Econ 330: Urban Economics

Lecture 6

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Lecture 6: Land-Use Patterns

Schedule

Today

1. **Hand in HW and Admin**
2. **Von Thunen Rings**
3. **Monocentric City**

Upcoming

- **Reading** (Chapter IV *ToTC*)

✅✅ HAND IN HW ✅✅

Admin

- I will post the *ToTC* book report instructions on Canvas after class. **Due end of week 9**
  - I will give you another reminder around week 6
  - Feel free to turn it in earlier
- 1000 words (roughly 2 to 2.5 pages single spaced)
- **This must be your own work**. You can discuss ideas with your friends but the writing **must** be your own
  - ⚠️ Plagiarism will be dealt with harshly ⚠️

Admin

⚠️ The next 3 weeks or so of this class are probably the most algebra intensive of the term ⚠️

- For many of you, this means the difficulty of the course will ramp up a bit
- If you have anxiety about math, come see me. I am happy to help 😀

Checklist

2) **Turn in HW & Admin** ✅

2) **Von - Thunen Model**

3) **Manufacturing Bid Rent**

Rents

- **Last time**: we looked at rents across cities and the consumer bid rent curve.
    - **Consumer bid rent**: Informs how prices for urban rental/housing units change with distance to center
- **Today**:
    - **Von Thunen Model**: (urban rural interface)
    - **Manufacturing bid rent** (different assumptions)
- **Next Class**
    - A small note on Office rents and neighborhood choice part 1

Von Thunen Rings

1826: Johann Heinrich von Thunen writes *The Isolated State*

- Foundational model of Human Geography
- Model describes interaction between cities and landscapes
- Uses basic economic principles to predict changes in land-use

What we will do: use the model to inform **agricultural rents** and predict **physical size** of cities

Von Thunen Model

Why do we care about a model developed in 1826?

- Current theories usually aim to explain the world as it is, or will be in the future
- The question of city location can be better understood via economics, history, and geography
    - Factors that influence the urban rural interface still largely relevant today

Von Thunen Model

Assumptions

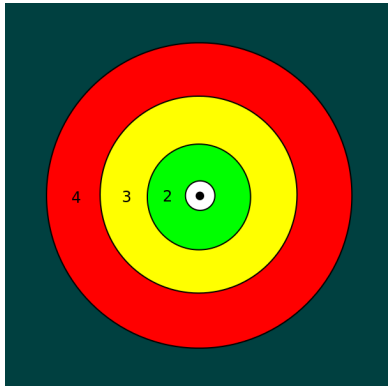
1) City is located in the center of a wilderness area

2) Farm land is equally productive throughout the city

3) Farmers behave rationally to maximize profit

4) Farmers transport their goods to a central location in the city

Von Thunen: Rings



- **Black Dot**: the city
- **White circle**: Dairy Products
- **Forest for fuel**
- **Grain and crops**
- **Ranching**

What do you notice?

- The rings go out from the center in order of transit cost. **Dairy**: spoils quickly and heavy. **Trees**: heavy. **Grain**, easier to transport, but still heavy. **Ranching**: land intensive

Von Thunen Model: Math

Von - Thunen (rural) rents are derived from the **zero profit condition**. We will work with a simple version, for now, where there is only one "ring" (we can call this agriculture)

$$\pi = TR - TC$$

- $TR = P * Q$
- $TC(x) = F(x) + C + R(x)$

- $R(X)$: Land rents
- Q, P: price and quantity
- C: product expense per unit of commodity

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In the Von Thunen Model,

- $TR = P * Q$
- $TC(x) = (F(x) + C) + R(x)$

- $R(x)$: Land rents
- Q, P: price and quantity
- C: product expense per unit of commodity
- $F(x)$ transit cost x mi from center

Von Thunen Equation

Profit equation is given by:

$$\pi = P * Q - F(x) - C - R(x)$$

Zero profits imply:

$$P * Q - F(x) - C - R(x) = 0$$

Solving for $R(x)$:

$$R(x) = (P * Q - F(x) - C)$$

Von Thunen Equation

So the **agriculturual bid rent** or **von thunen bid rent** curve is summarised by:

$$R(x) = (P * -F(x) - C)$$

In words, what does this equation say? **Discuss**

- Higher Revenue ($P * Q$) $\implies$ higher rents (why?)
- Higher Freight cost ($F(x)$) $\implies$ lower rents
- Higher Intermediate goods cost (C) $\implies$ lower rents

Von Thunen Model: Example

Using

$$R(x) = (P * Q - C - F(x))$$

Find the *radius of arable land* when freight costs are given by: $F(x) = B * x$

.

- That is, find the distance from the city where $R(x) = 0$
- Set $R(x) = 0$ and solve for x

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$$\begin{aligned} 0 &= (P * Q - C - B * x) \\ C - P * Q &= -B * x \end{aligned}$$

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$$\begin{aligned} 0 &= (P * Q - C - B * x) \\ C - P * Q &= -B * x \\ \frac{P * Q - C}{B} &= x \end{aligned}$$

Interpretation

What does the equation $\frac{P*Q-C}{B} = x$ tell us?

1. If the freight rate B, increases, will the agricultural area surrounding the city get smaller or larger?
    - **Smaller**, $\frac{1}{10} < \frac{1}{5}$
- Interpret this

As it becomes more expensive to ship goods, the oppurtunity cost of living further from the city center (where the exchange occurs) increases. Thus, the urban-rural area shrinks in radius

Von Thunen: Multiple Sectors

Now consider a version of the model in which we have 2 sectors and **no transit costs**. Profit in each sector is given by

$$\pi_1 = P_1 * Q_1 - R_1(x)$$
$$\pi_2 = P_2 * Q_2 - R_2(x)$$

Assume the following:

- $P_1 * Q_1 > P_2 * Q_2$ (rev in sector one is greater than sector 2)
- $R(x) = 20 - x$

task: Show that industry 2 is further away from the center and they pay lower rents. Hint: use the *radius of arable land* idea from above

Von Thunen Example

$$\pi_1 = P_1 * Q_1 - 20 + x_1 = 0$$
$$\pi_2 = P_2 * Q_2 - 20 + x_2 = 0$$

Solving for x_1 and x_2 yields:

- $x_1 = 20 - P_1 * Q_1$
- $x_2 = 20 - P_2 * Q_2$

Since $P_1 * Q_1 > P_2 * Q_2$ it follows that $x_1 < x_2$

Von Thunen Model: So What?

The model is a bit dated, but still useful

- Transportation costs have, and have always had heavy influence on land prices
- These constraints were larger in the past; still might be useful in explaining urban form of certain cities
    - Radius of arable land can give predictions on urban-rural size
    - City and agricultural area are intimately linked (Read Cronon's *Natures Metropolis*!)

Thoughts on the model? What assumptions do you like? What do you not like? **Discuss**

Checklist

1) **Turn in HW & Admin** ✅

2) **Von - Thunen Model** ✅

- Von Thunen Rents
- The radius of arable land

3) **Manufacturing Bid Rent**

Manufacturing Bid Rent

WTP for land from manufacturing firms is a function of the land's accessibility (similar to consumers)

- **Fact**: Urban manufacturing employment is largely decentralized and disperesed
  - Most firms locate close to the highway. **Why**? This has not always been the case
- Firms are balancing **freight** and **labor costs**
  - Further from labor $\implies$ higher wage (to compensate for increased commuting cost)
  - Further from shipping center $\implies$ higher freight cost

Manufacturing Bid Rent

Let's start with a simple model™ . **Assumptions**

1) Input & Output **prices** & **quantities** are fixed

- Firm only decides location

2) Firms import intermediate goods and export output to other cities via a **central terminal** (train)

3) Wage paid is to compensate workers for commuting. Workforce is suburban so wage is highest at center

4) Firms use horse carts to transport inputs and output to the **central terminal**

- We will relax this one soon

Firm's Bid Rent

What do we use to get the firm's bid - rent equation?

Axiom 5: *Competition generates zero economic profit*

Recall the profit equation:

$$\pi = TR - TC$$

In this model:

- $TR = P * Q$ (fixed, exogenous)
- TC is a function of freight cost, labor cost, and intermediate goods cost:

$$TC(x) = \text{Freight Cost}(x) + \text{Labor Cost}(x) + \text{Land Cost}(x) + \text{Intermediate Input Cost}$$

Firm Bid Rent

From here on out, let's call $\textbf{Intermediate Input Cost} = \bar{I}$

- Invoking zero economic profit, from the last slide we can write:

$$TR - (\textbf{Freight Cost}(x) + \textbf{Labor Cost}(x) + \textbf{Land Cost}(x) + \bar{I}) = 0$$

- **In words**: The most a firm would be willing to pay for land then is revenue net of non land cost. Rearranging:

$$\textbf{Land Cost}(x) = TR - \textbf{Freight Cost}(x) - \textbf{Labor Cost}(x) - \bar{I}$$

Note: Land Cost = $P(x) * L_m$, where:

- $P(x)$ is the *price of land at x miles away from the center*
- L_m is the *amount of land the manufacturer uses in production* (fixed input at L_m)

Firm Bid Rent: Equation

We can replace land cost with $P(x) * L_m$ to get the equation for the **manufacturing bid rent** curve

$$P(x) * L_m = TR - \text{Freight Cost}(x) - \text{Labor Cost}(x) - \bar{I}$$

Firm Bid Rent: Equation

We can replace land cost with $P(x) * L_m$ to get the equation for the **manufacturing bid rent** curve

$$P(x) * L_m = TR - \text{Freight Cost}(x) - \text{Labor Cost}(x) - \bar{I}$$

$$P(x) = \frac{TR - \text{Freight Cost}(x) - \text{Labor Cost}(x) - \bar{I}}{L_m}$$

In words, this equation says:

- Higher revenues $\implies$ higher land prices for every distance x
- An increase in freight costs, labor costs, or intermediate input costs will **decrease** the price for every distance x

Linearity

Note: If $\mathbf{Freight\ Cost}(x)$ and $\mathbf{Labor\ Cost}(x)$ are linear, then the firm bid rent curve is also linear. **Proof**:

- Let $\mathbf{Freight\ Cost}(x) = a_1 + b_1 * x$
  - Fixed freight cost is a_1, variable freight cost is $b_1 * x$
- $\mathbf{Labor\ Cost}(x) = a_2 - b_2 * x$
  - Fixed labor cost is a_2, variable labor cost is $b_2 * x$

Let's plug these into our $P(x)$ equation

Linearity

Plugging in yields

$$P(x) = \frac{TR - a_1 - b_1 * x - a_2 + b_2 * x - \bar{I}}{L_m}$$

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$$P(x) = \frac{TR - a_1 - b_1 * x - a_2 + b_2 * x - \bar{I}}{L_m}$$

$$P(x) = \frac{TR - a_1 - a_2 - \bar{I}}{L_m} + \frac{-b_1 * x + b_2 * x}{L_m}$$

Linearity

Plugging in yields

$$P(x) = \frac{TR - a_1 - b_1 * x - a_2 + b_2 * x - \bar{I}}{L_m}$$

$$P(x) = \frac{TR - a_1 - a_2 - \bar{I}}{L_m} + \frac{-b_1 * x + b_2 * x}{L_m}$$

$$P(x) = \underbrace{\frac{TR - a_1 - a_2 - \bar{I}}{L_m}}_{\text{b}} + \underbrace{\left(\frac{b_2 - b_1}{L_m}\right)}_{\text{m}} * x$$

- So we have proved that **when freight and variable costs are linear**, the **bid rent curve** for manufacturers is also **linear**
- Slope is given by m in the above equation
- Think about how the model's parameters (everything not x and P) impact slope and intercept + intuition (next homework)

Linearity

So note: the slope of the manufacturing bid rent curve depends on the value of b_2 relative to b_1.

- What if $b_1 = 10$ and $b_2 = 2$
  - Then $\frac{\Delta P(x)}{\Delta x} < 0$
  - Freight cost is high relative to labor rate
  - This is true for any $b_1 > b_2$
- Manufacturing firms bid most @ center of city when: $x = 0$

Manufacturing Graph

Back to Reality

How can a model like this help us understand the industrial revolution?

- What happened to freight costs? **They fell** A few innovations:

Transportation Innovations:

- Omnibus (1827)
- Cable Cars (1873)
- Electric Trolley (1886)
- Subways (1895)

In our model, what do these innovations do? $b_1 > b_2$

More History

- The *intracity* truck (1910): twice as fast and half as costly as the horse-drawn wagon[†]
- Truck decreased the cost of moving **output** `relative` to the cost of moving **workers**
- Manufacturing Firms moved closer to low-wage suburbs

The *intercity* truck (1930): alternative to ships and rail[††]

- **Highways**: orientation shifted from ports and railroad terminals to roads
- **Modern cities**: manufacturers oriented toward highways and beltways $b_2 > b_1$

† Intra = Within †† Inter = Across

Wrapping Up

So we had two models, the Von Thunen Model (rural bid rent) and the manufacturing bid rent

- Both derived bid rent curves from **zero economic profit**
- Bid rent curves are different because **costs** faced by **agriculture** and **manufacturing firms** are different
- But the story and derivation behind them is pretty similar

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3) **Manufacturing Bid Rent** ✅

- Deriving the manufacturing bid rent curve
- Graphing