

Supplemental Notes
von Thünen's land use model

I. Agricultural land use

The von Thünen model is a simple analytic model of land use that allows one to examine the effects of a change in the production environment on agricultural land uses. It is spatial economic model since space, absolute distance in this case, is explicit. The core concept of the model is that the spatial structure evident in agricultural land uses is the outcome of competitive bidding for land.

Theory

The model assumptions are as follows: (1) Output and input prices are fixed; (2) All agricultural goods are sold in a central marketplace; (3) Land is used by the farmer will to pay the highest rent and the market is competitive (costless entry/exit, zero economic profits); and (4) All land is equally fertile and the friction of distance is equal in every direction.

A typical farmer in this system pays a land owner 'rent' in exchange for the right to plant crops. Land owners will always accept the highest rent any farmer is willing to bid for use of the property. Farmers always sell their crops in the central market and transport their crops using the least cost route.

The model can be formalized by specifying a profit function for a representative farmer. One simple form for profit (usually represented by Π) would be, $\Pi = PQ - C - tQu - R$, where P = price of product, Q = quantity of product sold, C = non-transport and non-land production costs, t = transport costs per unit per mile, u = distance to market, and R = land rent. In a competitive market, farmers will continue to bid for land until their economic profits equal zero ($\Pi=0$). Thus, their **bid rent** function can be expressed as,

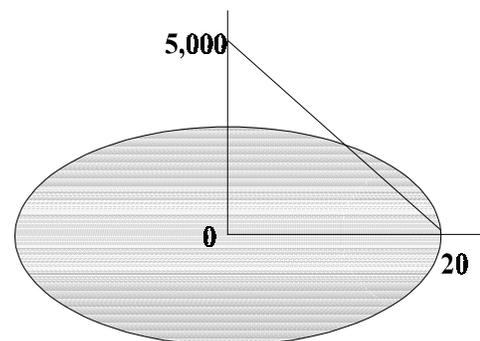
$$R = PQ - C - tQu$$

Application

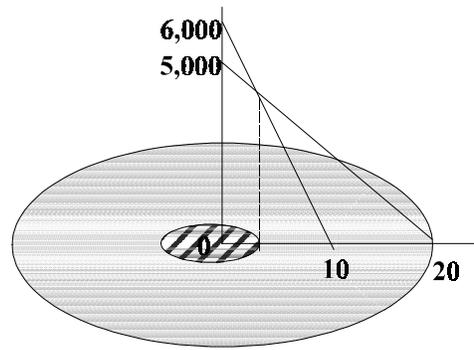
The model results in crops planted in concentric rings radiating out from the market center. Applications examine one or more crops and the extent of land used for each. Suppose only wheat is produced, the price of wheat is \$10 per bushel, each farmer produces 500 bushels, and it costs 50 cents per kilometer to ship the wheat to the central market. The **bid rent curve** for wheat is shown in the diagram. Assume the non-transport, non-land costs are zero ($C=0$).

The farmer is willing to bid \$5,000 at the market center, $R=(10 \times 500) - (0.5 \times 500 \times 0) = 5,000$. At 10 kilometers from the market the farmer is willing to bid \$2,500, $R=(10 \times 500) - (0.5 \times 500 \times 10) = 2,500$. Beyond 20 kilometers there will be no wheat produced since profits would be negative.

Under the given model the total area under production will be $\pi 20^2$ ($\approx 1,257$) square kilometers.



Now suppose another type of farmer enters the market wanting to grow sugar beets. Since beets are heavier they will cost more to transport but they will also fetch a higher market price. Suppose that each sugar beet farmer grows 200 pounds of beets, that the market price is \$30 per pound, and transport costs are \$3 per pound per kilometer. The figure shows the new spatial allocation of land. Beets are produced from 0 to $\frac{20}{7}$ kilometers and beyond that wheat is grown out to 20 kilometers.



The total amount of land cultivated in beets is $\pi(\frac{20}{7})^2$ (≈ 26) square kilometers and wheat cultivation is reduced to $\pi 20^2 - \pi(\frac{20}{7})^2$ square kilometers ($\approx 1,231$).

As just demonstrated, answering questions from the von Thünen model simply requires three analytical tools:

- (1) finding the y- and x-axis intercepts of a line,

$$\text{y-intercept: } R = PQ - tQu$$

$$\text{x-intercept: } u = (PQ/tQ) = P/t$$

- (2) finding the x-axis value for the point of intersection of two lines, and

Lines will cross where $R_1 = R_2$

$$P_1Q_1 - t_1Q_1u = P_2Q_2 - t_2Q_2u$$

$$u = \frac{P_1Q_1 - P_2Q_2}{t_1Q_1 - t_2Q_2}$$

- (3) finding the area of a circle.

$$\text{Area of a circle} = \pi r^2$$

II. Extensions

Other questions related to the basic model result in shifts in either the intercept or slope. If the market price of a crop increases, then the intercept of the bid rent curve shift up and more of that product is cultivated relative to other crops. If the quantity produced per farmer increases, the slope and intercept change. If the transport cost, t , increases the slope of the line becomes steeper.

A common extension is to relax the constant friction of distance assumption by incorporating some type of transportation technology. If a road is introduced into the model, farmers can either travel directly to the market center or travel directly to the road and then into the market. They will choose the least cost route. The resulting land use pattern is that the concentric circles morph into concentric teardrops with each crop pushing farther out along the road.