Both Sides Now:

Urban Growth and Convergence Dynamics in the Age of Internet

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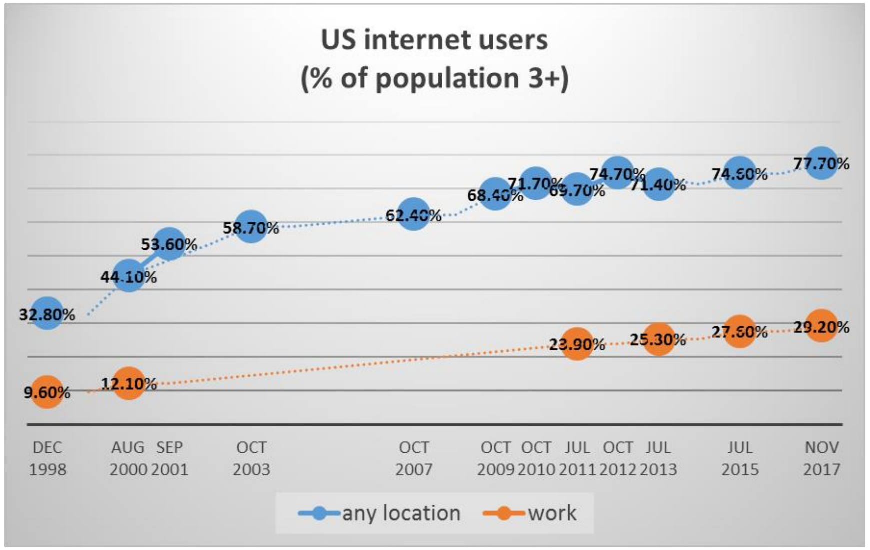
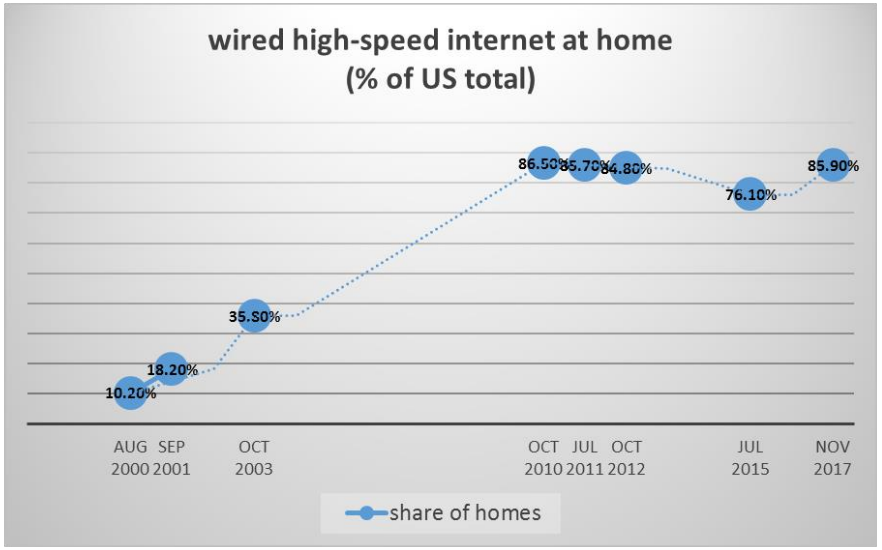
The age of internet

- the idea of a network allowing users from different nodes to communicate through their PCs dates back to the 1950s
- the first message was sent over the ARPANET (funded by the U.S. Department of Defense) in 1969 from a laboratory at UCLA to the second network node at Stanford
- National Science Foundation began to commercialize the Internet in 1992. Popularity of the net becomes massive during the 1990s thanks to the introduction of the World Wide Web
- **since the end of the 1990s**, broadband technology and hi-speed connections has allowed the rise of **near-instant communication** (electronic mail, instant messaging, voice over Internet Protocol (VoIP) telephone calls, two-way interactive video calls)





Source: Digital Nation Data Explorer, National Telecommunications and Information Administration, US Department of Commerce

Motivation of the paper

- near-instant communication services is likely to have an strong impact on the transmission of tacit knowledge
- knowledge is the basic input in research activities

$\Rightarrow$ the diffusion of near-instant communication is likely to affect:

$\rightarrow$ research activity and innovation

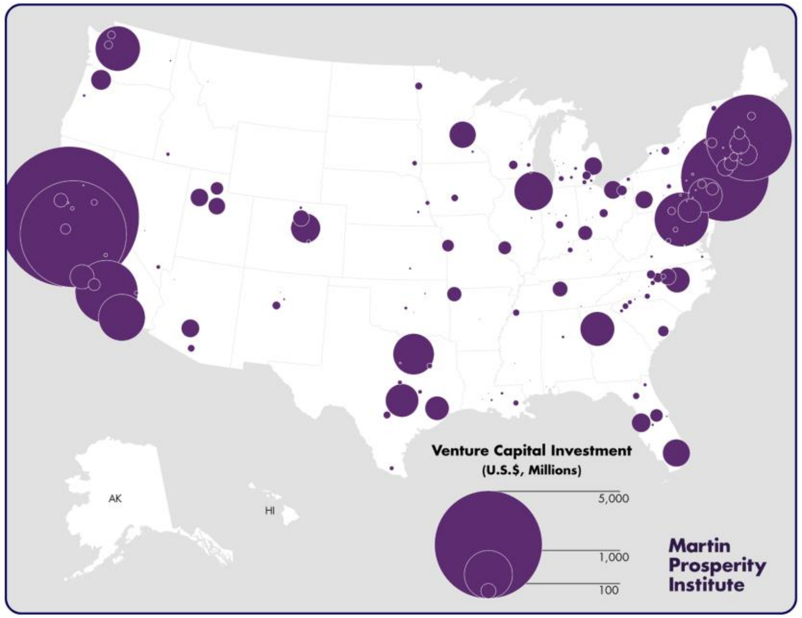
$\rightarrow$ the spatial distribution of research and innovation

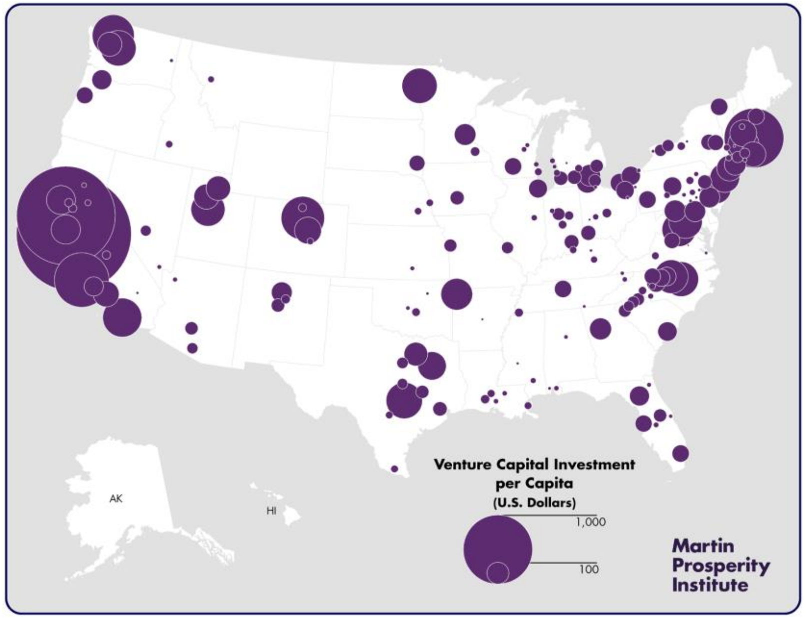
Research question: how has internet and, in particular, the development of near-instant communication impacted on economic growth and convergence dynamics across areas of an integrated economic system?

Some basic facts

Innovation is essentially a **clustered, urban phenomenon**

- the clustering of R&D labs in the US is greater than the clustering of manufacturing facilities (Buzard et al, 2017)
- the top 50 US metros account for 97 percent of all venture capital investment, a key driver of innovation (correlation with patents is 0.588, significant at the 1% level, between 2005 and 2009) (Florida and King, 2016)

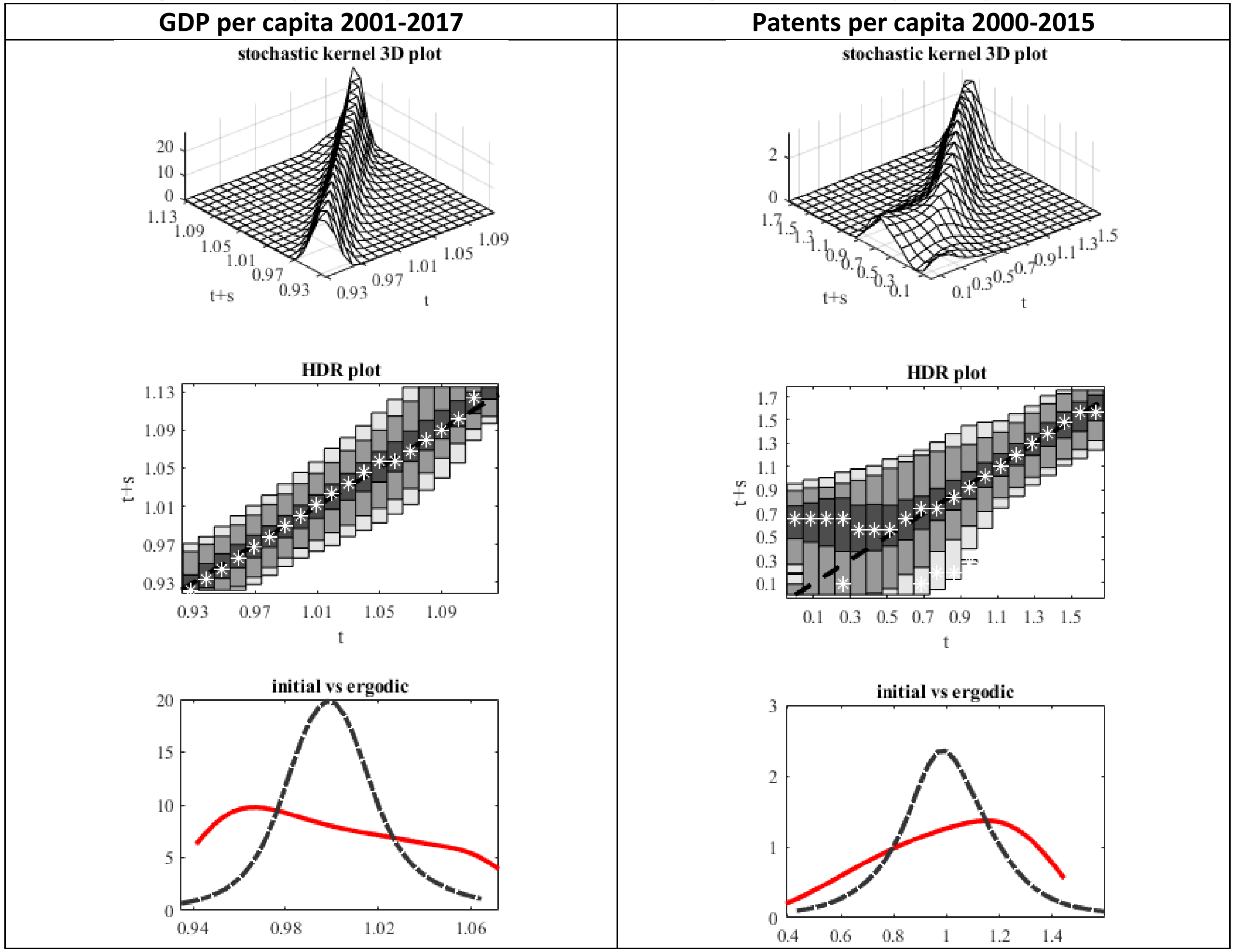




Some basic facts

Since the turn of the millennium, both per capita GDP and innovation across US metros have shown a tendency to diverge

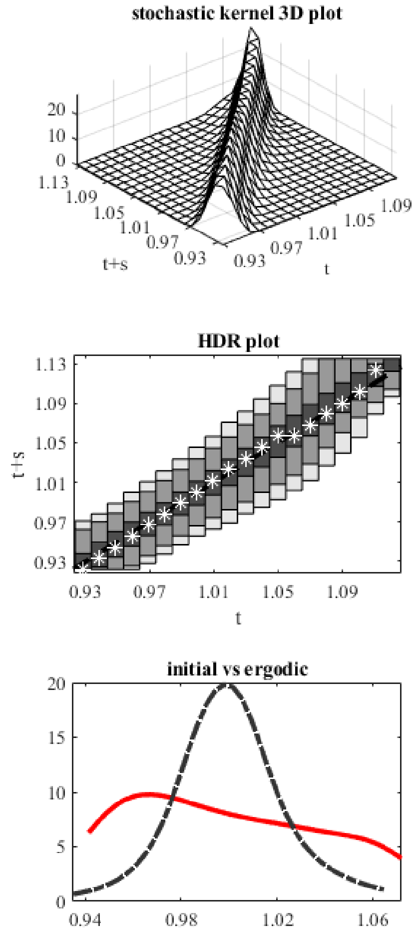
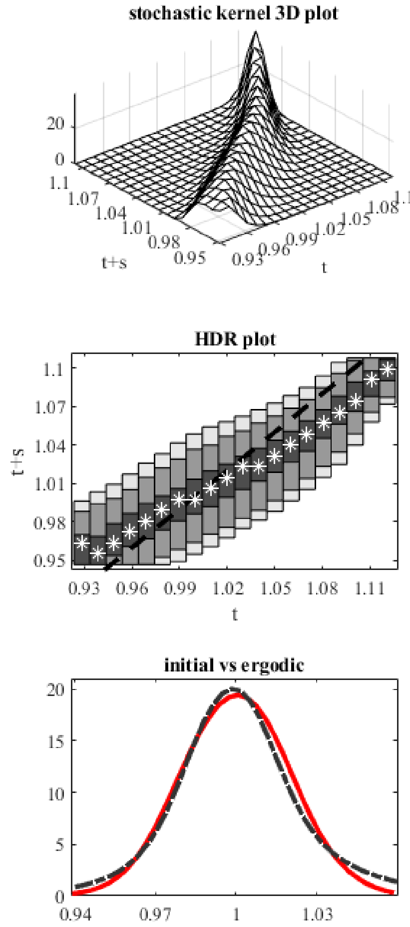
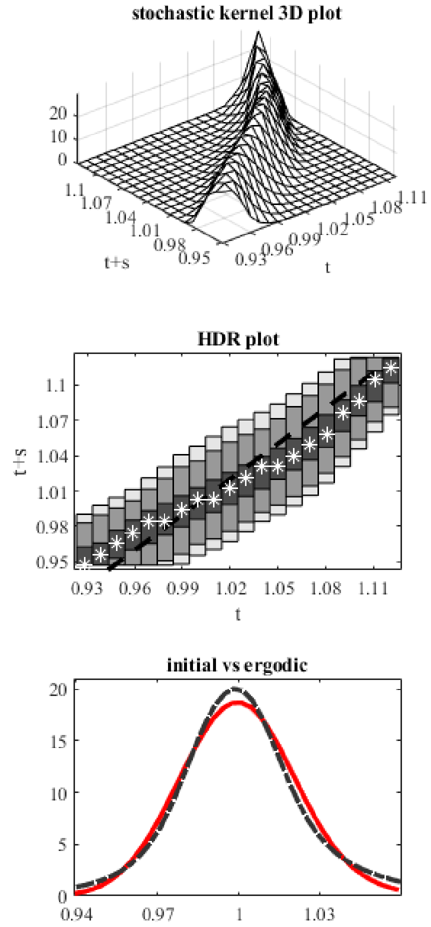
MSAs – log of GDP per capita (2001-2017) vs log of Patents per capita (2000-2015)



Some basic facts

Over the same period, the spatial features of divergence in per capita GDP mirror those of innovation

MSAs – GDP per capita (2001-2017)

obs 2001 – obs 2017	obs 2001 – cond (patents p.c., nn=5) 2017	obs 2001 – cond (patents p.c., nn=10) 2017
		

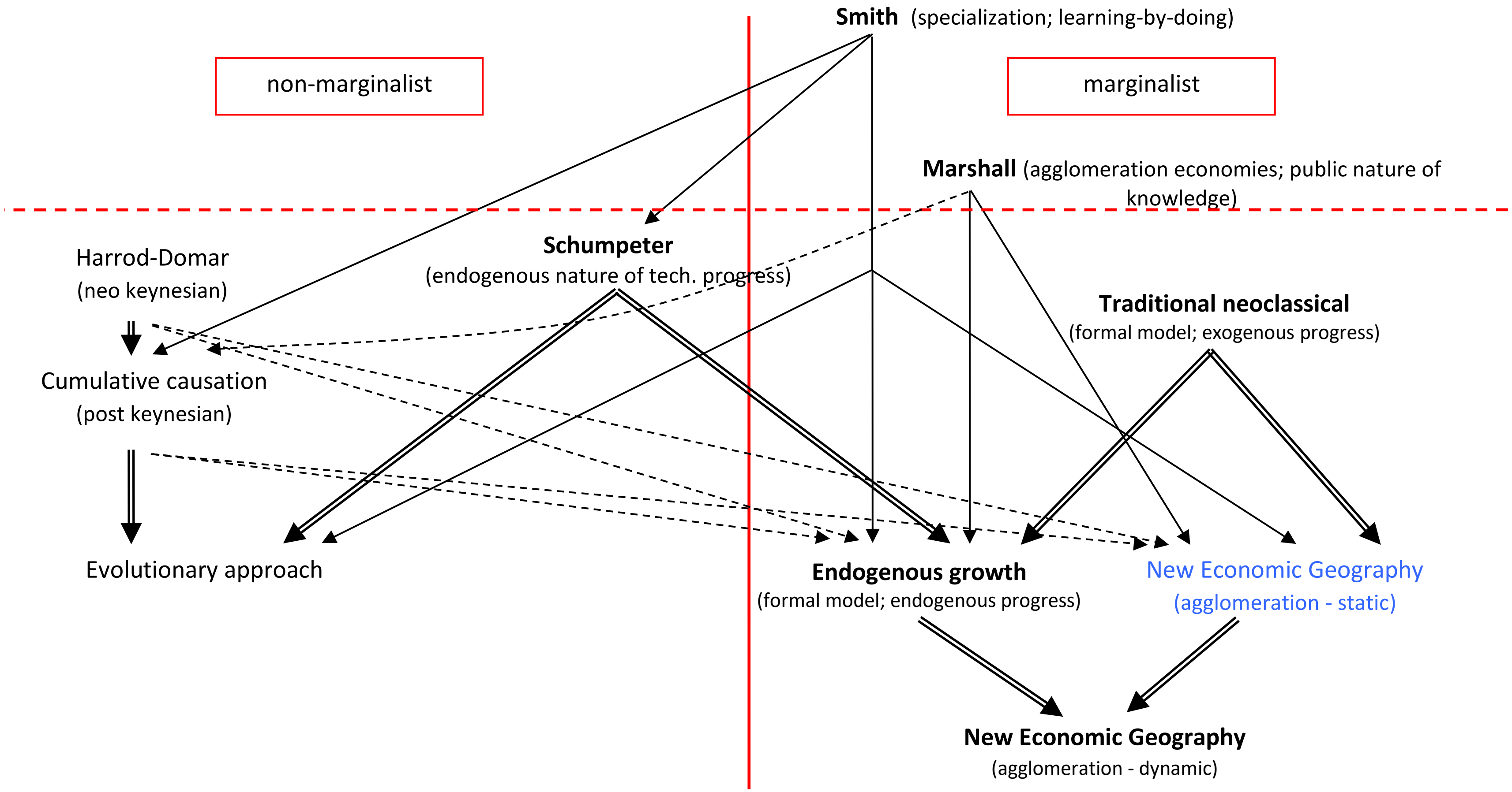
Summing up these basic facts

Since the turn of the millennium:

- near-instant communication services may have an impact on the transmission of tacit knowledge and, hence, on R&D activities
- R&D activities and innovation are geographically concentrated
- R&D and innovation are essentially urban activities
- there is a positive correlation between per capita GDP levels and innovations

$\Rightarrow$ we seek to develop a theoretical model of urban economic growth that conforms to these basic facts

Economic growth and technological progress: an overview



The traditional neoclassical model

Production function: $Y=F(K,AL)$

features: increasing
homogenous of degree 1
twice differentiable
jointly concave in all arguments
strictly concave in each argument
Inada conditions (1963): $\lim_{K\to 0} F'(K)=\infty \qquad \lim_{K\to\infty} F'(K)=0$

$$\lim_{L\to 0} F'(L)=\infty \qquad \lim_{L\to\infty} F'(L)=0$$

Technology: $A_t=A_0e^{\mu t}$ (μ = constant, exogenous rate of labour augmenting technological change)

Production per effective worker: $\tilde{y}=f(\tilde{k})$

where: $\tilde{y} \equiv Y/AL \quad \tilde{k} \equiv K/AL$

Fundamental dynamic equation: $\dot{\tilde{k}} = f(\tilde{k}) - \tilde{c} - (n + \mu + \delta)\tilde{k}$

where: $\tilde{c} \equiv C/AL$ $n = \dot{L}/L$ δ = capital depreciation rate

savings:

→ Solow, 1956; Swan, 1956: constant and exogenous propensity to save, *s*

$$\dot{\tilde{k}} = sf(\tilde{k}) - (n + \mu + \delta)\tilde{k}$$

→ Ramsey, 1928; Cass, 1965; Koopmans, 1965: intertemporal utility maximisation

$$U = \int_0^\infty u(c) e^{(n-\rho)t} dt \quad u(c) = \frac{c^{1-\sigma} - 1}{1-\sigma}$$ under an intertemporal budget constraint

$\Rightarrow$ F.O.C. $\frac{\dot{c}}{c} = \sigma^{-1}\left[f'(\tilde{k}) - \delta - \rho\right]$ + transversality conditions

where: σ (>0) = risk aversion coefficient, ρ (>0) = intertemporal discount rate

Steady-state equilibrium

- quantities in effective terms do not change: $\frac{\dot{\tilde{y}}}{\tilde{y}} = \frac{\dot{\tilde{c}}}{\tilde{c}} = \frac{\dot{\tilde{k}}}{\tilde{k}} = 0$
- per capita quantities grow at the rate of technological progress $\frac{\dot{y}}{y} = \frac{\dot{c}}{c} = \frac{\dot{k}}{k} = \mu$
- for any k_0 >0, optimal capital-consumption path converges asymptotically to balanced path (Cass, 1965)
- if transversality conditions are met, an economy that reaches the balanced growth path will remain on it

Endogenous growth theories

Provide a formal solution to the problem of how to treat formally of the relationship between:

- public aspect of technological knowledge
- endogenous nature of technological change

Economic goods can be characterised on the basis of two features:

- excludability $\rightarrow$ possibility to prevent people who haven't paid for a good from benefiting from it
- rivalry $\rightarrow$ the use of a good by one agent prevents its simultaneous use by others

Technological knowledge is non-rival and (partially) non-excludable $\Rightarrow$ a **public good** (Arrow, 1962)

Implications:

consider a production function: Y = F(**R**,**N**)

where **R** stands for all rival inputs (e.g. L and K) while **N** is the non-rival input (technological knowledge)

assume perfect competition $\Rightarrow$ F is homogenous of degree 1 in rival inputs

$\Rightarrow$ Y is used up in remunerating rival inputs

(Euler's Theorem: $F\left(L,K\right) = L\frac{\partial F}{\partial L} + K\frac{\partial F}{\partial K}$)

if technological knowledge increases $\Rightarrow$ F globally presents increasing returns to scale

$\Rightarrow$ but no output is left to remunerate technological knowledge

Endogenous growth theories

Possible solutions: technological knowledge is

- **non-rival**, **perfectly non-excludable** (pure public good) and **exogenous**
  → traditional neoclassical model
    - technological knowledge receives no remuneration
    - perfect competition
    - the competitive equilibrium is Pareto optimal
- **non-rival**, **perfectly non-excludable** (pure public good) and **endogenous** (side-effect of other activities ⇒ pure external effect)
  → AK models: Romer 1986; Lucas 1988
    - technological knowledge receives no remuneration
    - perfect competition
    - the competitive equilibrium is not Pareto optimal due to the external effects (perfect excludability)
- **non-rival**, **partially excludable** (partial public good) and **endogenous** (intentional creation)
  → Romer 1990a & b; Grossman and Helpman 1990, 1991; Aghion and Howitt 1992
    - technological knowledge receives remuneration (partial excludability)
    - monopolistic competition
    - the competitive equilibrium is not Pareto optimal due to the external effects (partial excludability)

The Romer (1990) model

research $\quad \dot{A}_t = \delta H_{At} A_t$

A: blueprints for intermediate inputs & technological knowledge

H_A: human capital employed in research

↓

intermediate inputs

production involves a fixed cost (patent) and a variable cost (forgone outpt)

↓

final good $\quad Y_t = H_{Yt}^{\alpha} L_t^{\beta} \int_A x(a)_t^{1-\alpha-\beta} d\,a$

additively separable function of all intermediate inputs

an increase in the number of intermediate inputs raises TFP

Research activity:

- increases technological knowledge (and raises productivity of H_A) $\rightarrow$ completely **non-excludable** effect
- increases the number of intermediate inputs $\rightarrow$ completely **excludable** effect (via patents) $\Rightarrow$ monopolistic competition

Steady state equilibrium

- capital accumulation framework: consumers maximise intertemporal utility
- allocation: consumers decide how to allocate human capital among research and manufacturing activities
- constant growth rate for y, k and c: $\quad g = \dfrac{\delta H - \tau\rho}{\tau\sigma + 1} \quad \Rightarrow$ **dynamic scale effect** through H

  where: τ (>0) = constant depending on α and β, σ (>0) = risk aversion coefficient, ρ (>0) = intertemporal discount rate

The Fujita-Thisse (2003) model

2 regions: A and B

3 sectors:	T (traditional)	homogenous consumption good
		produced under constant returns and perfect competition
		freely shipped across regions at no cost
	M (modern)	produces *M* varieties of a consumption good
		produced under monopolistic competition
		p(i) = mill price of variety *i*
		shipped across regions at a (positive) cost
	R (innovation)	develops patents
		produced under constant returns and perfect competition
		benefits from technological spillovers

2 factors:	L (unskilled):	employed in T and M
		each worker is endowed with one unit
		constant overall supply (L)
		evenly distributed and immobile across regions (L/2 in each region)
	H (skilled):	employed in R
		each worker is endowed with one unit
		constant overall supply
		mobile (with a positive cost)

The Fujita-Thisse (2003) model

The research sector

- productivity of researchers in one region increases with knowledge capital (K) available in the same region
- knowledge capital in one regions benefits from spillovers from the other region

$$K_{At} = \left(\frac{H_{At}}{H} + \eta \frac{H_{Bt}}{H} \right)^{1/\beta} M_t$$

where η ($0 \leq \eta \leq 1$) measures the intensity of knowledge spillovers between regions (measure of "globalness" of knowledge)

- the flow of new varieties (patents) is sum of the regional flows

$$\dot{M}_t = n_{At} + n_{Bt} = \frac{H_{At}}{H} \left(\frac{H_{At}}{H} + \eta \frac{H_{Bt}}{H} \right)^{1/\beta} M_t + \frac{H_{Bt}}{H} \left(\frac{H_{Bt}}{H} + \eta \frac{H_{At}}{H} \right)^{1/\beta} M_t$$

$\Rightarrow$ growth rate of new varieties (patents): $\dfrac{\dot{M}_t}{M_t} = g\left(\dfrac{H_{At}}{H} \right)$

symmetric around 1/2; *g(*0*)* = *g(*1*)* = 1

for $\eta < 1$: *g(•)* is highest when the R-sector is agglomerated in one region;
g(•) is lowest when the R-sector is fully dispersed
for given H_A/H, *g(•)* increases with η ("localness" of knowledge slows down innovation)

for $\eta = 1$: *g(•)* = 1 (when knowledge is global, the spatial distribution of the R-sector no longer matters)

The Fujita-Thisse (2003) model

Steady-state when migration is allowed → 3 equilibria:

1. $H_A/H = 1/2$ unstable   2. $H_A/H = 1$ stable   3. $H_A/H = 0$ stable

Concentrating on stable equilibria (e.g., $H_A/H = 1$)

i when transport cost is high

region A contains the entire R-sector ($H_A/H = 1$) and a larger share of the M-sector

ii when transport cost is low

region A contains both the R-sector and the M-sector entirely ($H_A/H = 1$; $M_A = M$)

Main implications

- starting from a dispersed equilibrium ($H_A/H=1/2$; $M_A=M_B=1/2$) any perturbation leads to a **core-periphery** structure
- if perturbation is such that $H_A/H >1/2$:
  - → all R-sector will agglomerate in region A
  - → most (or all, depending on transport costs) M-sector will agglomerate in A
  - → the growth rate of the economy increases as the R-sector agglomerates
  - → average real income in A increases relative to B

Main unappealing features

→ **high transport costs** and **immobility of unskilled workers** are needed to avoid extreme solutions (i.e., complete concentration of activities)

A model of urban growth in the age of Internet

Main features (Magrini, 1997)

- two urban regions at some distance one from the other
- three sectors (research, capital goods, final good)
  - final: produces a homogeneous consumption good employing unskilled labor, human capital, and physical capital
  - intermediate: physical capital is made up of a set of specialized intermediate inputs produced by profit maximizing entrepreneurs using forgone output and a patent
  - research: produces patents (and knowledge) using human capital and knowledge
- two forms of knowledge spillovers:
  - abstract knowledge: spills over freely to all researchers, in all regions
  - tacit knowledge: spills over as a result of interaction between individuals
- spillovers of tacit knowledge are hampered by distance

  → introduction and development of broadband technology and hi-speed connection reduces this friction

A model of urban growth in the age of Internet

The research sector

The flow of new knowledge (and patents) created in i is:

$$\dot{A}_i = \delta_i Hr_i Hr_i^{\phi} \left(Hr_j d_{ij}^{-1/\beta_{ij}} \right) A$$

where:

- H_{ri} is the level of human capital employed in the research sector of i
- δ_i is the level of technological competence of the research sector located in i
- A is the number of intermediate inputs existing in the system (overall level of abstract knowledge)
- ϕ reflects the size of intra-regional spillovers of tacit knowledge
- β_{ij} reflects the potential benefit to researchers in i from interaction with researcher in j

$$\beta_{ij} : \begin{cases} = 1 & \text{if } \delta_i > \delta_j \\ > 1 & \text{if } \delta_j > \delta_i \end{cases}$$

- d_{ij} is the distance between i and j

A model of urban growth in the age of Internet

The intermediate good sector

- fixed cost (patent)
  - $\Rightarrow$ monopolistic competition
  - $\Rightarrow$ in the long run, resources to finance the research effort equalize the present discounted value of future profits
- variable cost $\rightarrow$ one unit of intermediate input requires one unit of forgone output

The final good sector

- presence of external effects:
  - positive: an increase in the number of intermediate inputs increases TFP
  - negative: agglomeration manufacturing activities causes the emergence of congestion cost

$\rightarrow$ the size of these diseconomies depends also on the size of the regional research sector as concentration of research negatively affects local manufacturing firms through land rents

$\rightarrow$ managerial and research personnel are attracted by relatively expensive, sophisticated leisure and consumption amenities (Malecki, 1987).

$\rightarrow$ due to its effect on land markets, the concentration of research within one urban area poses a burden on the firms located there

$\rightarrow$ within the local research sector these diseconomies are more than offset by dynamic externalities deriving from localized spillovers of tacit knowledge

$$Q_i = L_i^{\alpha} Hq_i^{\eta} \left[\int_{A_i} x_i(a_i)^{\gamma} da + \int_{A_j} x_i(a_j)^{\gamma} da \right] Hr_i^{-\lambda L_i}$$

with $\alpha+\eta+\gamma = 1$ $\rightarrow$ perfect competition

A model of urban growth in the age of Internet

Individuals

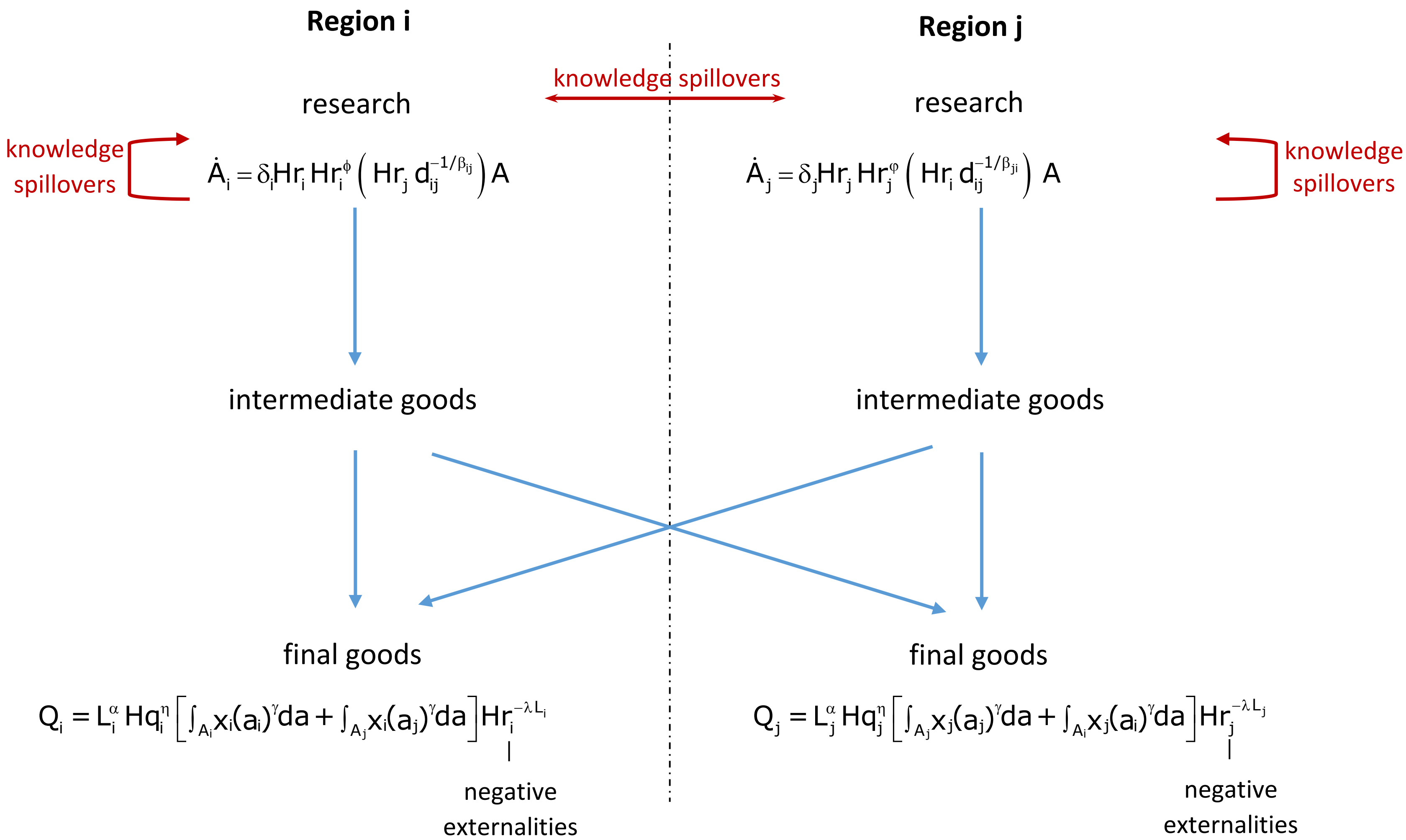
- fixed overall supply of human capital $H = H_{qi} + H_{qj} + H_{ri} + H_{rj}$
- fixed overall supply of unskilled labor $L = L_i + L_j$
- as workers, they move freely across regions and, in the case of human capital, across sectors and evaluate locations and sectors solely in terms of wage rates
- as consumers, they maximize intertemporal (CES) utility with savings devoted to the acquisition of physical capital

$$U[C] = \int_0^{\infty} e^{-\rho t} L_i^{\alpha} \frac{C^{1-\sigma}}{1-\sigma} dt$$

ρ is the intertemporal rate of discount and

σ^{-1} (with $0<\sigma<1$) is the willingness to substitute intertemporally

A model of urban growth in the age of Internet



A model of urban growth in the age of Internet

Steady state equilibrium

- constant (common) growth rate in per capita income
- the growth rate positively depends on overall stock of human capital $\Rightarrow$ **dynamic scale effect**
- **stable differences in per capita income levels** across urban regions
- differences are due to specialisation:
  - $\rightarrow$ the region in which productivity of researchers is higher ends up concentrating most research activities; the other region ends up specialising in manufacturing
  - $\rightarrow$ since research makes a more intensive use of human capital, specialisation leads to concentration of human capital
  - $\rightarrow$ since human capital receives a higher wage than raw labour, income per capita is higher in the region that specialises in research

Introduction and development of broadband technology and hi-speed connection

- takes the form of a reduction of the "cost of distance" for knowledge spillovers
- by strengthening spillovers across urban regions, reinforces the degree of specialisation
- **two effects**:
  - $\rightarrow$ internal and external allocation effects lead to a **higher (common) growth rate**
  - $\rightarrow$ external allocation effect leads to **stronger regional disparities**

A model of urban growth in the age of Internet

A rough attempt to get some tentative evidence…

Take the log of representation of the research sector:

$$\log(\text{new patents}_{it}) = \log(\text{knowledge}_t) + \log(Hr_{it})\alpha + W\log\left(Hr_{jt}\right)\beta + \varepsilon$$

Panel Fixed Effect estimation of an SLX model for MSAs (with largest flows of patents in 2005)

Time: 2005-2015

Dep. Variable: log of utility patents

	Top 100	Top 150
Log of unskilled workers (High School or less)	0.4850*** (0.1031)	0.0380*** (0.0798)
Log of skilled workers (Bachelor or more)	0.5904*** (0.1154)	0.5295*** (0.0860)
Spatial lag of log of skilled workers	0.1359*** (0.0208)	0.0963*** (0.0121)
γ	0.0421 (0.0258)*	0.0312 (0.0198)

Notes: W = distance^-γ

γ estimated non linearly as in Halleck Vega and Elhorst (2015)

Regressions include year dummies interacted with log of Personal Income per capita

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