Spatial Economics

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Essential Reading

- Fujita, M., P. Krugman, and A. Venables (1999) *The Spatial Economy: Cities, Regions and International Trade*, MIT Press, Chapters 4, 5 and 14.

- Allen, Treb and Costas Arkolakis (2014) "Trade and the Topography of the Spatial Economy," *Quarterly Journal of Economics*, 129(3), 1085-1140.

- Redding, S. and D. Sturm (2008) "The Costs of Remoteness: Evidence from German Division and Reunification," *American Economic Review*, 98(5), 1766-1797.

- Redding, S. (2016) "Goods Trade, Factor Mobility and Welfare," *Journal of International Economics*, 101, 148-167, 2016.

Motivation

- Until the early 1990s, economic geography received relative little attention in mainstream economic theory
- Despite the fact that production, trade and income are distributed extremely unevenly across physical space
- Agglomeration of overall economic activity most evident in cities
  - In 2016, 54.5 per cent of the world?s population lives in urban areas, a proportion that is expected to increase to 66 per cent by 2050
  - In 2016, 31 "megacities" with a population > 10 Million
  - Of these megacities, 24 are located in less developed countries, and China is home to 6
- Geographical concentration of particular activities
  - US manufacturing belt in NE and Eastern Midwest
  - Dalton as a carpet manufacturing centre in Georgia
  - Silicon Valley and Route 128 in Massachusetts

Motivation

- What do we mean by economic geography?
  - Location of economic activity in space
- First-nature geography
  - Physical geography of coasts, mountains and endowments of natural resources
- Second-nature geography
  - The spatial relationship between economic agents
- Our analysis will largely focus on second-nature geography
  - How does the spatial relationship between agents determine how they interact, what they do, and how well off they are?

Agglomeration Forces

- This lecture introduces Krugman (1991) and Helpman (1998)
  - Love of variety, Increasing returns to scale and trade costs
- Marshall (1920) identified three forces for agglomeration
  - Market for workers with specialized skills
  - Provision of non-traded inputs in greater variety and lower cost
  - Technological knowledge spillovers
- Krugman (1991) and Helpman (1998) focus on pecuniary rather than technological externalities
  - Love of variety, Increasing returns to scale and trade costs (forward & backward linkages)
  - Mobile workers (more relevant within than across countries)
  - Krugman (1991): immobile agricultural laborers are dispersion force
  - Helpman (1998): immobile land is dispersion force
- Krugman and Venables (1995) develop a model of agglomeration with immobile workers through the introduction of trade in intermediate inputs

Helpman (1998)

- Economy consists of N of regions indexed by n
- Each region is endowed with an exogenous quality-adjusted supply of land (H_i)
- Economy as a whole is endowed with a measure $\bar{L}$ of workers, where each worker has one unit of labor that is supplied inelastically with zero disutility
- Workers are perfectly geographically mobile and hence in equilibrium real wages are equalized across all populated regions.
- Regions connected by goods trade subject to symmetric iceberg variable trade costs
  - where $d_{ni} = d_{in} > 1$ units must be shipped from region i for one unit to arrive in region $n \neq i$
  - where $d_{nn} = 1$

Preferences

- Preferences are defined over goods consumption (C_n) and residential land use (H_{Un})

$$U_n = \left(\frac{C_n}{\alpha}\right)^{\alpha}\left(\frac{H_{Un}}{1-\alpha}\right)^{1-\alpha}, \qquad 0 < \alpha < 1.$$

- Goods consumption index (C_n) is defined over the endogenous measures of horizontally-differentiated varieties supplied by each region (M_i) with dual price index (P_n):

$$C_n = \left[\sum_{i \in N} \int_0^{M_i} c_{ni}(j)^{\rho}\, dj\right]^{\frac{1}{\rho}}, \qquad P_n = \left[\sum_{i \in N} \int_0^{M_i} p_{ni}(j)^{1-\sigma}\, dj\right]^{\frac{1}{1-\sigma}}.$$

Production

- Varieties produced under conditions of monopolistic competition and increasing returns to scale.
- To produce a variety, a firm must incur a fixed cost of F units of labor and a constant variable cost in terms of labor that depends on a location's productivity A_i.

$$l_i(j) = F + \frac{x_i(j)}{A_i}.$$

- Producer of each variety chooses prices to maximize profits subject to its downward-sloping demand curve

$$\max_{p_i(j)} \left\{ p_i(j) x_i(j) - w_i \left(F + \frac{x_i(j)}{A_i} \right) \right\}.$$

Profit Maximization and Zero-Profits

- First-order condition for profit maximization implies that prices are a constant markup over marginal cost

$$p_i(j) = p_i = \left(\frac{\sigma}{\sigma - 1}\right) \frac{w_i}{A_i},$$

$$p_{ni}(j) = p_{ni} = d_{ni} p_i$$

- Profit maximization and zero profits implies that equilibrium output of each variety depends solely on parameters

$$x_i(j) = \bar{x}_i = A_i(\sigma - 1)F$$

- Using the production technology, equilibrium employment for each variety also depends solely on parameters

$$l_i(j) = \bar{l} = \sigma F.$$

Labor Market Clearing

- Labor market clearing requires demand equals the supply for labor

$$L_i = M_i \bar{l}$$

- Therefore the mass of varieties produced by each location is proportional to its supply of labor

$$M_i = \frac{L_i}{\sigma F}.$$

Price Indexes

- Using the symmetry of equilibrium pricing, the price index is:

$$P_n = \left[\sum_{i \in N} M_i p_{ni}^{1-\sigma} \right]^{\frac{1}{1-\sigma}}$$

- Using labor marker clearing and the pricing rule, we have:

$$P_n = \frac{\sigma}{\sigma - 1} \left(\frac{1}{\sigma F} \right)^{\frac{1}{1-\sigma}} \left[\sum_{i \in N} L_i \left(d_{ni} \frac{w_i}{A_i} \right)^{1-\sigma} \right]^{\frac{1}{1-\sigma}} .$$

Expenditure Shares

- Equilibrium expenditure shares

$$\pi_{ni} = \frac{M_i p_{ni}^{1-\sigma}}{\sum_{k \in N} M_k p_{nk}^{1-\sigma}} = \frac{L_i \left(d_{ni} \frac{w_i}{A_i} \right)^{1-\sigma}}{\sum_{k \in N} L_k \left(d_{nk} \frac{w_k}{A_k} \right)^{1-\sigma}}.$$

- Using the denominator of the expenditure share, the price index can be re-written as:

$$P_n = \frac{\sigma}{\sigma - 1} \left(\frac{L_n}{\sigma F \pi_{nn}} \right)^{\frac{1}{1-\sigma}} \frac{w_n}{A_n}.$$

Land Market Clearing

- Expenditure on land in each location is redistributed lump sum to the workers residing in that location

- Per capita income in each location (v_n) equals labor income (w_n) plus per capita expenditure on residential land ($(1-\alpha)v_n$):

$$v_n L_n = w_n L_n + (1-\alpha) v_n L_n = \frac{w_n L_n}{\alpha}.$$

- Land market clearing implies that the equilibrium land rent (r_n) can be determined from the equality of land income and expenditure:

$$r_n = \frac{(1-\alpha) v_n L_n}{H_n} = \frac{1-\alpha}{\alpha} \frac{w_n L_n}{H_n},$$

Population Mobility

- Population mobility implies that workers receive the same real income in all populated locations:

$$V_n = \frac{v_n}{P_n^{\alpha} r_n^{1-\alpha}} = \bar{V}.$$

- Using the price index, income equals expenditure, and land market clearing in the population mobility condition, we obtain:

$$\bar{V} = \frac{A_n^{\alpha} H_n^{1-\alpha} \pi_{nn}^{-\alpha/(\sigma-1)} L_n^{-\frac{\sigma(1-\alpha)-1}{\sigma-1}}}{\alpha \left(\frac{\sigma}{\sigma-1}\right)^{\alpha} \left(\frac{1}{\sigma F}\right)^{\frac{\alpha}{1-\sigma}} \left(\frac{1-\alpha}{\alpha}\right)^{1-\alpha}}$$

Gains from Trade and Market Access

- A region's welfare gains from trade depend on the change in its domestic trade and share and the change in its population

$$\frac{V_n^T}{V_n^A} = \left(\pi_{nn}^T\right)^{-\frac{\alpha}{\sigma-1}} \left(\frac{L_n^T}{L_n^A}\right)^{-\frac{\sigma(1-\alpha)-1}{\sigma-1}} .$$

- Rearranging the population moblity condition to obtain an expression for L_n, and dividing by total labor supply $\bar{L} = \sum_{n \in N} L_n$, population shares depend on productivity, land supply and market access

$$\lambda_n = \frac{L_n}{\bar{L}} = \frac{\left[A_n^\alpha H_n^{1-\alpha} \pi_{nn}^{-\alpha/(\sigma-1)}\right]^{\frac{\sigma-1}{\sigma(1-\alpha)-1}}}{\sum_{k \in N} \left[A_k^\alpha H_k^{1-\alpha} \pi_{kk}^{-\alpha/(\sigma-1)}\right]^{\frac{\sigma-1}{\sigma(1-\alpha)-1}}},$$

- where market access summarized by the domestic trade share (π_{nn})

General Equilibrium

- General equilibrium : two systems of equations across locations
  - Gravity of trade flows
  - Population mobility

Population Mobility

$$P_n^{\alpha} = \frac{v_n}{\bar{V} r_n^{1-\alpha}}.$$

- Using $v_n = w_n/\alpha$ and land market clearing ($r_n = \frac{1-\alpha}{\alpha}\frac{w_n L_n}{H_n}$)

$$P_n = \frac{w_n}{\bar{W}}\left(\frac{H_n}{L_n}\right)^{\frac{1-\alpha}{\alpha}}, \qquad \bar{W} \equiv \left[\alpha\left(\frac{1-\alpha}{\alpha}\right)^{1-\alpha}\bar{V}\right]^{\frac{1}{\alpha}}.$$

- Recall

$$P_n = \frac{\sigma}{\sigma-1}\left(\frac{1}{\sigma F}\right)^{\frac{1}{1-\sigma}}\left[\sum_{i\in N} L_i\left(d_{ni}\frac{w_i}{A_i}\right)^{1-\sigma}\right]^{\frac{1}{1-\sigma}}.$$

- Obtain a first wage equation from population mobility

$$\bar{W}^{1-\sigma}\frac{1}{\sigma F}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} = \frac{w_i^{1-\sigma}\left(\frac{H_i}{L_i}\right)^{(1-\sigma)\frac{1-\alpha}{\alpha}}}{\sum_{n\in N} L_n\left(d_{in}\frac{w_n}{A_n}\right)^{1-\sigma}}.$$

Gravity I

- Gravity and income equals expenditure implies:

$$w_i L_i = \sum_{n \in N} \frac{\frac{L_i}{\sigma F}\left(\frac{\sigma}{\sigma-1} d_{ni} \frac{w_i}{A_i}\right)^{1-\sigma}}{P_n^{1-\sigma}} w_n L_n.$$

- Recall that the price index can be expressed as

$$P_n^{1-\sigma} = \frac{\frac{L_n}{\sigma F}\left(\frac{\sigma}{\sigma-1} \frac{w_n}{A_n}\right)^{1-\sigma}}{\pi_{nn}}.$$

- Obtain a second wage equation from gravity

$$w_i^{\sigma} A_i^{1-\sigma} = \sum_{n \in N} \pi_{nn} d_{ni}^{1-\sigma} w_n^{\sigma} A_n^{1-\sigma}.$$

Gravity II

- Recall price index from previous slide

$$P_n^{1-\sigma} = \frac{\frac{L_n}{\sigma F}\left(\frac{\sigma}{\sigma-1}\frac{w_n}{A_n}\right)^{1-\sigma}}{\pi_{nn}}.$$

- Recall price index from population mobility

$$P_n = \frac{w_n}{\bar{W}}\left(\frac{H_n}{L_n}\right)^{\frac{1-\alpha}{\alpha}}, \qquad \bar{W} \equiv \left[\alpha\left(\frac{1-\alpha}{\alpha}\right)^{1-\alpha}\bar{V}\right]^{\frac{1}{\alpha}}.$$

- Equating these two expressions, we obtain the following solution for the domestic trade share

$$\pi_{nn} = \bar{W}^{1-\sigma}\frac{1}{\sigma F}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma} L_n^{1-(\sigma-1)\frac{1-\alpha}{\alpha}} H_n^{(\sigma-1)\frac{1-\alpha}{\alpha}} A_n^{\sigma-1}.$$

Gravity III

- Recall our earlier wage equation from gravity

$$w_i^{\sigma} A_i^{1-\sigma} = \sum_{n \in N} \pi_{nn} d_{ni}^{1-\sigma} w_n^{\sigma} A_n^{1-\sigma}.$$

- Using our expression for the domestic trade share on previous, slide this wage equation from gravity becomes

$$\bar{W}^{1-\sigma} \frac{1}{\sigma F} \left(\frac{\sigma}{\sigma - 1} \right)^{1-\sigma} = \frac{w_i^{\sigma} A_i^{1-\sigma}}{\sum_{n \in N} d_{ni}^{1-\sigma} L_n^{1-(\sigma-1)\frac{1-\alpha}{\alpha}} H_n^{(\sigma-1)\frac{1-\alpha}{\alpha}} w_n^{\sigma}}.$$

General Equilibrium I

- Two systems of equations for wages and population

$$\bar{W}^{1-\sigma}\frac{1}{\sigma F}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}=\frac{w_i^{1-\sigma}\left(\frac{H_i}{L_i}\right)^{(1-\sigma)\frac{1-\alpha}{\alpha}}}{\sum_{n\in N}L_n\left(d_{in}\frac{w_n}{A_n}\right)^{1-\sigma}}.$$

$$\bar{W}^{1-\sigma}\frac{1}{\sigma F}\left(\frac{\sigma}{\sigma-1}\right)^{1-\sigma}=\frac{w_i^{\sigma}A_i^{1-\sigma}}{\sum_{n\in N}d_{ni}^{1-\sigma}L_n^{1-(\sigma-1)\frac{1-\alpha}{\alpha}}H_n^{(\sigma-1)\frac{1-\alpha}{\alpha}}w_n^{\sigma}}.$$

- Under our assumption of symmetric trade costs ($d_{ni}=d_{in}$), this system of equations has the following closed-form solution

$$w_n^{1-2\sigma}A_n^{\sigma-1}L_n^{(\sigma-1)\frac{1-\alpha}{\alpha}}H_n^{-(\sigma-1)\frac{1-\alpha}{\alpha}}=\phi.$$

General Equilibrium II

- Using this closed-form solution, we obtain a single system of equations that determines equilibrium population

$$L_n^{\tilde{\sigma}\gamma_1} A_n^{-\tilde{\sigma}(\sigma-1)} H_n^{-\tilde{\sigma}\sigma\frac{1-\alpha}{\alpha}} =$$

$$\bar{W}^{1-\sigma} \sum_{i \in N} \frac{1}{\sigma F} \left(\frac{\sigma}{\sigma - 1} d_{ni} \right)^{1-\sigma} \left(L_i^{\tilde{\sigma}\gamma_1} \right)^{\frac{\gamma_2}{\gamma_1}} A_i^{\tilde{\sigma}\sigma} H_i^{\tilde{\sigma}(\sigma-1)\frac{1-\alpha}{\alpha}},$$

$$\tilde{\sigma} \equiv \frac{\sigma - 1}{2\sigma - 1},$$

$$\gamma_1 \equiv \sigma \frac{1-\alpha}{\alpha},$$

$$\gamma_2 \equiv 1 + \frac{\sigma}{\sigma - 1} - (\sigma - 1)\frac{1-\alpha}{\alpha}.$$

Existence and Uniqueness

Proposition

Assume $\sigma(1-\alpha) > 1$*. Given the land area, productivity and amenity parameters* $\{H_n, A_n, B_n\}$ *and symmetric bilateral trade frictions* $\{d_{ni}\}$ *for all locations* $n, i \in N$*, there exist unique equilibrium populations* (L_n^*) *that solve this system of equations.*

Proof.

The proof follows Allen and Arkolakis (2014). Assume $\sigma(1-\alpha) > 1$. Given the land area and productivity for each location $\{H_n, A_n\}$ and bilateral trade frictions $\{d_{ni}\}$, there exists a unique fixed point in this system because $\gamma_2/\gamma_1 < 1$ (Fujimoto and Krause 1985). □

- Intuition: Unique equilibrium requires that agglomeration forces are sufficiently weak relative to dispersion forces
  - Higher $(1-\alpha)$ implies that land accounts for a larger share consumer expenditure
  - Higher elasticity of substitution (σ) implies that varieties are closer substitutes for one another

Market Access

- Model provides micro-foundations for a theory-consistent measure of *market access*
  - Ad hoc measures of *market potential* following Harris (1954)

$$MP_{nt} = \sum_{i \in N} \frac{L_{it}}{\text{dist}_{ni}}$$

  - Theory-based measure highlights the role of price indexes (connection with Anderson and Van Wincoop 2003)

- We now examine the predictions of the model for the equilibrium relationship between wages, population and market access

- Market access is itself an endogenous variable

Wages and Market Access

- From profit maximization

$$p_i(j) = p_i = \left(\frac{\sigma}{\sigma - 1}\right)\frac{w_i}{A_i},$$

- From profit maximization and zero profits

$$x_i(j) = \bar{x}_i = A_i(\sigma - 1)F$$

- From CES demand and market clearing, we have:

$$\bar{x}_i = p_i^{\sigma} \sum_{n \in N} d_{ni}^{1-\sigma} \left(w_n L_n\right) \left(P_n\right)^{\sigma - 1},$$

Wages and Market Access

- Combining profit maximization, zero profits, CES demand and market clearing, we obtain the following wage equation:

$$\left(\frac{\sigma}{\sigma-1}\frac{w_i}{A_i}\right)^{\sigma} = \frac{1}{\bar{x}_i}\text{FMA}_i$$

$$w_i = \left(\frac{\sigma-1}{\sigma}\right)^{\frac{\sigma-1}{\sigma}} A_i^{\frac{\sigma-1}{\sigma}} \left(\bar{l}\right)^{-\frac{1}{\sigma}} \left(\text{FMA}_i\right)^{\frac{1}{\sigma}}.$$

- where firm market access is defined as

$$\text{FMA}_i \equiv \sum_{n\in N} d_{ni}^{1-\sigma} \left(w_n L_n\right) \left(P_n\right)^{\sigma-1},$$

- Wages increase in productivity A_i and firm market access (FMA_i)
- Reductions in transport costs (d_{ni}) increase firm market access and wages (w_i)
- For empirical evidence, see Dekle and Eaton (1999), Hanson (2005), Donaldson and Hornbeck (2016)

Price Indexes and Market Access

- Market access also affects the price index, which depends on consumers' access to tradeable varieties

- We summarize this access to tradeable varieties using *consumer market access* (CMA_n):

$$P_n = (\text{CMA}_n)^{\frac{1}{1-\sigma}},$$

$$\text{CMA}_n \equiv \sum_{i \in N} M_i \left(d_{ni} p_i\right)^{1-\sigma},$$

- where we use symmetric trade costs

Estimating Market Access

- Use international trade data to "reveal" market access
- CES demand function

$$X_{ni} = M_i p_i x_{ni} = M_i p_i^{1-\sigma} d_{ni}^{1-\sigma} X_n P_n^{\sigma-1}$$

- Can be re-written in terms of market and supply capacity

$$X_{ni} = s_i d_{ni}^{1-\sigma} m_n,$$

$$s_i \equiv M_i p_i^{1-\sigma}, \qquad m_n \equiv X_n P_n^{\sigma-1},$$

- Firm and consumer market access can be written:

$$FMA_i = \sum_{n \in N} d_{ni}^{1-\sigma} m_n, \qquad CMA_n = \sum_{i \in N} s_i d_{ni}^{1-\sigma}$$

- where we again use symmetric trade costs
- Redding and Venables (2004) estimate these market access measures using fixed effects gravity equation estimation

Population and Market Access

- Population mobility implies:

$$V_n = \frac{v_n}{P_n^{\alpha} r_n^{1-\alpha}} = \bar{V}.$$

- Using income equals expenditure, the price index and land market clearing, together with the definitions of firm and consumer market access, this population mobility condition can be written as:

$$L_n = \chi A_n^{\left(\frac{\alpha}{1-\alpha}\frac{\sigma-1}{\sigma}\right)} H_n (\text{FMA}_n)^{\frac{\alpha}{(1-\alpha)\sigma}} (\text{CMA}_n)^{\frac{\alpha}{(1-\alpha)(\sigma-1)}},$$

- Equilibrium population is increasing in productivity, housing supply, and firm and consumer market access
- For evidence, see Redding and Sturm (2008)
- In our earlier GE system of equations, we solved for equilibrium population as a function of the exogenous variables

Firm and Consumer Market Access

- Firm and consumer market access are closely related
- From the definitions of firm and consumer market access:

$$\mathrm{FMA}_i \equiv \sum_{n \in N} d_{ni}^{1-\sigma} \left(w_n L_n \right) \mathrm{CMA}_n^{-1}.$$

- From the definition of consumer market access and using profit maximization and labor market clearing, we have:

$$\mathrm{CMA}_n \equiv \sum_{i \in N} \frac{L_i}{\sigma F} \left(\frac{\sigma}{\sigma - 1} \frac{w_i}{A_i} d_{ni} \right)^{1-\sigma}.$$

- Note that CES demand implies the following gravity equation for bilateral exports from location i to location n:

$$X_{ni} = \frac{L_i}{\sigma F} \left(\frac{\sigma}{\sigma - 1} \frac{w_i}{A_i} \right)^{1-\sigma} d_{ni}^{1-\sigma} \left(w_n L_n \right) \mathrm{CMA}_n^{-1},$$

- where we have used $X_n = \alpha v_n L_n = w_n L_n$.

Firm and Consumer Market Access

- Summing across destinations and using goods market clearing ($X_i = \sum_{n \in N} X_{ni} = w_i L_i$), we obtain:

$$w_i L_i = \frac{L_i}{\sigma F} \left(\frac{\sigma}{\sigma - 1} \frac{w_i}{A_i} \right)^{1-\sigma} \sum_{n \in N} d_{ni}^{1-\sigma} \left(w_n L_n \right) \mathrm{CMA}_n^{-1}.$$

- Using the definition of firm market access, this relationship implies:

$$\frac{L_i}{\sigma F} \left(\frac{\sigma}{\sigma - 1} \frac{w_i}{A_i} \right)^{1-\sigma} = \frac{w_i L_i}{\mathrm{FMA}_i}.$$

- Using this result in the expression for consumer market access, we obtain:

$$\mathrm{CMA}_n \equiv \sum_{i \in N} d_{ni}^{1-\sigma} \left(w_i L_i \right) \mathrm{FMA}_i^{-1},$$

- which reversing the notation becomes:

$$\mathrm{CMA}_i \equiv \sum_{n \in N} d_{in}^{1-\sigma} \left(w_n L_n \right) \mathrm{FMA}_n^{-1}.$$

Firm and Consumer Market Access

- Assuming symmetric trade costs ($d_{ni} = d_{in}$), any solution to these two systems of equations must satisfy:

$$\mathrm{MA}_i \equiv \mathrm{FMA}_i = \psi \mathrm{CMA}_i,$$

- as can be confirmed by using this relationship under symmetric trade costs in these equations to obtain the recursive solutions:

$$\mathrm{FMA}_i \equiv \sum_{n \in N} d_{ni}^{1-\sigma} \left(w_n L_n \right) \psi^{-1} \mathrm{FMA}_n^{-1},$$

$$\mathrm{FMA}_i \equiv \sum_{n \in N} d_{ni}^{1-\sigma} \left(w_n L_n \right) \psi^{-1} \mathrm{FMA}_n^{-1},$$

- where we determined w_n and L_n from our GE system above
- Therefore with symmetric trade costs firm and consumer market access can be reduced to a single market access measure

References

- Allen, Treb and Costas Arkolakis (2014) "Trade and the Topography of the Spatial Economy," *Quarterly Journal of Economics*, 129(3), 1085-1140.
- Anderson, James and Eric van Wincoop (2003) "Gravity with Gravitas: A Solution to the Border Puzzle," *American Economic Review*, 93(1), 170-192.
- Dekle, Robert and Jonathan Eaton (1999) "Agglomeration and Land Rents: Evidence from the Prefectures," *Journal of Urban Economics*, 46(2), 200-214.
- Donaldson, D., and R. Hornbeck (2016) "Railroads and American Economic Growth: A Market Access Approach," *Quarterly Journal of Economics*, 131(2), 799-858.
- Fujimoto, T. and U. Krause (1985) "Strong Ergodicity for Strictly Increasing Nonlinear Operators," *Linear Algebra and its Applications*, 71, 101-112.

References

- Harris, Chauncy D. (1954) "The Market as a Factor in the Localization of Industry in the United States," *Annals of the Association of American Geographers*, 44(4), 315-348.
- Hanson, Gordon H. (2005) "Market Potential, Increasing Returns, and Geographic Concentration," *Journal of International Economics*, 67(1), 1-24.
- Helpman, E. (1998) "The Size of Regions," in *Topics in Public Economics: Theoretical and Applied Analysis*, (ed.) by D. Pines, E. Sadka, and I. Zilcha. Cambridge: Cambridge University Press.
- Krugman, P. (1991) "Increasing Returns and Economic Geography," *Journal of Political Economy*, 99(3), 483-99.
- Krugman, P. (1991) *Geography and Trade*, Cambridge: MIT Press.
- Krugman, P. and A. J. Venables (1995) "Globalisation and Inequality of Nations," *Quarterly Journal of Economics*, 60, 857-80.

References

- Marshall, A. (1920) *Principles of Economics*, London: Macmillan.
- Redding, S. J., and D. M. Sturm (2008) "The Costs of Remoteness: Evidence from German Division and Reunification," *American Economic Review*, 98(5), 1766-1797.
- Redding, S. J. and A. J. Venables (2004) "Economic Geography and International Inequality," *Journal of International Economics*, 62(1), 53-82.