is called Pareto-optimal. Although this criterion is useful and reasonable, it does not solve the social welfare problem because most changes in the economy make some individuals better off and others worse off, so they cannot be ranked by the Pareto criterion.

Representative-agent models sidestep the issue of utility aggregation by assuming that everyone is the same. Because every person's utility moves in the same direction we can often make normative statements about the relative social welfare of being in two alternative states. However, when applying our models to the real world, we must be careful to remember that the identical-agent assumption is not true. Policymakers must always recognize which individuals are likely to gain from any given change and which are likely to lose.

Real income as an indicator of welfare

Adding together unobservable individual utilities to measure social welfare is problematic, so economists often rely on observable macroeconomic variables as indicators of welfare. For example, although it is impossible to establish that every individual is at least as well off, an increase in ***real per-capita income*** that is spread over a large part of the population shifts the budget constraints of most households outward, which allows them to achieve higher levels of utility if everything else is held constant. Unless other factors have changed (such as a decrease in leisure or an increase in pollution), it is reasonable to interpret such a broadly shared increase in income as being beneficial to the economy as a whole.

Income is not the only variable that economists use as a proxy for social welfare. The ***unemployment rate*** is a frequently cited measure of the health of the economy.[8] A higher unemployment rate (assuming it is measured accurately) reflects an increase in the fraction of the labor force that is unable to work as much as it would like, which may leave them with lower utility than would be possible with a low unemployment rate. However, a lower unemployment rate is not always better. As we shall study later in this course, unemployment often reflects the process by which workers search for new job opportunities. If unemployment is so low that too few workers are searching (or workers are not searching long enough) to find optimal job matches, then society might benefit from a higher unemployment rate. In particular, an unemployment rate of zero is neither attainable nor desirable in diverse, modern economies.

The welfare effects of inflation

A high ***rate of inflation*** is often asserted to be socially undesirable, though the effects of inflation on individuals in the economy depends crucially on whether the inflation is correctly anticipated and whether it is taken into account in such government policies as tax laws and transfer programs like Social Security. If inflation is higher than everyone expected, then those making dollar payments that are fixed in

[8] Indeed, the connection between unemployment and individual's self-assessed happiness is much stronger than that between income and happiness. See Chapter 4 of Frey (2008).

advance will be better off and those receiving such payments will be worse off. For example, borrowers will repay lenders in less valuable dollars than expected, as will firms paying employees on fixed-wage contracts. The lenders and the workers get less than they had bargained for, while the borrowers and the employers are better off. Similarly, retirees whose pensions are fixed in dollar terms can end up with less real retirement income than they expected while the agency paying the retirement claim (often the government) ends up gaining.

Note that only *unexpected* inflation causes these transfers between people. To the extent that inflation is correctly anticipated, borrowers and lenders will agree on a higher nominal interest rate to compensate for the decline in the purchasing power of the dollar. Similarly, workers and firms are likely to incorporate cost-of-living increases in long-term wage contracts to raise the nominal wage with expected inflation.

Because of the transfers associated with unexpected inflation, *uncertainty about inflation* may cause people to change their behavior in order to avoid inflation-induced losses. In the examples discussed above, they may avoid borrowing or lending or they might sign shorter-term contracts as a result of inflation uncertainty. If they give up the advantages of access to capital markets or the convenience and security of long-term agreements, then they are worse off.

Even correctly anticipated inflation has some negative effects. Because (non-interest-bearing) money loses its value when inflation occurs, it becomes a less desirable store of value when inflation gets high. This means that people will go out of their way to transfer their wealth into forms other than money in order to avoid this loss. (This is especially true in hyperinflations, where people often hold unproductive "inflation hedges" such as gold jewelry in order to avoid the cost of inflation.) Since they must reconvert these alternative assets into money in order to make expenditures, high inflation causes households to incur extra transaction costs (sometimes called "shoe-leather costs" for all the extra wear on the shoes when pre-Internet consumers made extra trips to the bank).

Perhaps the greatest cost of even correctly anticipated inflation is the simple inconvenience of having to remember to figure inflation into all the monetary calculations of one's life. Money makes our lives convenient by providing a common yardstick of value that we can use to compare the prices of all of the goods we buy and sell. When inflation (or deflation) causes that value to change over time, money becomes a poor standard of comparison for goods traded at different times.

Finally, we must recognize that it is inflation—changes in the price level—that affects welfare, not the level of prices *per se*. The monetary units in which we measure money and prices are of only trivial importance.[9] High nominal prices, with relative prices unchanged, are no different for society than low nominal prices.

Real interest rates and real wage rates: Measures of welfare?

Are high real interest rates good or bad? Your answer to that question likely depends on your role in society. If you are a net lender, perhaps a retiree or a frugal saver, then high interest rates mean that you earn a higher rate of return on your assets. If you are a borrower, maybe a student or a firm expanding its capital stock, then your cost of funds is increased. Like unexpectedly high or low inflation, high or low interest rates improve the lot of one set of agents and make another group worse off, so the net welfare implications of high real interest rates are ambiguous.

Commentators sometimes talk about high real interest rates negatively because they view a high cost of capital as reflecting an impediment to real capital accumulation and growth. However, capital can be scarce (and interest rates high) either due to a low supply or to a high demand. It is possible, as these commentators may implicitly assume, that the high interest rates are caused by a restricted supply of saving. However, a booming abundance of productive investment projects could also cause high interest rates by raising the demand for capital. Thus, a healthy economy with outstanding growth opportunities might have high interest rates.

One can think of high real wages in much the same way. High wages are good for those who receive them (workers) and bad for those who must pay (firms and their customers). They can be caused either by a shortage of labor or by abundant and highly productivity uses for labor.

Economists generally resist the temptation to attach direct welfare implications to changes in relative prices such as real interest rates and real wages. In a properly functioning market economy, prices reflect the relative scarcities of goods and services. Low prices are a symptom of high supply and/or low demand. To the extent that either of these is a macroeconomic problem (for example, low labor or capital productivity), it is the underlying supply and demand variables that should be targeted, not the relative price signal. Increasing labor productivity will lead to a rise in the real wage. An artificial increase in wages leaving productivity unchanged will just prevent the labor market from clearing and reduce employment.

[9] One time that monetary units can become important is when prices become so high that it becomes inconvenient to have to count all the zeroes. This sometimes happens after several years of hyperinflation. The monetary authority usually responds to this situation by issuing a new currency whose value is a large multiple of the old, say, 1,000,000 "old pesos" equal one "new peso."

G. Measuring Key Macroeconomic Variables

Every introductory and intermediate macroeconomics text devotes one or more early chapters to how macroeconomic variables are measured. For example, Chapter 2 of Mankiw (2003) provides a good summary of some basic facts about macroeconomic measurement. This section supplements and summarizes the standard textbook facts.

Measuring real and nominal income and output

As noted in the previous section, we are interested in some macro variables as indicators of aggregate economic well-being. The most prominent indicator of macroeconomic activity is ***gross domestic product*** (***GDP***). GDP is the headline variable of a system of ***national income and product accounts*** that measure flows of production and income in an economy. Other closely related variables that you may come across are gross national product and national income—at our level of abstraction we will not need to worry about the differences among these variables.

GDP aims to measure the total amount produced in an economy during a period of time.[10] Since economies produce an endlessly diverse variety of goods and services, there is no reasonable physical metric to use in adding them up. (Imagine the nonsensical result of simply adding the tons of gold produced to the tons of cement, to say nothing of trying to measure how many tons of health care or software are produced.) Instead of physical units, use the value to their buyers as a metric to add up the amounts of the various goods and services produced. Thus the units of GDP are (trillions of) dollars per year.

Using dollars as a yardstick is problematic during periods of inflation or deflation. If all prices were to rise by 10% from 2012 to 2013, then GDP would appear to increase by 10% even if exactly the same goods and services were produced. To compensate for the effects of changes in the overall price level on ***nominal GDP***, we use ***real GDP*** as a measure of production and income. Real GDP is calculated using the same set of prices for commodities for all years. Since it attempts to measure output using a constant value of the dollar, real GDP is often called "constant-dollar" GDP, in contrast with "current-dollar" or nominal GDP.

Traditionally, real GDP for all years was calculated by adding up the values of all goods and services produced using the prices that prevailed in a selected base

[10] Formally, GDP measures production of "final" goods—those that are not used up in the production of other goods. For example, we would exclude purchases of paint by a house-painter because the cost of the paint is embodied in the amount he charges his customers for painting services. In this case, the paint is considered an "intermediate" good.

year. For example, if we choose 2000 as the base year, then real GDP in 2012 would be the total value of all goods produced in 2012 added up using the prices of those goods in 2000. If the same set of goods and services were produced in 2013 as in 2012, then real GDP would be the same in the two years regardless of any change in prices that might have occurred between 2012 and 2013 because real GDP in both years is added up using the same set of 2000 prices.

The use of a fixed base year can be problematic if relative prices change a lot between the base year and the year being measured. For example, gasoline sold for less than $1.50 per gallon in 2000 but for about $3.50 per gallon in 2012. If gasoline production increased by 1 billion gallons from 2007, this would be an increase in GDP of $3.5 billion at current prices but less than half as much ($1.5 billion) at base-year prices. This problem is even more severe for new products such as cellular phones. Back in the 1980s, mobile phones cost thousands of dollars. If we counted today's output of phones at those prices, we would overestimate the value of the phone industry's output greatly.

To cope with the problem of changing relative prices and out-of-date base years, data collectors are switching to a strategy of "chained" indexes. A chained index for GDP calculates a growth rate between each pair of adjacent years is calculated using prices from the earlier year. The details of chained indexes are rather arcane, but because the value of GDP is always added up using prices that are no more than one year out of date, chained indexes mitigate the effects of relative price changes over longer time periods.

Output = expenditure = income

As a first approximation, GDP can be used as a measure of three different aggregates, all of which should be equal. First, as discussed above, GDP measures the value of total output of an economy during a period of time. When we think of GDP as output, we are sometimes interested in figuring out how much of that output was produced by each individual industry in the economy. For example, what is the output of the higher-education sector? To calculate industry output we rely on the concept of "value added." An industry's value added is the difference between the value of the products that it sells and the value of the intermediate goods it buys in order to produce. For the higher-education sector, we would start with the total net tuition paid by all of the students, then deduct out the purchases of electricity, food, chalk, library journal subscriptions, tree-trimming services, and all the other non-durable goods and services that colleges and universities buy. The difference is the value-added of higher education—the output of the higher-education sector.

Since every dollar of output must be sold to someone, total expenditure in the economy must equal total output.[11] When thinking of GDP as total expenditure, we sometimes break down the goods and services comprising GDP by the kind of expenditures that purchased them. The biggest expenditure category is personal consumption expenditures, which includes spending by households on food, clothing, rent, and everything else that they buy. Another large category is investment, which refers to purchases by firms of durable plant, equipment, and inventories as well as purchases of new housing units whether bought by firms or households.[12] A third category is purchases of goods and services by governments. The final expenditure type is net exports, consisting of sales of domestically produced goods to foreigners minus purchases of foreign goods by domestic buyers. In terms of a formula, this breakdown of expenditures leads to the familiar $Y = C + I + G + NX$ equation, where Y measures real GDP and the variables on the right-hand side are the real values of the expenditure components.

Not only does GDP measure the economy's total output and total expenditures, but it also measures total income. Each dollar spent on output accrues to someone in the economy as income. Suppose that you buy a $20 book at Powell's. Some part of that $20 becomes wage or salary income to the Powell's staff. Some may be rental income to the owners of the land on which the store sits. Some will be profit to the owners of Powell's. A large share of the $20 probably goes to the publisher of the book (an intermediate good when sold from the publisher to Powell's), who uses parts of it to pay wages to its workers, royalties to the author, interest on its capital, rent on its land, and profits to the firm's owners. The publisher also must pay the printing company, who must pay for paper, etc. At each stage of production, parts of your $20 are distributed to the owners of the labor, capital, land, and entrepreneurial resources that are used to produce the book. Ultimately, the entire $20 becomes part of someone's wages and salaries, interest income, rental and royalty income, or profits.

Thus, GDP can measure the economy's total output, income, or expenditures—they are all the same. Of course, there are a lot of minor complications such as taxes, depreciation, and foreign transactions that must be taken into account when actually measuring these magnitudes in an actual economy. For purposes of this course,

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[11] National income accountants deal with inventories of unsold goods by considering them to be "purchased" by the firm that holds them at the end of the year. Inventory investment is one of the components of expenditures.

[12] It is very important to distinguish the "real capital investment" definition used in macroeconomics from the common use of the word "investment" to refer to purchase of financial assets. The latter is not truly investment in the aggregate economy because one person's purchase is offset by another's sale. Only the purchase of newly created physical capital goods is considered investment in macroeconomics.

however, we can ignore these subtleties and think of GDP as measuring all three of these flows interchangeably.[13]

GDP and welfare

GDP is of interest to macroeconomists because it is the broadest measure of the amount of productive activity going on in an economy. Growing real GDP means that the economy as a whole is producing more goods and services that can be used to satisfy the wants and needs of its population. As noted above, this corresponds to the use of real income as a proxy for the utility level achievable by households in the economy.

However, we must be very cautious in associating changes in GDP with changes in the well-being of the people in an economy. First, an increasing population will require more goods and services just to maintain an unchanged living standard. Thus, ***per-capita real GDP*** is a better measure of welfare than total real GDP.

Per-capita real GDP is calculated by dividing total real GDP by the economy's population. An increase in per-capita GDP means that the average person's income has increased, but depending on how the increase is distributed, some people's income may have stayed the same or even decreased. Thus, it may be important to consider the distribution of income as well as the average in assessing welfare implications.

Finally, while the goods purchased with measured income are certainly important components of people's utility, they are far from the only source of utility. GDP usually measures only goods and services that are purchased. It does not include the value of goods and services that an individual provides for herself or that are obtained without payment. The utility benefits of garden-grown vegetables, home-cooked meals, self-mowed lawns, and care of one's own children—so-called "home production"—are neglected. So too are the utility benefits of personal and national security and a clean environment.[14]

For example, consider an oil spill that fouls miles of beaches. The benefits that we get from the beaches are largely uncounted in GDP (except for related explicit expenditures such as travel and lodging). If we spend a lot on the cleanup (which is probably fully counted in GDP, perhaps as government expenditures), then it is pos-

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[13] In the United States, national-income accounting is undertaken by the Bureau of Economic Analysis, a division of the Department of Commerce. Details of updates to the national income and product accounts are published in the BEA's monthly *Survey of Current Business*.

[14] And, as behavioral economists have demonstrated, people's happiness depends not only on their economic well-being but also on their social and personal interactions. Marriage, friendships, and membership in social groups are very important. If they are adversely affected by increases in income, then people might be less happy even though economists would think they had higher utility in traditional terms.

sible that GDP could increase even though the "production" that is taking place is merely trying (perhaps unsuccessfully) to restore the clean beaches that we previously had for free. We are worse off, but GDP has gone up. Similarly, spending on protection services to offset an increase in crime or on medical care to restore one's health might increase GDP but not reflect a true improvement in living standards.

One of the largest sources of utility that is uncounted in national accounts is leisure. Most people value their non-work time more highly than the time they spend in the labor force. If everyone were to work more hours, the economy could surely produce more goods and services, but the reduction in leisure time might lower people's utility by more than the increase coming from the higher measured income.

Thus, while we often treat growth in per-capita GDP as a good thing, reflecting an increase in living standards, it is important that we remember the caveats involved. Is the per-capita growth in income shared among all the people in the economy? Has growth been associated with other changes such as environmental degradation or longer hours of work that may offset the increase in utility? Only if the increase in GDP is broadly shared and not offset by negative side-effects can we be confident that growth increases utility.

Measuring prices and inflation

Implicit in the distinction between nominal and real GDP is the ability to measure changes in the overall level of prices. In fact, one of the most common price indexes is the ***GDP deflator***, which is (100 times) the ratio of nominal GDP to real GDP. If nominal GDP is greater than real GDP, then today's bundle of goods and services cost more at today's prices than at the prices in the base year, so prices overall must be higher today than in the base year.

The GDP deflator is an example of a price index. All price indexes are ratios of the cost of a bundle of goods today to the cost of the same bundle at the prices prevailing in the base year. Suppose that the bundle of goods we choose has quantities q_i of N different goods. Then the cost of that bundle in year t is $\sum_{i=1}^{N} p_{i,t} q_i$ and the cost in the base year b is $\sum_{i=1}^{N} p_{i,b} q_i$. The value of the price index in year t is the ratio of these sums:

$$P_t = 100 \times \frac{\sum_{i=1}^{N} p_{i,t} q_i}{\sum_{i=1}^{N} p_{i,b} q_i} \qquad (5)$$

Clearly, P_t equals 100 in the base year because the numerator and denominator of the fraction are equal.

The summations in the numerator and denominator of equation (5) are weighted averages of the prices in year t and in year b of the N commodities, with the quantities q_i playing the role of "weights" attached to the various commodities. Price indexes differ mainly in the choice of what bundle of commodities is to be used as weights.

The traditional GDP deflator takes q_i to be the total production of good i in the current year t. Because it uses "current-year weights" it is an example of a Paasche price index. The GDP deflator is a very broad price index because it includes all of the goods produced in the economy.

The other headline price index is the ***consumer price index***. As suggested by its name, the CPI attempts to measures changes in prices faced by consumers. Thus, the bundle of commodity weights it uses attempts to reflect the purchases of an average urban consumer. Goods not purchased by households (missiles and supercomputers) are omitted from the CPI altogether, making it a narrower price index than the GDP deflator.

The CPI is an example of a Laspeyres price index because it uses weights based on consumption in the base year b rather than the given year t. In calculating the CPI, q_i is the typical urban consumer's purchases of good i in the base year.

Despite all the attention that economists give to measuring prices accurately, there are several reasons why price indexes—especially Laspeyres indexes such as the CPI—might tend to overestimate the amount of price change. Because the CPI is used to index changes in Social Security payments and income-tax brackets it is important to know whether it describes changes in the cost of living accurately.

A blue-ribbon panel of macroeconomists was appointed in the mid-1990s to estimate the magnitude of the error in the CPI measure of inflation. They found that the CPI overestimates inflation for several reasons. By using base-year weights, the index gives high importance to goods that were consumed heavily in the base year. To the extent that consumers substitute lower-priced goods for higher-priced ones, the goods receiving heavy weight will be those that were cheap in the base year and thus those whose prices have likely risen since the base year.

An example might help clarify why this leads to overstatement of inflation. Suppose that the economy consists of two goods: gasoline and cell phones. Gasoline was cheap in the base year and is expensive now; cell phones were expensive in the base year and are cheap now. Because consumers will buy more of whatever is cheapest at the time, they bought lots of gasoline and few cell phones in the base year. Using these consumption weights, we attach a high weight to gasoline and a low weight to phones. But gasoline's price has risen since the base year and the price of phones has fallen. Giving heavy weight to gasoline makes inflation seem very high by accentuating the effect of the good whose price has risen and diminishing the effect of the good with falling price. This results in an overestimation of inflation.

Note that a Paasche index such as the GDP deflator has the opposite bias. By using current-year weights it overemphasizes cell phones and under-weights gasoline, leading to an underestimate of inflation. Economists have begun to use two methods to overcome these biases. First, they often use "Fisher ideal index numbers," which are a geometric average of the Laspeyres and Paasche indexes to allow the biases in the two to offset one another. Second, as noted above, chain-weighted indexes are now commonly used to minimize the time difference between the two periods, reducing the magnitude of changes in weights.

A second important reason that price indexes of all kinds often overestimate inflation is the inability to distinguish price increases from improvements in quality. Suppose that the average cell phone in 2000 cost $500 and that the average phone today also costs $500, but that today's phone incorporates many new features such as a camera and Internet connectivity that were unavailable in 2000. Clearly you are getting "more phone" today than in 2000 at the same price, so holding quality constant the price of a "unit of cell phone" has actually declined. It requires great effort on the part of those who collect price data to assess changes in quality and many (perhaps most) quality changes inevitably go undetected. To the extent that quality improves over time, this means that measured inflation is higher than the true rate of increase in the cost of living. Instead of reflecting the true decline in the price of phones, a price collector who misses the quality improvement would report no change in prices: a zero inflation rate for this good rather than a negative one.

There are several other reasons why there is a tendency to overestimate inflation when collecting price data. The details are summarized by the commission in Boskin et al. (1997). They conclude that the CPI measure of inflation is probably 0.75 to 1.50 percentage points higher than the true inflation rate in a typical year.

Employment and unemployment statistics

Data on the employment status of the population is compiled by the Bureau of Labor Statistics from the monthly Current Population Survey (CPS) conducted by the Census Bureau. Based on the responses to several questions, each of the 60,000-plus respondents is categorized as employed, out of the labor force, or unemployed. These results are then extrapolated to the entire population and sub-groups of the population based on the characteristics of the individuals in the sample.

The CPS questions refer to the "reference week" before the mid-month survey. Anyone who worked at all for pay during the reference week, whether as an employee or through self-employment, is considered to be employed. A person who did not work is unemployed if he or she was actively seeking and available for work or was awaiting recall from a recent layoff. Those who are neither employed nor unemployed are classified as out of the labor force. The unemployment rate is the number unemployed divided by the total labor force (employed plus unemployed).

The unemployment rate is an imprecise measure of the social impact of unemployment. Some people who aren't working as much as they would like are excluded; other people who are quite content with their status may be classified as unemployed. Among the former group are the "underemployed"—those who are working fewer hours than they would like but are classified as employed—and the discouraged workers who would like to work but have given up looking and are for that reason considered out of the labor force. The latter group includes unemployed people who have turned down reasonable job offers or who are not really searching very hard.

With respect to this last group, it is important that the unemployment data are based on a survey that is *not* connected to claims for unemployment insurance benefits. Since such claims encourage people to appear unemployed, data on insurance claims are likely to overstate the number truly unemployed. Some claimants will likely either be working covertly (perhaps in the underground economy) or not truly seeking work, but will pose as unemployed when applying in order to qualify for benefits. While it is possible that these people would also lie to the Census Bureau on the CPS questionnaire, there is no financial benefit to doing so, which gives us more faith in the CPS survey than in the records of unemployment insurance programs.

International comparability of macroeconomic data

The above descriptions of variables apply to the United States. Data collection methods for other advanced countries are generally quite similar. However, it is risky to put too much faith in direct comparisons of numbers across countries. It is difficult (perhaps impossible) to design survey questions that will be read and answered in identical ways in different countries and languages. Even the methods of collection often differ from country to country.

International organizations often act as repositories for data of many countries. However, the degree to which the data can be treated as comparable across countries varies. It is important to read the "fine print" describing the methods of collection and discussing comparability issues if your application depends on having homogeneous data across countries.

The Organization for Economic Cooperation and Development (OECD) has taken a leading role in trying to standardize the collection of national accounts data for its member countries, which consist of most of the developed world. The International Labor Organization (ILO) collects standardized unemployment rates for many countries. The International Monetary Fund (IMF) collects both trade and financial data on its members, which include most of the world. The World Bank also collects data on characteristics of developing countries. Comparability is obviously more problematic with low-income countries that have few resources for data collection and in countries where despotic or corrupt rulers may turn data publications into political manifestos rather than objective economic reports.

The data collected by the OECD, IMF, and others are generally measured in the domestic currency of each individual country. In order to compare them, one must convert to a common currency (usually dollars). The traditional conversion is to use currency exchange rates because that is how traders actually convert foreign currencies to dollars. However, in the floating exchange rate regime that has prevailed in most of the world since the 1970s, exchange rates sometimes fluctuate widely.

For example, the euro appreciated approximately 25 percent against the dollar from the beginning of 2006 to the middle of 2008. Converting European GDP to dollars would suggest that European incomes had grown dramatically during this period when in fact living standards improved only modestly. To correct for the financial volatility of exchange rates, we often convert at "purchasing-power parity" (PPP) rates—the conversion rate at which the dollar and the euro would buy comparable bundles of commodities. The OECD collects its own PPP exchange rates for use in comparing member-countries' income data. Alternatively, the Penn World Tables (PWT) are the result of a massive ongoing 40-year study to measure purchasing power in over 100 countries world-wide. We will use PWT data in some assignments in this class.

H. Works Referenced in Text

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