On Spatial Dynamics

Klaus Desmet
Universidad Carlos III

and

Esteban Rossi-Hansberg
Princeton University

April 2009

Introduction

- Economists have long discussed the relationship between agglomeration and growth
  - Both are based on some form of weakly increasing returns
    - ★ Lucas (1988) and Krugman (1997)

- But no Dynamic Spatial Theory has emerged: Why?

The Literature

Literature can be divided in three main strands:

1. Dynamic extensions of the New Economic Geography framework

- Krugman (1991) meets Grossman and Helpman (1991). Nice survey in Baldwin and Martin (2004)
- Mostly 2 locations and no land
- Useful to think about the relationship between regional imbalances and growth
- But very stylized, not rich enough to capture other spatial characteristics within and across industries

The Literature

2. Urban dynamics and the size distribution of cities

- Built to match the size distribution of cities
- Use Gabaix (1999) insight that dynamic evolution key to determine the observed city heterogeneity
- Emphasis on obtaining a dynamic evolution of city size based on model's fundamentals: Black and Henderson (1999), Duranton (2007) and Rossi-Hansberg and Wright (2007)
- Establishes link from growth to the distribution of economic activity in cities
- But no space and no spatial links between cities (like transport costs)
  - Potential selection bias when looking only at cities

The Literature

3. Optimal evolution of capital in space with forward looking agents

- Full dynamic spatial framework with either diffusion or capital mobility
- The problem solved by Boucekkine et al. (2009) is given by:

$$\max_{c} \int_0^\infty \int_{\mathbb{R}} U\left(c\left(\ell, t\right)\right) L\left(\ell, t\right) e^{-\beta t} d\ell dt$$

subject to

$$\frac{\partial k\left(\ell, t\right)}{\partial t} - \frac{\partial^2 k\left(\ell, t\right)}{\partial \ell^2} = Z\left(\ell, t\right) f\left(k\left(\ell, t\right)\right) - \delta k\left(\ell, t\right) - c\left(\ell, t\right)$$

$$k(\ell, 0) = k_0\left(\ell\right) > 0 \text{ and } \lim_{\ell \to \pm\infty} \frac{\partial k\left(\ell, t\right)}{\partial \ell} = 0$$

- An 'ill-posed' problem so cannot be fully analyzed apart from special cases. Only necessary conditions can be advanced
- For examples with diffusion see Brock and Xepapadeas (2008)

The Importance of Space

Why is modeling geographically ordered space important?

- Land at a particular location is a rival non-replicable input
    - Economic density is endogenous, but non-replicability of land leads to decreasing returns: a dispersion force
- The ordering of economic activity in space determines outcomes
    - Ample evidence for patents (Jaffe et al., 1993), co-location of firms (Duranton and Overman 2005, 2008 and Ellison and Glaeser, 1997), and in general transport costs and mobility costs

The Importance of Space

Why is it hard?

- Adds another dimension
  - Forward looking agents need to understand the distribution of economic activity in all future dates for all feasible decisions
- Clearing markets is difficult
  - One possibility is to make probabilistic statements for a large number of locations as in trade (e.g. Eaton and Kortum, 2002)
  - Another is to clear market sequentially with compact continuous space (e.g. Rossi-Hansberg, 2005)
    - ★ Hard to do with non-symmetric two dimensional setups (like reality!)

An Alternative Model with Space

- Developed in Desmet and Rossi-Hansberg (2009) with two sectors
- Land is given by the unit interval $[0, 1]$, time is discrete, and total population is $\bar{L}$
- Agents solve

$$\max_{\{c(\ell,t)\}_0^\infty} E \sum_{t=0}^{\infty} \beta U(c\,(\ell, t)) \text{ s.t. } w\,(\ell, t) + \frac{\bar{R}(t)}{\bar{L}} = p\,(\ell, t)\, c\,(\ell, t)$$

- Free mobility implies that utilities equalize across regions each period
- Firm solve

$$\max_{L(\ell,t)} (1 - \tau\,(\ell, t)) \left(p\,(\ell, t)\, Z\,(\ell, t)\, L\,(\ell, t)^{\mu} - w\,(\ell, t)\, L\,(\ell, t)\right)$$

Innovation

- The government of a county can decide to buy an opportunity to innovate by taxing local firms $\tau(\ell, t)$
- Buys a probability $\phi \leq 1$ of innovating at a cost $\psi(\phi)$ per unit of land
- If it innovates it draws a technology multiplier $z(\ell)$ from

$$\Pr[z < z_\ell] = \left(\frac{1}{z}\right)^a$$

  such that TFP becomes $z_\ell Z_i(\ell, t)$.
- County G, with land measure I, will then maximize

$$\max_{\phi(\ell,t)} \int_G \frac{\phi(\ell, t)}{a-1} p(\ell, t) Z(\ell, t) L(\ell, t)^\mu d\ell - I\psi(\phi)$$

Diffusion, Transport Costs and Market Clearing

- Innovation diffuses spatially between time periods according to

$$Z_i(\ell, t+1) = \max_{r \in [0,1]} e^{-\delta|\ell - r|} Z(r, t)$$

- Transport costs such that if goods are produced in ℓ and consumed in r, $p(r, t) = e^{\kappa|\ell - r|} p(\ell, t)$
- Goods markets clear sequentially so define $H_i(\ell, t)$ by $H_i(0, t) = 0$ and by the differential equation

$$\frac{\partial H(\ell, t)}{\partial \ell} = \theta(\ell, t)\, x(\ell, t) - c(\ell, t) \left(\sum_i \theta(\ell, t)\, L(\ell, t) \right) - \kappa \left| H(\ell, t) \right|$$

then, the goods market clears if $H(1, t) = 0$.
- The labor market clearing condition is given by

$$\int_0^1 L(\ell, t)\, d\ell = \bar{L}, \text{ all } t$$

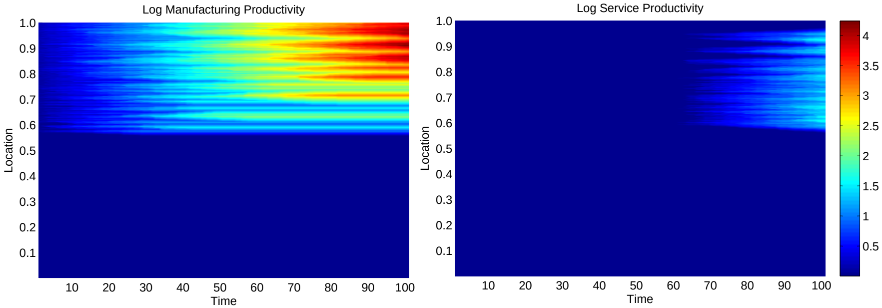
Two Growth Effects

With two sectors:

1. 'Spillover' effect: locations close to other locations in the same sector grow faster because they benefit from innovation investments close by. This in turn increases incentives to innovate in this locations

2. 'Trade' effect: locations close to areas that import a particular good experience high prices for that good, thus providing incentives to innovate in that sector

Two Growth Effects



Some Evidence for Manufacturing

Decay Emp. Kernel:				0.1 (half life 7 km)				
Decay Imp. Kernel:	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14
Half-Life Imp. Kernel (km):	9.9	8.7	7.7	6.9	6.3	5.8	5.3	5.0
Dependent variable: Log(Industry Employment 2000)-Log(Industry Employment 1990)								
Log(Ind. Emp. 1990)	-0.053	-0.0526	-0.05222	-0.05191	-0.05166	-0.05162	-0.0514	-0.05125
	[12.70]***	[12.59]***	[12.49]***	[12.41]***	[12.34]***	[12.32]***	[12.26]***	[12.21]***
Log(Ind. Emp. Kernel 1990)	0.00624	0.00617	0.00607	0.00602	0.00605	0.00592	0.00584	0.00567
	[2.08]**	[2.05]**	[2.02]**	[2.00]**	[2.01]**	[1.97]**	[1.94]*	[1.88]*
Log(Ind. Imp. Kernel 1990)	0.00626	0.00624	0.00628	0.00638	0.00639	0.00632	0.00633	0.00626
	[10.71]***	[10.54]***	[10.49]***	[10.59]***	[10.53]***	[10.36]***	[10.36]***	[10.22]***
Constant	0.56213	0.55913	0.55678	0.55473	0.55276	0.55297	0.55164	0.55117
	[19.06]***	[18.92]***	[18.82]***	[18.74]***	[18.65]***	[18.64]***	[18.59]***	[18.55]***
Observations	2543	2543	2543	2543	2543	2543	2543	2543
R-squared	0.1221	0.121	0.1206	0.1213	0.1209	0.1197	0.1197	0.1187
Dependent variable: Log(Industry Employment 1990)-Log(Industry Employment 1980)								
Log(Ind. Emp. 1980)	-0.03445	-0.03389	-0.03371	-0.03338	-0.03287	-0.03256	-0.0323	-0.03207
	[7.35]***	[7.22]***	[7.18]***	[7.10]***	[6.99]***	[6.92]***	[6.86]***	[6.81]***
Log(Ind. Emp. Kernel 1980)	0.03753	0.03786	0.03795	0.03806	0.0382	0.0382	0.03824	0.03828
	[10.77]***	[10.89]***	[10.92]***	[10.97]***	[11.03]***	[11.05]***	[11.08]***	[11.10]***
Log(Ind. Imp. Kernel 1980)	0.00176	0.00223	0.0024	0.00265	0.00297	0.00313	0.00332	0.00348
	[2.45]**	[3.06]***	[3.26]***	[3.59]***	[4.00]***	[4.21]***	[4.47]***	[4.68]***
Constant	0.1047	0.09882	0.09711	0.09398	0.08948	0.0871	0.08495	0.08312
	[3.21]***	[3.02]***	[2.97]***	[2.88]***	[2.73]***	[2.66]***	[2.60]***	[2.54]**
Observations	2857	2857	2857	2857	2857	2857	2857	2857
R-squared	0.0417	0.0428	0.0432	0.044	0.045	0.0456	0.0463	0.047

Absolute value of t statistics in brackets
** significant at 10%; ** significant at 5%; *** significant at 1%*

Some Evidence for Services

Decay Emp. Kernel:				0.1 (half life 7 km)				
Decay Imp. Kernel:	0.07	0.08	0.09	0.10	0.11	0.12	0.13	0.14
Half-Life Imp. Kernel (km):	9.9	8.7	7.7	6.9	6.3	5.8	5.3	5.0
Dependent variable: Log(Service Employment 2000)-Log(Service Employment 1990)								
Log(Serv. Emp. 1990)	0.00346	0.00383	0.00409	0.00426	0.0043	0.00443	0.00451	0.00458
	[1.29]	[1.43]	[1.53]	[1.59]	[1.61]	[1.66]*	[1.69]*	[1.72]*
Log(Serv. Emp. Kernel 1990)	0.00624	0.00603	0.00587	0.00576	0.00572	0.00563	0.00557	0.00552
	[4.55]***	[4.40]***	[4.28]***	[4.20]***	[4.17]***	[4.11]***	[4.07]***	[4.03]***
Log(Serv. Imp. Kernel 1990)	-0.00028	0.00014	0.00044	0.00065	0.00073	0.00089	0.00101	0.00113
	[0.74]	[0.36]	[1.15]	[1.67]*	[1.85]*	[2.26]**	[2.55]**	[2.87]***
Constant	0.18715	0.18406	0.18195	0.1805	0.18018	0.17918	0.17855	0.17789
	[8.08]***	[7.95]***	[7.86]***	[7.80]***	[7.79]***	[7.75]***	[7.73]***	[7.71]***
Observations	2277	2277	2277	2277	2277	2277	2277	2277
R-squared	0.0131	0.013	0.0135	0.0141	0.0144	0.0151	0.0157	0.0165
Dependent variable: Log(Service Employment 1990)-Log(Service Employment 1980)								
Log(Serv. Emp. 1980)	0.04007	0.04012	0.04028	0.04034	0.04026	0.04024	0.04023	0.0402
	[13.89]***	[13.91]***	[13.99]***	[14.02]***	[14.00]***	[14.00]***	[14.00]***	[13.99]***
Log(Serv. Emp. Kernel 1980)	0.01013	0.01003	0.00987	0.00977	0.00977	0.00973	0.00975	0.00978
	[6.89]***	[6.82]***	[6.72]***	[6.67]***	[6.67]***	[6.65]***	[6.66]***	[6.68]***
Log(Serv. Imp. Kernel 1980)	0.00153	0.00176	0.00208	0.00232	0.00236	0.00249	0.00251	0.00245
	[3.72]***	[4.22]***	[4.96]***	[5.49]***	[5.58]***	[5.86]***	[5.90]***	[5.76]***
Constant	-0.19616	-0.19598	-0.19655	-0.19644	-0.19573	-0.19524	-0.19523	-0.19522
	[8.12]***	[8.11]***	[8.15]***	[8.15]***	[8.12]***	[8.11]***	[8.11]***	[8.11]***
Observations	2616	2616	2616	2616	2616	2616	2616	2616
R-squared	0.1191	0.1204	0.1227	0.1245	0.1248	0.1259	0.1261	0.1255

Absolute value of t statistics in brackets

** significant at 10%; ** significant at 5%; *** significant at 1%*

Conclusion

- Frameworks in the literature either not rich enough, lack space, or only partially understood
- Need to develop new spatial dynamic framework that can be contrasted to the data
  - On what dimensions?
  - Should have both 'spillover' and 'trade' effects
- Need a structural way of relating to the data to be able to run counterfactual exercises
- These are mayor challenges for the next fifty years of regional science!