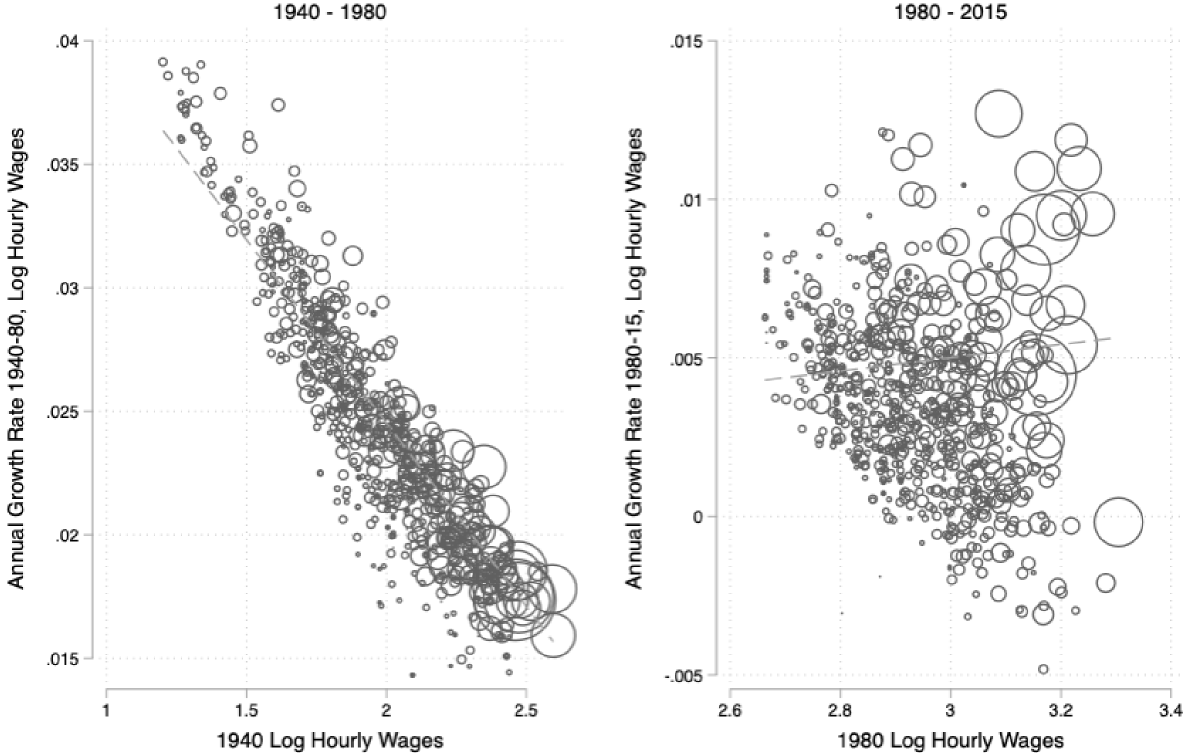
Disruptive Innovation and Interregional Inequality

A LONG-RUN VIEW

Tom Kemeny, QMUL
Sergio Petralia, LSE
Michael Storper, UCLA

Scene setting: 1980 as a watershed

Figure 1. Beta convergence and divergence across US Commuting Zones, 1940-2015

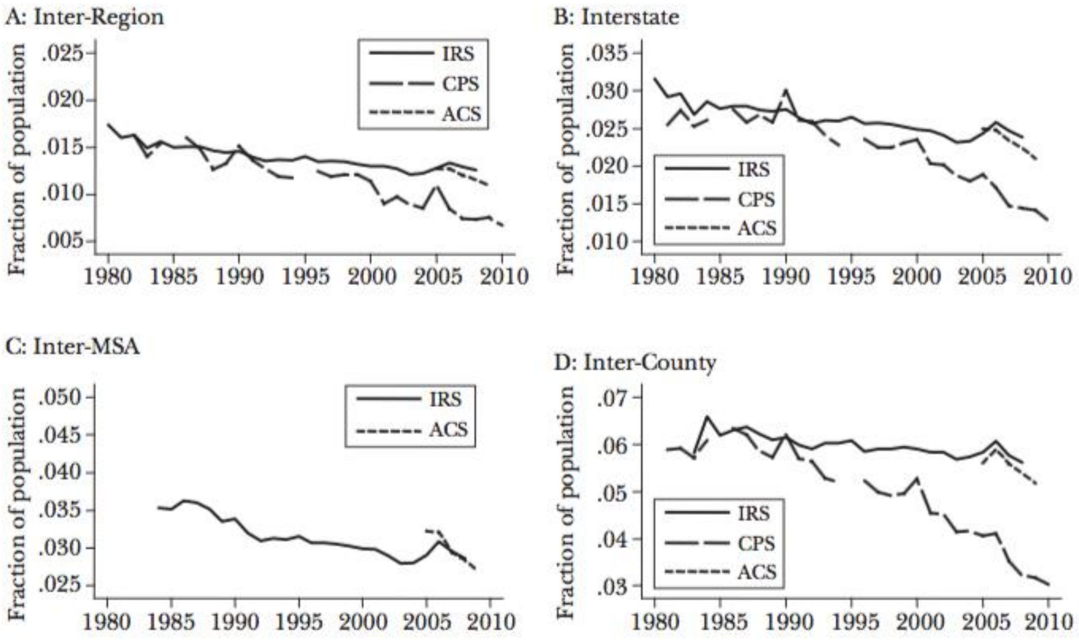


Note: Kemeny & Storper (2017) estimates using data public-use Decennial and ACS data

- Fact 1: divergence (β & σ)
- Various scales
  - CZs (our evidence)
  - States: Ganong & Shoag (2017)
  - MSAs: Giannone (2017)
- Not just incomes
  - Storper & Kemeny (2017): intra-regional inequality, task structure; returns to education etc.

Scene setting: 1980 as a watershed

Figure 2
Annual Internal Migration Rates

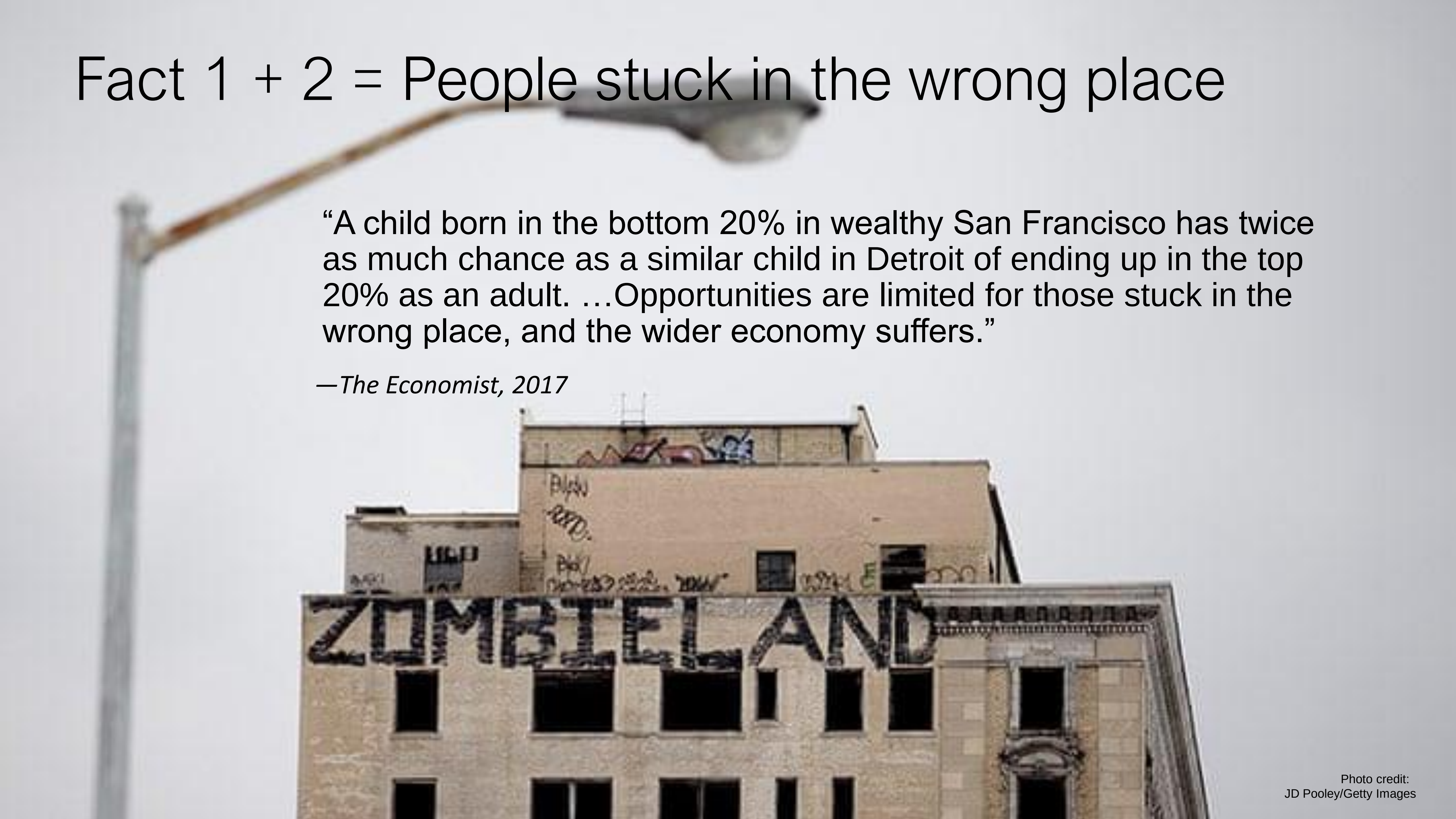


Source: Author's calculations based on Internal Revenue Service (IRS), Current Population Survey (CPS), and American Community Survey (ACS) data.
Notes: Current Population Survey and American Community Survey statistics are authors' calculations from microdata excluding residents of group quarters and imputed values of migration. IRS statistics are authors' calculations based on state-level and county-level flows. "MSA" is Metropolitan Statistical Area.

From: Molloy et al (2011 JEP) Internal Migration in the United States

- Fact 2: declining internal migration
- Not just compositional
  - Across age, education, dual vs single earners etc (Molloy et al, 2011)
- It is about structural forces

Fact 1 + 2 = People stuck in the wrong place



"A child born in the bottom 20% in wealthy San Francisco has twice as much chance as a similar child in Detroit of ending up in the top 20% as an adult. …Opportunities are limited for those stuck in the wrong place, and the wider economy suffers."

—*The Economist, 2017*

Photo credit:
JD Pooley/Getty Images

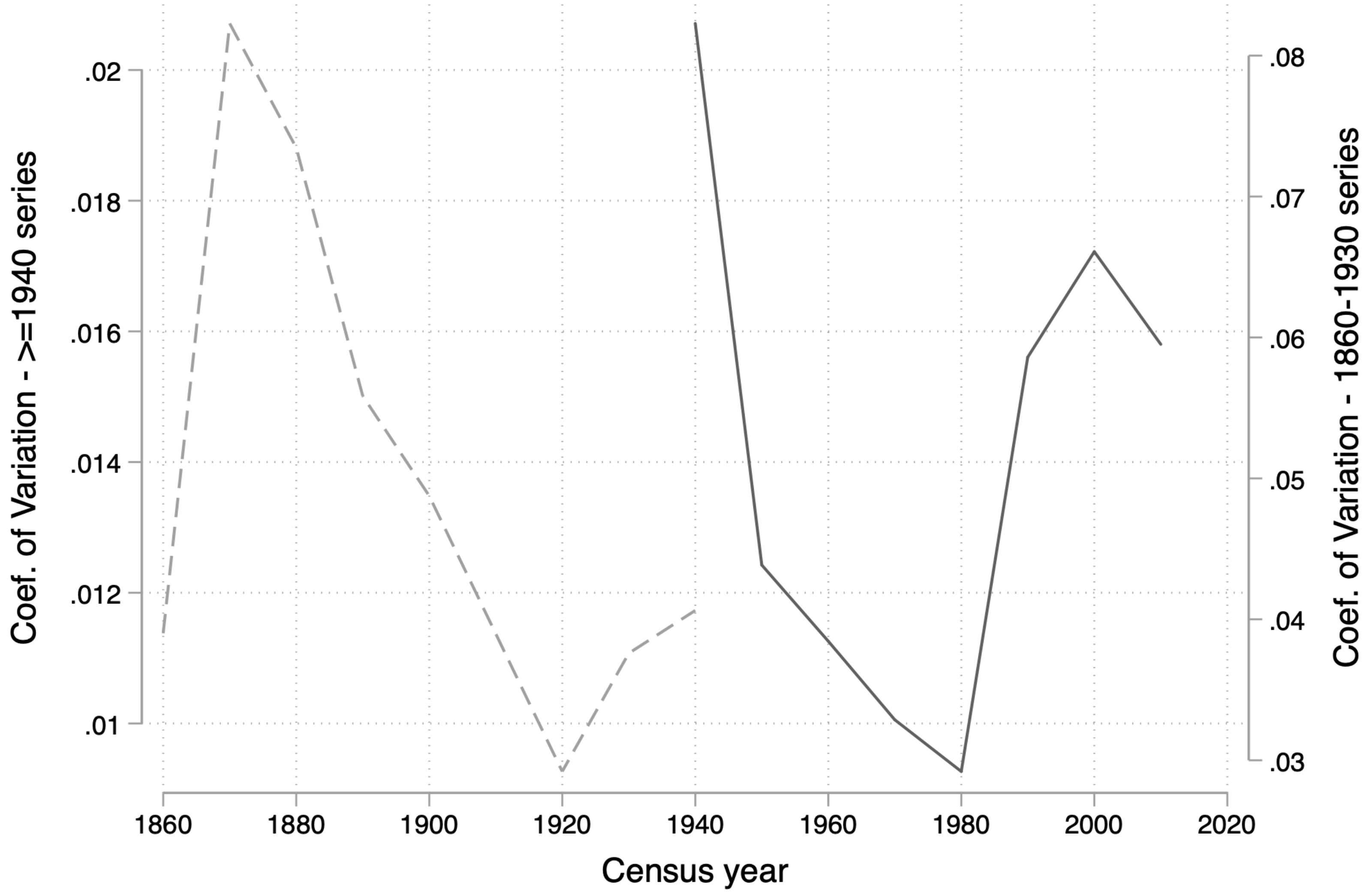
Causes remain poorly understood

- What forces are generating these patterns?
  - Lots of debate throughout society
  - Growing wave of academic work
- Little clarity or consensus
- Stakes are high:
  - If we cannot understand and respond to the causes, “populist insurgents will” (Economist, 2016)

We need new theories

- Convergence-oriented theories
  - Development economics: Barro & Sala-i-Martin, Mankiw, Galor
  - Urban economics: Roback, Rosen, Glaeser
- Divergence-oriented theories
  - ‘New’ economic geography: Krugman/Venables/Fujita
  - Schumpeterian knowledge-based creative destruction
- Important pieces, but none explain alternations

A hint from history: Alternating phases



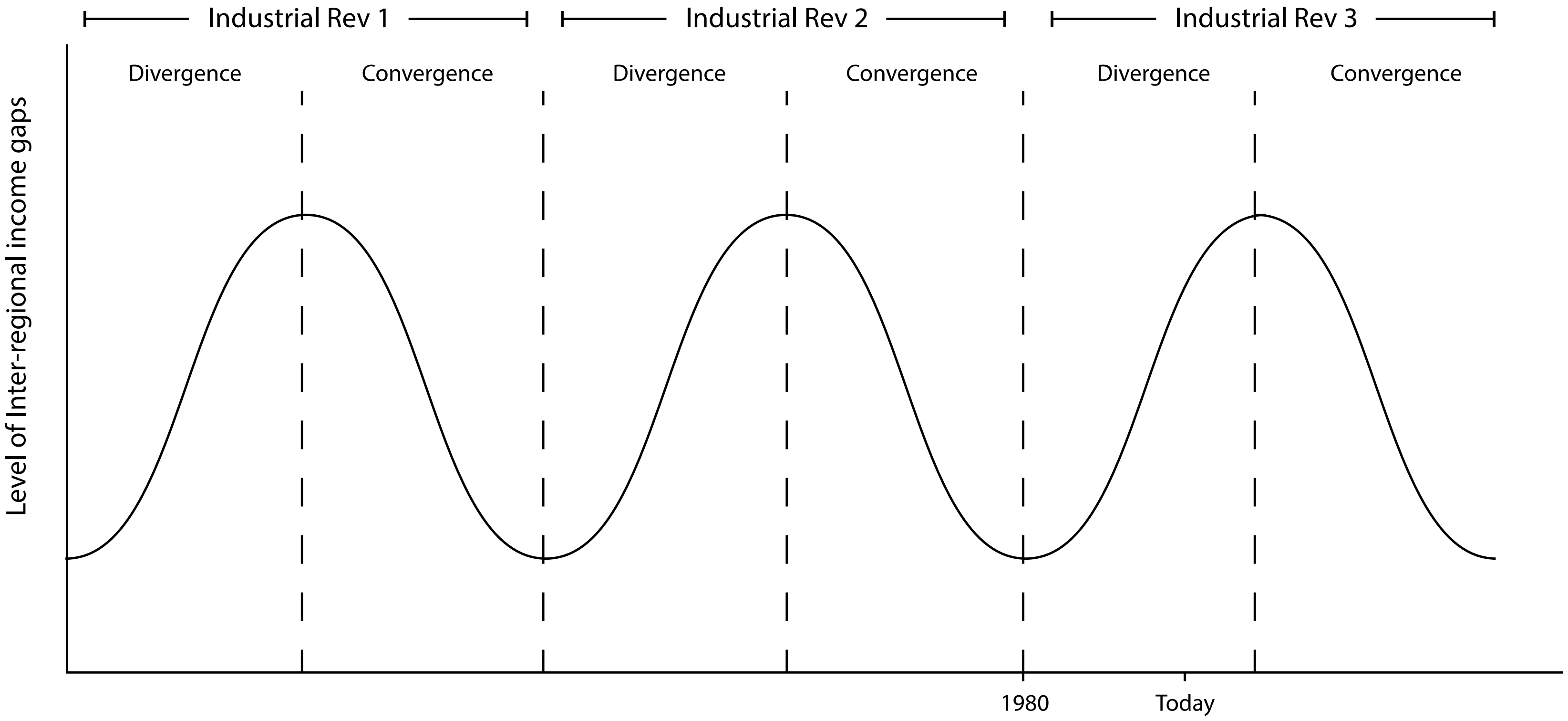
Trends in interregional wage gaps, 1860-2015

Source: Authors’ calculations based Decennial Censuses and the Census of Manufactures

Series 1. Log county annual manufacturing wages

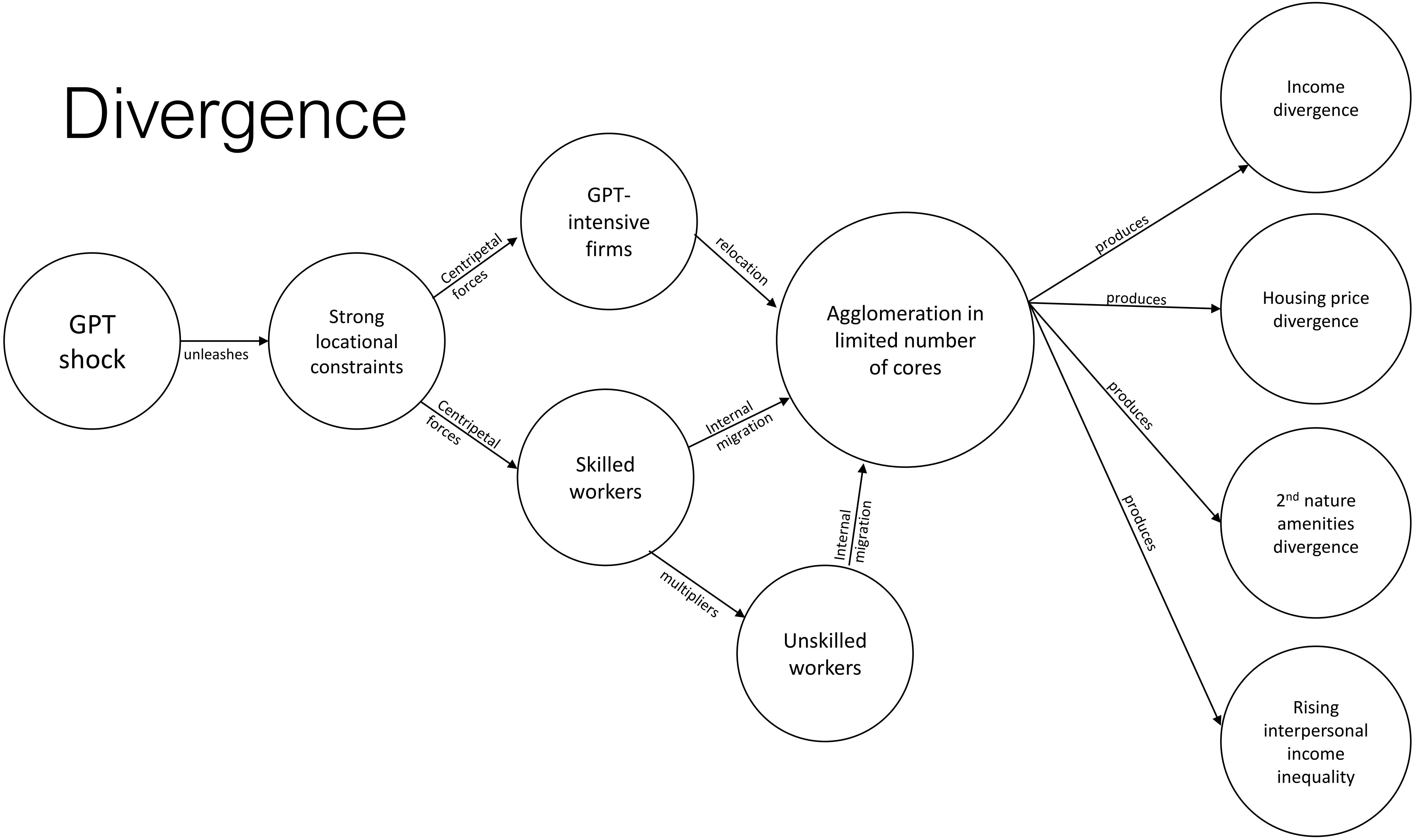
Series 2: Log CZ annual wages

A long-run theory of technology-driven development in space

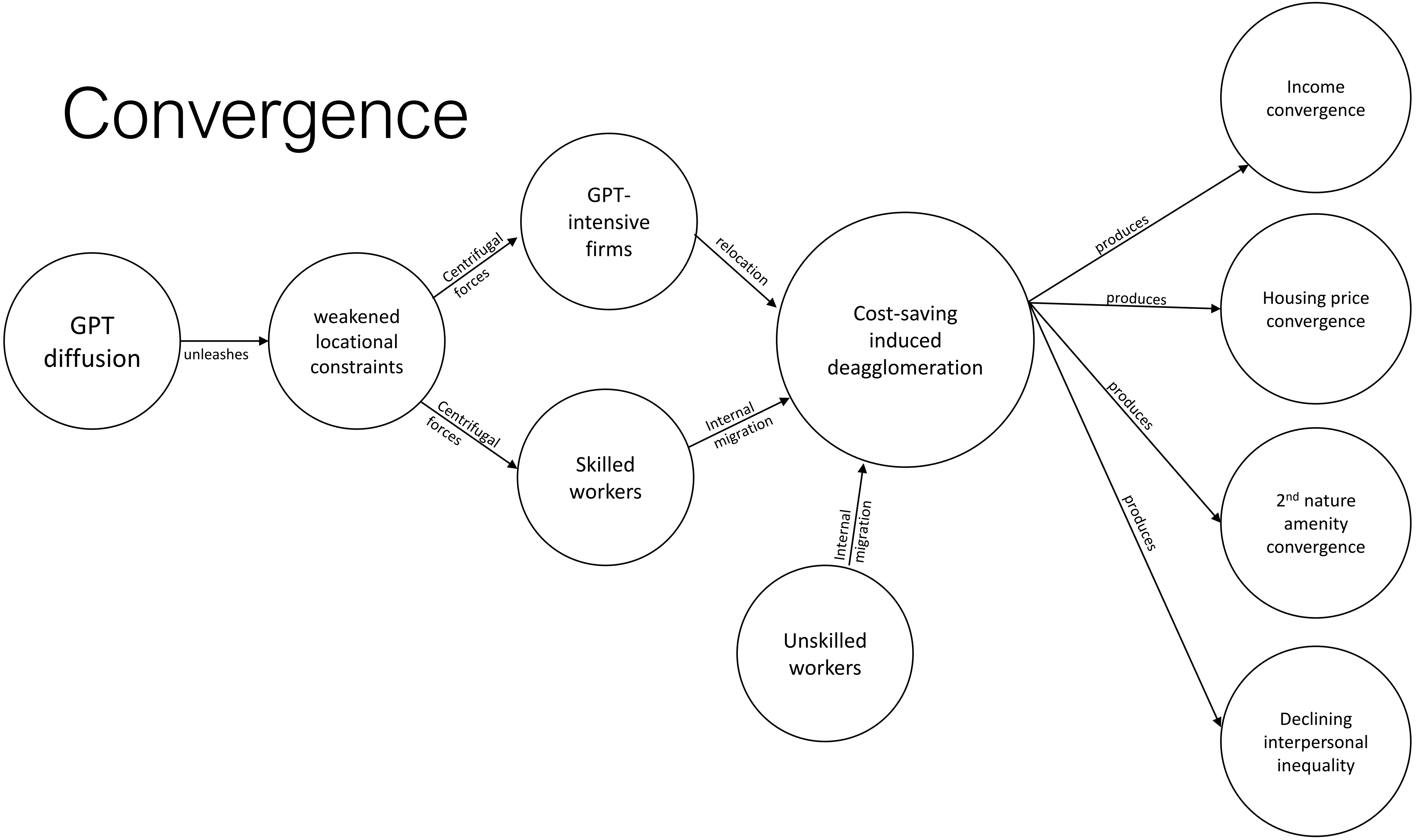


- Structural
  - Technology shocks and locational forces of attraction
  - Not just any technological change, but major, episodic shocks → <u>GPTs</u>

Divergence


GPT shock
unleashes
Strong locational constraints
Centripetal forces
GPT-intensive firms
Centripetal forces
Skilled workers
relocation
Internal migration
multipliers
Unskilled workers
Internal migration
Agglomeration in limited number of cores
produces
produces
produces
produces
Income divergence
Housing price divergence
2nd nature amenities divergence
Rising interpersonal income inequality

Convergence



Empirics

- Lots to test here – we are in the very early stages
- H1: GPTs regulates wage levels and its interregional dispersion
  - GPT-intensive locations should grow faster – at least in divergence periods
  - GPT-intensity should matter less (not at all?) in convergence phases
- Challenge: How do we measure GPTs?
  - Part of a long and broad discussion about valuing innovations
    - ie Schankerman & Pakes, 1986; Hegde & Sampat, 2009
  - Patents as a common unit of measure
  - We offer a new definition, leveraging long-run patent data
    - 1836-2010 (Petralia, Balland and Rigby, 2016)
    - 436 classes in 6 NBER categories

What's a GPT? 3 major features

1. Wide scope for improvement and elaboration.
   - change more than a typical technology
2. Innovation complementarity
   - get implicated in other kinds of innovations
3. Use complementarity
   - get used in a wide range of different production contexts

Novel method

1. *Improvement and elaboration.*
   - Patent class growth
2. *Innovation complementarity*
   - Count # of classes with which each class co-occurs (ignoring same category)…ie here classes 360(CC) and 386 (EE)
3. *Use complementarity*
   - Machine learning applied to patent texts, using keywords (L=2) found in class definitions from USPTO manual

- **GPTs are classes that are above average in ALL THREE**

United States Patent Office

2,956,114

Patented Oct. 11, 1960

1

2,956,114

BROAD BAND MAGNETIC TAPE SYSTEM AND METHOD

Charles P. Ginsburg, Los Altos, Shelby F. Henderson, Jr., Woodside, Ray M. Dolby, Cupertino, and Charles E. Anderson, Belmont, Calif., assignors to Ampex Corporation, Redwood City, Calif., a corporation of California

Filed July 25, 1955, Ser. No. 524,004

8 Claims. (Cl. 178—6.6)

This invention relates generally to electromagnetic tape systems, methods and apparatus, particularly to systems and methods of this character capable of recording and reproducing signal intelligence over a wide frequency spectrum, including for example, video frequencies.

Various problems are involved when it is attempted to record and reproduce frequencies over a wide spectrum, as for example frequencies ranging higher than one megacycle, on magnetic tape. Assuming the use of reasonable tape speeds, conventional equipment is limited with respect to its usable frequency range. The recordable range can be increased by increasing the speed of the tape, but the speeds required for the recording of such high frequencies are such that the system becomes impractical because of the large amount of tape employed for a given recording period. It is possible to reduce the linear tape speed by recording successive tracks extending laterally across the tape. Equipment with this purpose involves the use of magnetic record units which are mounted to sweep successively across the coated surface of the tape while the tape is being advanced in the direction of its length. While this arrangement makes it theoretically possible to provide relative speeds such that frequencies up to four megacycles or higher can be recorded, its application necessarily involves a number of problems. For example the outputs of the several heads are subject to amplitude variations, due to various causes such as lack of exact registration on the recorded track, amplitude variations in the record because of slight variations in pressure between the several heads, and slight variations in the electrical characteristics of the heads. The conventional magnetic tape recording system, using currents varying in amplitude for application to the recording head, is particularly susceptible to undesired amplitude variations. The undesired signal variations cause distortion of the reproduced signal, and make it difficult if not impossible to reproduce the original frequency spectrum with reasonable fidelity, and particularly with sufficient fidelity to permit the recording and reproduction of television or like visual images.

2

as previously explained is generally determined by the relative speed between the heads and the tape and the characteristics of the head. When the carrier frequency is so selected the recording system depends upon single sideband or vestigial sideband transmission. In other words the upper band of frequencies containing the frequency modulation components is not recorded or reproduced to any substantial extent. We have found that such a magnetic record can be reproduced to provide, after demodulation, the original modulating frequencies with a good degree of fidelity.

In addition to the foregoing, a practical system for the recording and reproduction of frequencies over a wide spectrum requires highly accurate speed control means for both recording and reproduction.

It is an object of the present invention to provide a system and method for the recording and reproduction of a wide frequency band, which will be relatively immune to spurious variations in signal strength.

Another object of the invention is to provide a system and method of the above character which, when used for the recording and reproduction of video frequencies, makes possible the reproduction of visual images with good fidelity.

Another object of the invention is to provide a system and method of making use of narrow band frequency modulation for recording over a wide frequency band.

Another object of the invention is to provide improved means for controlling the speed of operation of various parts during recording and reproduction.

Another object of the invention is to provide a system and apparatus for the recording of frequency components over a wide spectrum, such as video frequencies, which utilizes a plurality of record heads sweeping laterally across a magnetic tape, but without causing troublesome distortion or disturbances of the reproduced signal due to amplitude variations.

Additional objects and features of the invention will appear from the following description in detail in conjunction with the accompanying drawings.

Referring to the drawings:

Figure 1 is a circuit diagram illustrating a complete recording and reproducing system incorporating the present invention.

Figure 2 is a circuit diagram illustrating a modification of Figure 1.

Figure 3 is a plan view schematically illustrating mechanism for mounting the magnetic heads and for transporting the tape.

Figure 4 is a cross sectional view taken along the line 4—4 of Figure 3.

Figure 5 is a cross sectional detail taken along the line 5—5 of Figure 3.

Figure 6 is an enlarged cross sectional detail illustrating the guide means for the tape and the manner in

Linking to data on labor markets

- Public-use Decennial + ACS extracts
  - 1940, 1950, 1960, 1970, 1980, 1990, 2000, 2010
- Probabilistically match workers to 722 1990-vintage Commuting Zones (CZs)
- Match patents to CZs
- No known work examines long-run development patterns using CZs
  1. Mostly urban pop today; NOT true of the past
  2. Need all U.S. to talk about ‘left-behind’ places
  3. Incompletely identified metros, post-1970

A simple specification

$$y_{ct} = GPT_{ct} + NonGPTct + Pop + \varepsilon_{ct}$$

- where
  - *y* → log of wages for full-time employed workers in CZ *c* and time *t*
  - *GPT* → share of GPT patent stock in total patent stock
  - NonGPT→ log of total patenting stock less GPT patents
  - Pop → log of population
  - Varepsilon → usual error term
    - decomposed to include year- and location-specific effects

Preliminary results

Table 1: Regression Estimates of the Relationship between Shares of GPT Patenting Stocks and Wage Levels, Commuting Zones, 1940-2010

	Hourly Wages (log)		Annual Wages (log)	
	(1)	(2)	(3)	(4)
GPT Patents (Share)				
Raw	0.405***		0.452***	
	(0.000)		(0.000)	
20y Depreciation Rate		0.075**		0.073**
		(0.003)		(0.003)
Non-GPT Patent Count (log)	0.026***	0.060***	0.026***	0.063***
	(0.001)	(0.000)	(0.000)	(0.000)
Population (log)	-0.007	-0.013	-0.010	-0.015*
	(0.382)	(0.112)	(0.156)	(0.049)
Observations	4543	3950	4543	3950
R^2	0.940	0.944	0.955	0.959

p-values in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Year and Commuting Zone fixed effects in all models.

Preliminary results

Table 3: Period-specific Regression Estimates of the Relationship between Shares of GPT Patenting Stocks and Hourly Wage Levels, Commuting Zones 1940-2010

	Convergence 1940-70 (1)	Divergence 1980-2010 (2)	Convergence 1940-70 (3)	Divergence 1980-2010 (4)
GPT shares	-0.019	0.186***		
	(0.903)	(0.000)		
GPT shares, 20-year Depreciation			-0.097*	0.094***
			(0.047)	(0.000)
Non-GPT Patent Count (log)	-0.016	0.017	-0.002	0.038***
	(0.479)	(0.102)	(0.943)	(0.000)
Population (log)	-0.014	0.102***	-0.036*	0.109***
	(0.357)	(0.000)	(0.031)	(0.000)
Observations	2065	2478	1751	2199
R^2	0.950	0.747	0.954	0.760

p-values in parentheses. * $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

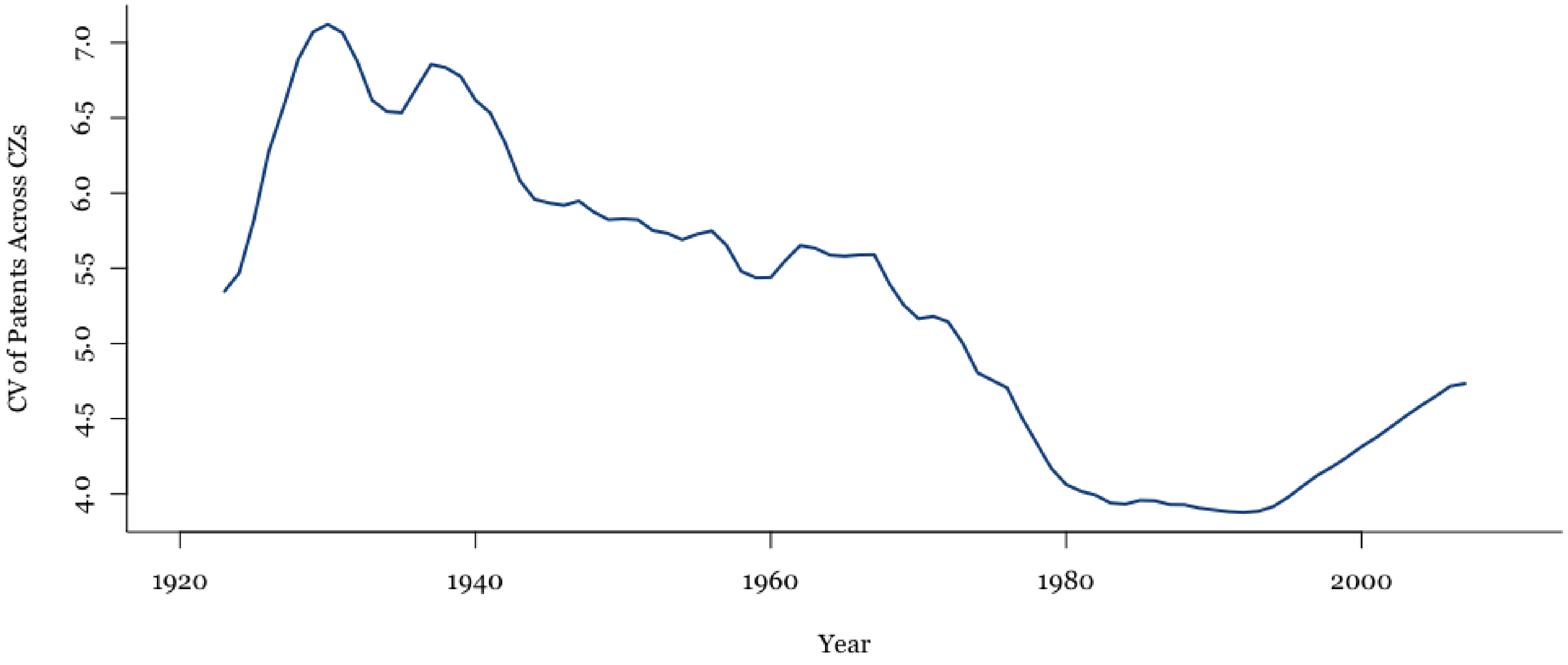
Dependent variable is log of hourly wages. Year and Commuting Zone fixed effects in all models.

Discussion

- Contributions
  - New evidence on long run patterns of interregional inequality
  - A technology-driven theory to explain these patterns
  - Novel measures of GPTs and patent quality
  - Preliminary evidence on the theory with GPT measures
- Findings
  - GPT innovations drive wages in divergence phase
  - Largely unimportant when convergence process dominates*
    - **GPT-ness defined relative to annual avgs so perhaps GPT-ness overstated in this phase?*
- Stay tuned for (much) more

thanks!

GPT patenting patterns



More on defining GPTs

- Steps to identify use-complementarity
  1. Create a vocabulary of class-specific technical words
     - USPTO patent manual contains descriptions of patent classes and subclasses
     - Identify sets of two consecutive words specific to class
  2. Count appearances of these words outside of the class to which it pertains can be considered to be users

More on defining GPTs

Table I: Correlation Table

	IC	UC	Growth
IC	1	0.251	0.180
UC	0.251	1	0.217
Growth	0.180	0.217	1

Figure I: Distribution (Top 10)

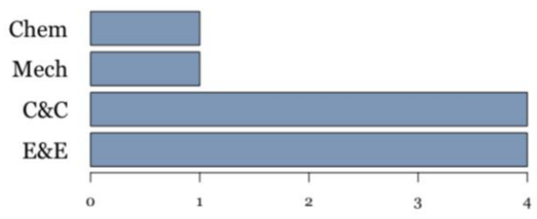
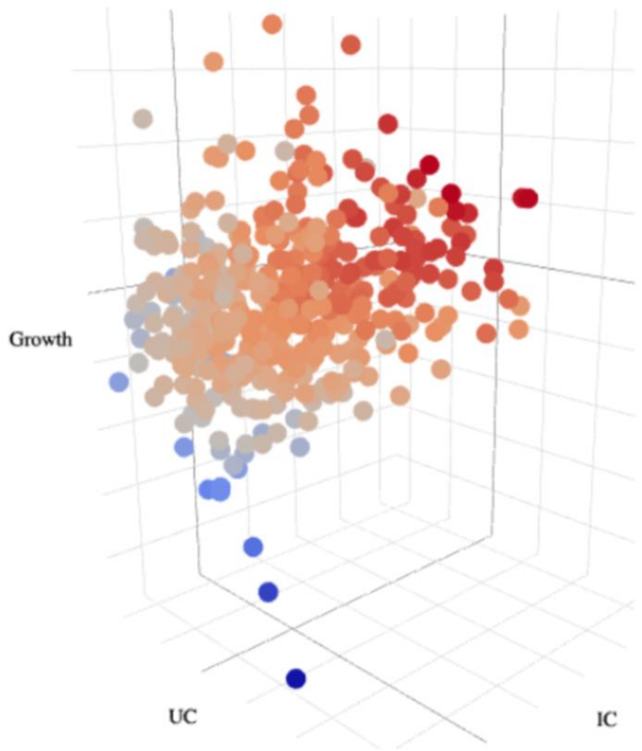


Figure II: Technological Frontier (2005-2010)



Note: Growth, UC, and IC values were averaged over the period 2005-2010. In Figure II warmer colors (red) represent higher values and thus proximity to the technological frontier. Table I shows the correlation between these measures.

Top GPTs, 2010

	USPC	Year	Class	NBER	Growth	IC	UC
1	348	2010	Television	Electrical and Electronic	1.65	1.63	1.47
2	429	2010	Chemistry: electrical current producing apparatus,	Electrical and Electronic	1.09	1.25	2.78
3	340	2010	Communications: electrical	Computers and Communications	0.75	3.44	1.31
4	701	2010	Data processing: vehicles, navigation, and relativ	Computers and Communications	1	2	1.63
5	455	2010	Telecommunications	Computers and Communications	1.33	1.55	1.45
6	382	2010	Image analysis	Computers and Communications	1.5	1.48	1.04
7	705	2010	Data processing: financial, business practice, man	Computers and Communications	3.94	1.28	0.45
8	55	2010	Gas separation	Chemical	1.48	0.66	2.04
9	362	2010	Illumination	Electrical and Electronic	0.73	1.84	1.29
10	703	2010	Data processing: structural design, modeling, simu	Computers and Communications	1.54	1.11	0.95
11	320	2010	Electricity: battery or capacitor charging or disc	Electrical and Electronic	2.14	0.21	3.55
12	257	2010	Active solid-state devices (e.g., transistors, sol	Electrical and Electronic	0.56	2.27	1.03
13	349	2010	Liquid crystal cells, elements and systems	Chemical	1.2	0.55	1.94
14	396	2010	Photography	Mechanical	1.57	0.41	1.92
15	96	2010	Gas separation: apparatus	Chemical	0.94	0.81	1.61
16	600	2010	Surgery	Drugs and Medical	0.46	1.77	1.37
17	250	2010	Radiant energy	Electrical and Electronic	0.23	2.61	1.84
18	361	2010	Electricity: electrical systems and devices	Electrical and Electronic	0.64	2.88	0.56
19	435	2010	Chemistry: molecular biology and microbiology	Drugs and Medical	0.23	1.78	2
20	427	2010	Coating processes	Chemical	0.5	2.56	0.62
21	370	2010	Multiplex communications	Computers and Communications	1.94	0.39	1.01
22	436	2010	Chemistry: analytical and immunological testing	Chemical	0.88	1.37	0.61
23	381	2010	Electrical audio signal processing systems and dev	Electrical and Electronic	1.3	0.62	0.88
24	358	2010	Facsimile and static presentation processing	Computers and Communications	1.35	0.46	1.11
25	399	2010	Electrophotography	Mechanical	1.06	0.79	0.78
26	252	2010	Compositions	Chemical	0.59	1.78	0.6
27	345	2010	Computer graphics processing and selective visual	Computers and Communications	0.78	1.68	0.42
28	95	2010	Gas separation: processes	Chemical	0.66	0.78	1.06
29	374	2010	Thermal measuring and testing	Electrical and Electronic	0.92	0.41	1.35

More on defining GPTs

Rank	Category	Class	Growth	IC	UC
1	E&E	Television	0.4	147.3	163.2
2	C&C	Telecommunications	0.6	128.8	162.5
3	E&E	Radiant energy	0.4	191.7	182.5
4	E&E	Illumination	0.3	155.3	160.3
5	C&C	Communications: electrical	0.3	229.5	155.3
6	C&C	Image analysis	0.5	136.8	148.2
7	E&E	Active solid-state devices	0.2	188	146.2
.	.	.	.	.	.
413	Mechanical	Advancing material of indeterminate length	-1	33.2	59.3
414	Others	Heating systems	-1.1	21.8	103.5
415	Others	Industrial electric heating furnaces	-1.1	18	107.5
416	Electrical and Electronic	Recorders	-1.1	23.2	91.3
417	Chemical	Explosive and thermic compositions	-1.3	13.2	137.3
418	Chemical	Combinatorial chemistry technology	-1.6	27	133.5
419	E&E	Scanning-probe techniques or apparatus	-1.9	18.3	161.3

Top GPTs, 1940

	USPC	Year	Class	NBER	Growth	IC	UC
1	200	1940	Electricity: circuit makers and breakers	Electrical and Electronic	0.83	2.73	3.29
2	74	1940	Machine element or mechanism	Mechanical	0.41	3.45	1.51
3	236	1940	Automatic temperature and humidity regulation	Others	0.65	1.72	1.73
4	335	1940	Electricity: magnetically operated switches, magne	Electrical and Electronic	0.9	0.4	3.21
5	315	1940	Electric lamp and discharge devices: systems	Electrical and Electronic	0.37	1.22	2.09
6	62	1940	Refrigeration	Others	0.17	1.93	2.37
7	313	1940	Electric lamp and discharge devices	Electrical and Electronic	0.16	1.58	2.54
8	318	1940	Electricity: motive power systems	Electrical and Electronic	0.33	1.79	0.8
9	336	1940	Inductor devices	Electrical and Electronic	0.69	0.37	1.49
10	292	1940	Closure fasteners	Others	0.31	0.83	1.48
11	15	1940	Brushing, scrubbing, and general cleaning	Others	0.13	2.69	1.05
12	417	1940	Pumps	Mechanical	0.19	0.96	1.65
13	219	1940	Electric heating	Electrical and Electronic	0.08	2.55	1.3
14	43	1940	Fishing, trapping, and vermin destroying	Others	0.85	0.58	0.43
15	312	1940	Supports: cabinet structure	Others	0.13	1.19	1.34
16	242	1940	Winding, tensioning, or guiding	Mechanical	0.15	1.24	0.99
17	91	1940	Motors: expansible chamber type	Mechanical	0.42	0.64	0.56
18	116	1940	Signals and indicators	Others	0.11	1.55	0.79
19	30	1940	Cutlery	Others	0.23	0.84	0.7
20	166	1940	Wells	Others	1.58	0.1	0.65
21	8	1940	Bleaching and dyeing; fluid treatment and chemical	Chemical	0.14	1.1	0.59
22	362	1940	Illumination	Electrical and Electronic	0.03	1.51	2
23	148	1940	Metal treatment	Mechanical	0.39	0.46	0.43
24	474	1940	Endless belt power transmission systems or compone	Mechanical	0.97	0.07	0.5
25	426	1940	Food or edible material: processes, compositions,	Others	0.15	0.8	0.28
26	359	1940	Optical: systems and elements	Mechanical	0.35	0.88	0.09
27	131	1940	Tobacco	Others	0.47	0.13	0.38