Sustainable Production with More Labor and Less Natural Resources

We produce goods and services by combining "factors of production." In classical economics, these were "land," "labor" and "capital." In neoclassical economics, these were labor and capital; land having been merged with capital. With the coming of environmental or ecological economics, land has reemerged as "natural capital" as distinguished from "manufactured capital," which corresponds to classical "capital." (The classical economists did not recognize "human capital.") In what follows, to keep terms short, I will use the classical terms, land, labor and capital to refer to "natural capital," labor and "manufactured capital."

All production requires at least a little bit of all three factors. For example a primitive farmer, *labor*, cultivates a field, *land*, using a hoe, *capital*. The same output can be produced by various combinations of factors. In a two-dimensional diagram, we can show how by using more of one factor, we can produce the same output by using less of another. In a super-simple world where there are no great "lumps" of capital investment required, we can draw an *isoquant*, that is, a graph of the tradeoffs between two factors.

Figure 1
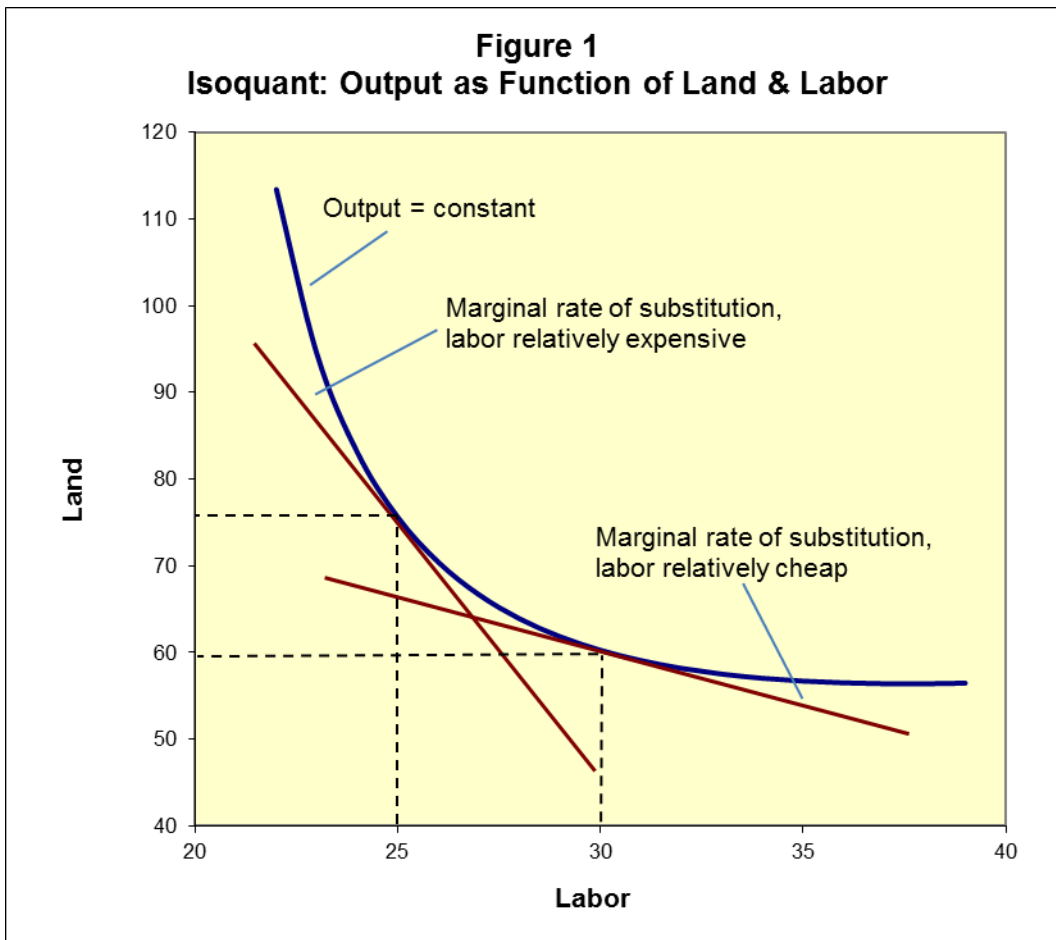**Isoquant: Output as Function of Land & Labor**

Figure 1 shows an isoquant for output as a function of land and labor. The blue line represents all the possible combinations of land and labor to produce a given quantity of output. The slope of the isoquant is the rate of tradeoff between land and labor. This is called the *marginal rate of substitution*.

As you can see by looking at the graph, as we employ more labor, we need less land, and vice versa. As we move down and to the right on the graph, the ratio of land to labor falls. As we move up and to the left, the ratio of land to labor rises.
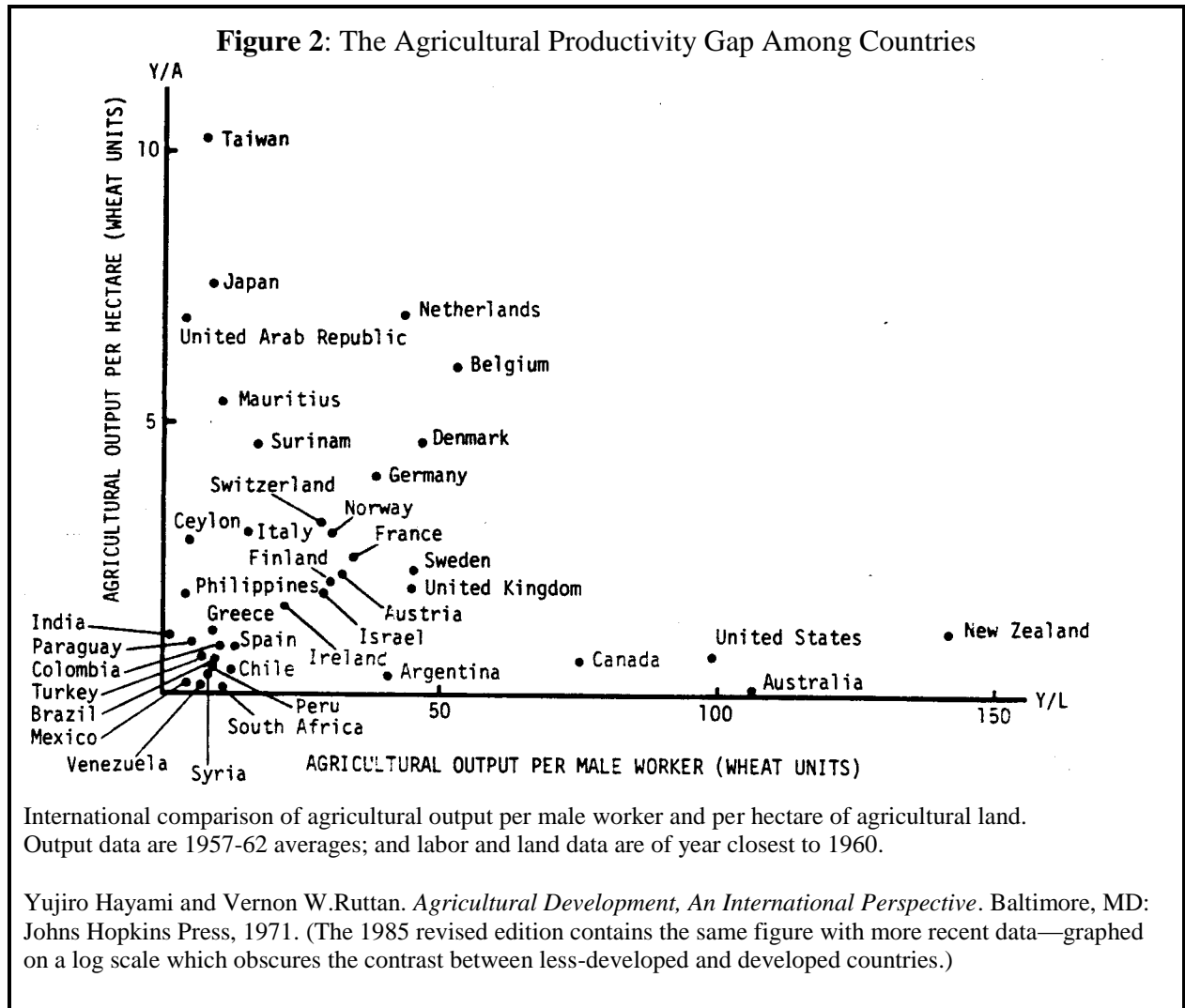
The diagram shows the marginal rate of substitution (MRS) line tangent to the isoquant at two points: the point where labor = 25 units and land = 75.6 units, and the point where labor equals 30 units and land equals 60.3 units. At the first point, the MRS is 2.52, which means that to keep output the same, if we give up a unit of labor, we must add 2.52 units of land. At the second point, the MRS is 1.27, which means that to keep output the same, if we give up a unit of labor, we must add only 1.27 units of land. (Remember that the slope equals the rise over the run, that is, the change in land divided by the change in labor.)

We could draw equivalent figures showing the tradeoffs and marginal rates of substitution between land and (manufactured) capital, and between labor and (manufactured) capital.

The marginal rate of substitution in actual production in turn depends on the relative costs of inputs. If natural resources are relatively cheap and abundant, while labor is relatively scarce and expensive, producers will use more resources and less labor. This is the situation in land-abundant countries like the United States and Australia. If natural resources are relatively scare and expensive, while labor is relatively cheap and abundant, producers will use less resources and more labor. This is the case in countries like Japan and Taiwan. European countries are in the middle

The Example from Agriculture

Figure 2, from Hayami and Ruttan *Agricultural Development: An International Perspective* (1971), plots output per hectare against output per worker for a large number of countries, developed and less developed.

Figure 2: The Agricultural Productivity Gap Among Countries

International comparison of agricultural output per male worker and per hectare of agricultural land.
Output data are 1957-62 averages; and labor and land data are of year closest to 1960.

Yujiro Hayami and Vernon W.Ruttan. *Agricultural Development, An International Perspective*. Baltimore, MD:
Johns Hopkins Press, 1971. (The 1985 revised edition contains the same figure with more recent data—graphed
on a log scale which obscures the contrast between less-developed and developed countries.)

Note that densely-populated countries like Japan show a high output per hectare, but a
relatively low output per man-hour; lightly populated countries like the United States show a
high output per man-hour, but low output per hectare. Intermediate countries like Denmark lie
in-between. But less-developed countries huddle in the lower left corner with low output per
man-hour and per hectare, regardless of population density.

If there were any question about it, this graph shows there's nothing necessarily primitive
about highly labor-intensive agriculture. How do Taiwan and Japan do it? They do it by growing
several crops a year on the same plots, and by careful hand-tilling. They mix crops, for example,
raising fish in rice paddies. They have developed mini-tractors and other small machines for
small plots. The organic gardens at UC Santa Cruz show that the same high land productivity is
possible in the US too.

However, it isn't just the relative cost and abundance of factors of production that determines
the proportions in which they are used. Public policy also has an effect. On Hayami and Ruttan's
graph, the less-developed countries like Paraguay and Turkey show low output per worker *and*
per hectare, regardless of population density. These countries don't necessarily lack in resources.

Rather they suffer from bad government and very unequal wealth, which in turn has lead to a lack of investment in education and infrastructure.

But there are biases in developed countries too. In the US, tax and subsidy systems encourage spreading agriculture over too much land, using too much (manufactured) capital and too little labor. In effect, US agriculture suffers from "agricultural sprawl." Subsidies include agricultural college research programs like the one that developed the mechanized tomato harvester. They include subsidized irrigation in the desert, which brings more land into production in the deserts of California and Arizona, at the expense of rain-watered areas in the east and south. Then there are price supports for staple crops like corn, and support for marketing order cartels like Sunkist. Tax biases include rapid depreciation for investments in equipment. Biases against labor include payroll taxes. (Payroll taxes are of course a bias against labor everywhere, but especially low wage labor.)

There's also the bias in favor of large corporate farmers. Large corporate farmers are intrinsically biased against labor and in favor of too much land and capital, for reasons I explain at length in my paper on "Equality, Productivity and Growth."

Figure 3 shows how even small tax and subsidy biases against labor and in favor of land can produce dramatic shifts in technology. The figure shows two isoquants, one for a land-intensive technology (eg. the tomato harvester) and one for a more labor-intensive technology, (eg. hand-picked tomatoes). The marginal rate of substitution (MRS) is drawn where the two curves have the same slope. However, if labor gets just a tiny bit more expensive relative to land, making the slope a bit steeper, production will switch over to more land-intensive technology, with a large loss of employment.

Figure 3
Effect of Prices on Technology Choice
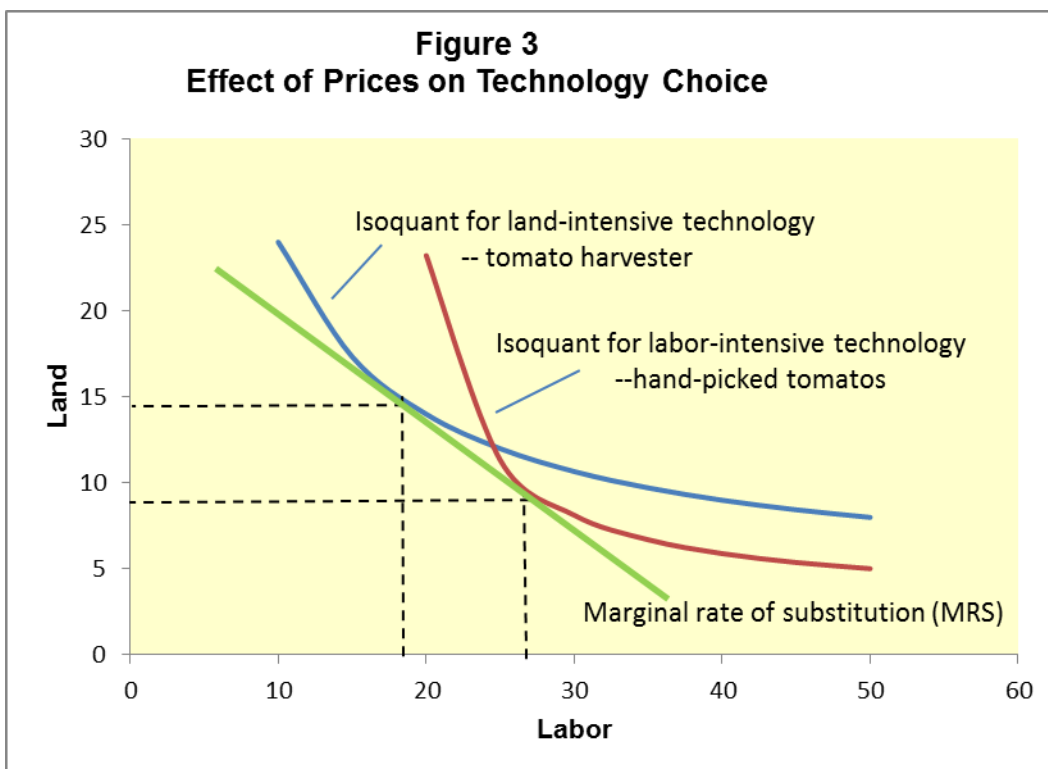
Example from Housing

Urban sprawl is not "natural." Rather, it results from biases similar to those in agriculture, in favor of using more land, and more (manufactured) capital and less labor. In a later lecture, I will examine some of these biases in detail. Here are a couple of charts that show it's possible to maintain a good lifestyle at much higher urban density.

International Urban Population Density

US Urban Population Density
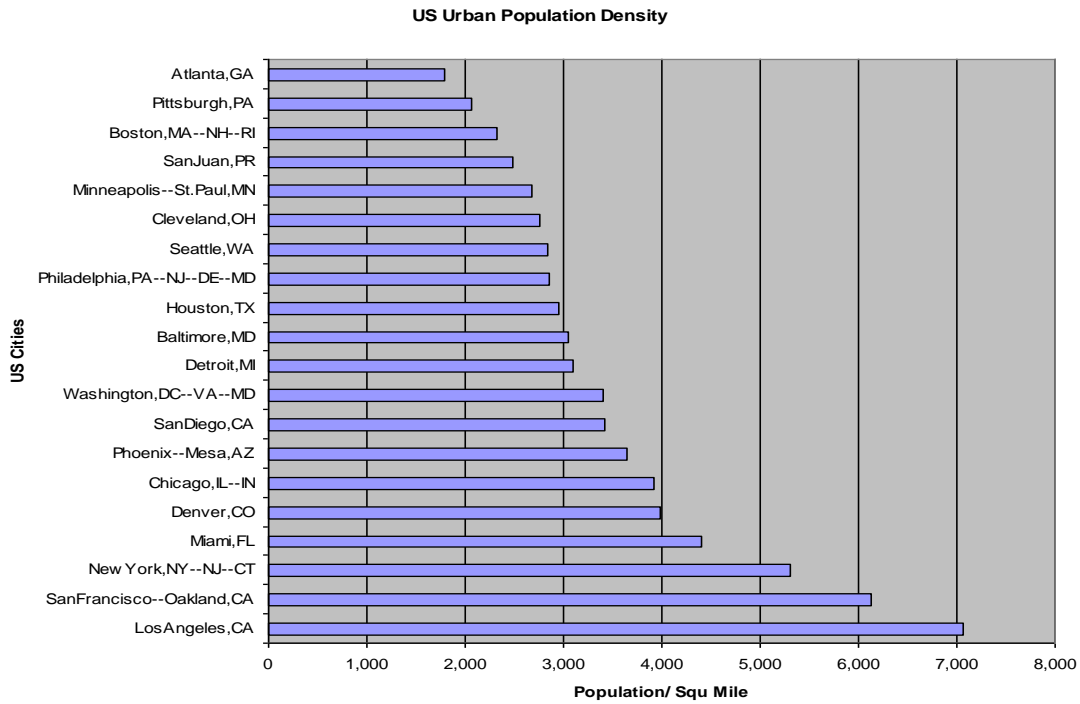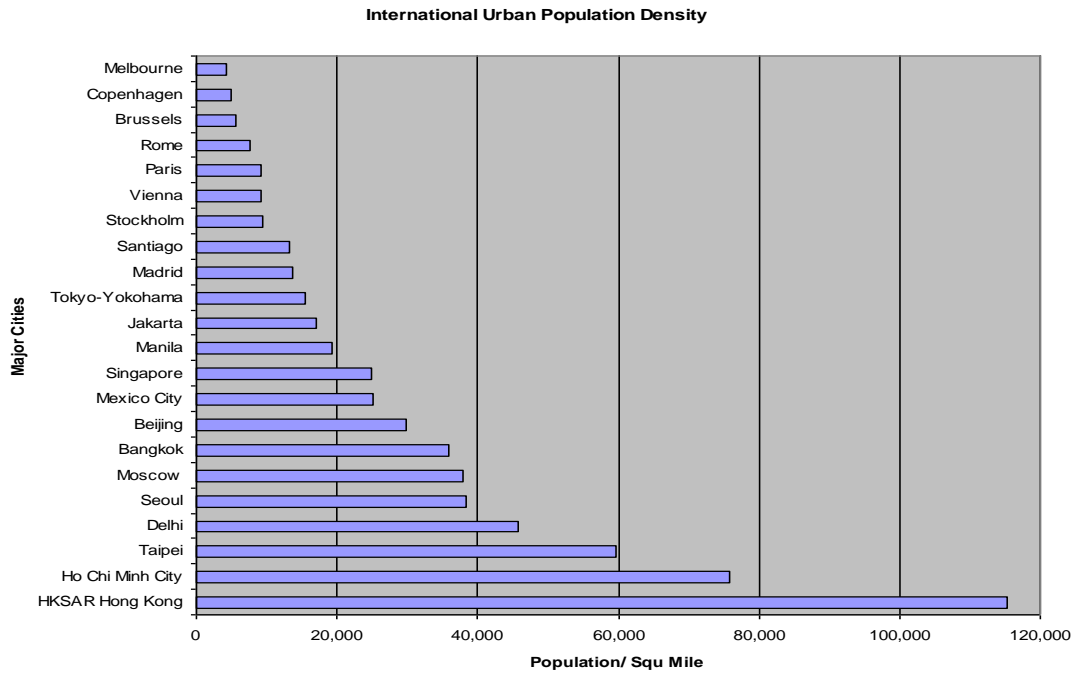
And here's a quick example of the substitution of building materials. Concrete is made by mixing cement with sand and gravel. In turn cement is made by baking limestone at high temperatures to drive out the carbon dioxide. Cement manufacturing is one of the world's largest sources of carbon dioxide. But concrete-pouring is a substitute for older more labor-intensive construction with stone, brick and wood. And unlike stone and brick, concrete is hard to recycle. Biases against labor and in favor of urban sprawl thus encourage excessive use of concrete.

The Possibility of Substitution.

In short, there is enormous potential for substituting inputs to production so as to maintain high quality lifestyles with greatly reduced drain on natural resources and pollution and with higher levels of wages and employment.