

On Price Dispersion, Search Externalities, and the Digital Divide

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Siena - May 27th 2009



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Outline

- ⑥ Literature on price dispersion
 - △ Search externalities
 - △ The *digital divide*
- ⑥ The model
 - △ n firms competing on prices
 - △ consumers are heterogeneous in searching possibilities
 - △ they buy one good at lowest price
- ⑥ Price dispersion is a characteristic of equilibrium
- ⑥ Comparative statics
 - △ more search from partially informed consumers may have negative externalities on low-informed ones

Price dispersion

Stigler (1961) “The Economics of Information”:

- ⑥ firms exogenously price randomly
- ⑥ optimal strategy for buyers is to sample only some firms
- ⑥ comparative statics changing the pricing random distribution

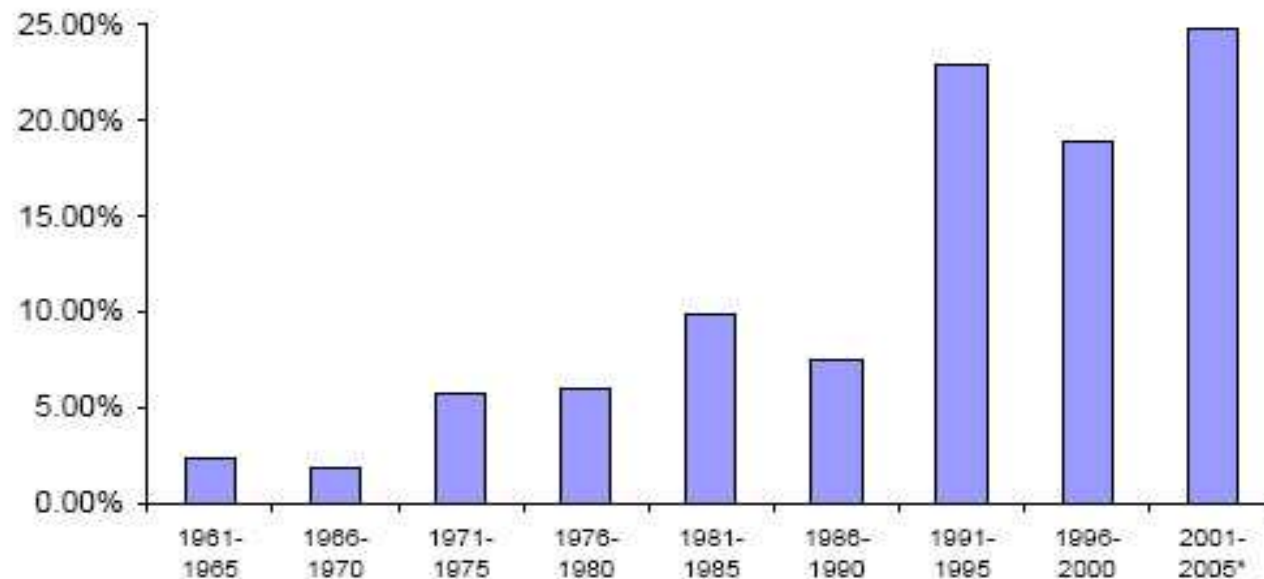
Wilde & Schwartz (1979) and Varian (1980) (WSV):

- ⑥ buyers are either uninformed or fully informed
- ⑥ firms compete on prices
- ⑥ there are no equilibria in pure strategies
- ⑥ there is a symmetric equilibrium in mixed strategies

A growing literature

Baye & alii (2006): $\simeq 120$ papers building on Stigler (1961)

Figure 1: Percentage of Articles Published in the *American Economic Review*, *Journal of Political Economy*, and *Econometrica* on Information, Search or Price Dispersion



Source: *Social Science Citation Index*, Keyword search for "Information OR Price Dispersion OR Search," and Authors' Calculations.

*2005 data through third quarter.

Empirical literature on price dispersion(1/3)

Table 1a: Measures of Price Dispersion Reported in the Literature in Offline Markets¹

Study	Data Period	Product Market	Intervals of Estimated Price Dispersion Measures	Dispersion Measure
Bailey (1998)	1997	Books	13.2%	Standard Deviation
		Books	10.4%	Standard Deviation
		Compact Discs	17.6%	Standard Deviation
		Compact Discs	11.0%	Standard Deviation
		Software	7.1%	Standard Deviation
Borenstein and Rose (1994)	1986	U.S. Airline	0.018 - 0.416	Gini coefficient
Carlson and Pescatrice (1980)	1976	Consumer Sundries	3.3% - 41.4%	Coefficient of Variation
Eckard (2004)	1901 - 2001	Baking Powder, Sugar, Salt -- 1901	3.1% - 10.1%	Coefficient of Variation
		Baking Powder, Sugar, Salt -- 2001	0.0% - 13.4%	Coefficient of Variation
Friberg, Ganstrandt and Sandstrom (2001)	1999	Books	\$54.00 - \$122.00	Range
		Books	\$21.94 - \$76.20	Standard Deviation
		Compact Discs	\$20.00 - \$40.00	Range
		Compact Discs	\$12.91 - \$23.86	Standard Deviation
		Books (Sweden)	\$19.00 - \$58.00	Range
		Compact Discs (Sweden)	\$21.00 - \$46.00	Range
Lach (2002)	1993 - 1996	Refrigerator (Israel)	4.9%	Coefficient of Variation
		Chicken, Flour, Coffee (Israel)	11.4% - 19.7%	Coefficient of Variation
Marvel (1976)	1964 - 1971	Regular Gasoline	\$0.048	Range
		Regular Gasoline	\$0.015	Standard Deviation
		Premium Gasoline	\$0.048	Range
		Premium Gasoline	\$0.017	Standard Deviation
Pratt, Wise and Zeckhauser (1979)	1975	Various Products and Services	4.4% - 71.4%	Coefficient of Variation
		Various Products and Services	11.0% - 567.0%	Range
Roberts and Supina (2000)	1963 - 1987	Various Products and Services	7.2% - 200.0%	Value of Information
		Wood Products	13.8% - 90.2%	Coefficient of Variation
		Fabrics	18.8% - 78.1%	Coefficient of Variation
		Coffee	14.3% - 25.1%	Coefficient of Variation
		Ready-Mixed Concrete	13.2% - 37.2%	Coefficient of Variation
		Newsprint	4.5% - 8.2%	Coefficient of Variation
		Gasoline	6.2% - 11.8%	Coefficient of Variation
		Tinplate Steel Cans	25.0% - 31.0%	Coefficient of Variation
Scholten and Smith (2002)	1976 - 2000	Pan Bread	26.0% - 49.6%	Coefficient of Variation
		Corrugated Shipping Containers	21.8% - 39.6%	Coefficient of Variation
		Consumer Sundries -- 1976	3.3% - 41.4%	Coefficient of Variation
		Consumer Sundries -- 2000	1.6% - 42.0%	Coefficient of Variation
Sorensen (2000)	1998	Consumer Sundries -- 2000	5.7% - 28.4%	Coefficient of Variation
		Prescription Drugs	\$13.17	Range
Stigler (1961)	1953	Prescription Drugs	22.0%	Coefficient of Variation
		Anthracite Coal	\$3.46	Range
Villas-Boas (1995)	1985 - 1987	Anthracite Coal	\$1.15	Standard Deviation
		Identical Automobiles	\$165.00	Range
Villas-Boas (1995)	1985 - 1987	Identical Automobiles	\$42.00	Standard Deviation
		Coffee	21.5%	Coefficient of Variation

¹ Table 1a includes studies comparing offline and online price dispersion.

Empirical literature on price dispersion(2/3)

Table 1b: Measures of Price Dispersion Reported in the Literature in Online Markets Only
Intervals of

Study	Data Period	Product Market	Estimated Price Dispersion Measures	Dispersion Measure
Ancarani and Shankar (2004)	2002	Books (Italy)	€4.26 - €4.84	Standard Deviation
		Books (Italy)	€20.00 - €22.88	Range
		Compact Discs (Italy)	€2.29 - €2.79	Standard Deviation
		Compact Discs (Italy)	€11.82 - €14.75	Range
Arbatskaya and Baye (Forthcoming)	1998	Mortgage Interest Rates	> 0.25	Range
Arnold and Saliba (2002)	2001	Textbooks	10.7% - 52.6%	Range
		Textbooks	3.5% - 10.0%	Coefficient of Variation
		Textbooks	0.2% - 12.5%	Price gap
Baye, Morgan and Scholten (2003)	2000 - 2001	Consumer Electronics	\$123.88 - \$143.15	Range
Baye, Morgan and Scholten (2004a)	2000 - 2001	Consumer Electronics	9.1% - 9.7%	Coefficient of Variation
		Consumer Electronics	3.79% - 5.38%	Gap
Baye, Morgan and Scholten (2004b)	1999 - 2001	Consumer Electronics	57.4%	Range
		Consumer Electronics	12.5%	Coefficient of Variation
Baylis and Perloff (2002)	1999	Camera	\$342.00	Range
		Scanner	\$106.00	Range
		Books	33.0%	Range
Brynjolfsson and Smith (2000)	1998-1999	Books	33.0%	Range
		Compact Discs	25.0%	Range
Chevalier and Goolsbee (2003)	2001	Books	8.1% - 12.3%	Range
Clay, Krishnan, and Wolff (2001)	1999 - 2000	Books	27.7%	Coefficient of Variation
		Books	\$7.62	Range
Clay, Krishnan, Wolff and Fernandes (2003)	1999	Books	10.0% - 18.0%	Coefficient of Variation
Clemons, Hann and Hitt (2002)		Travel	\$8.03 - \$13.40	Range
Ellison and Ellison (2004)	2000 - 2001	Memory Modules	5.9% - 29.0%	Range
Gatti and Kattuman (2003)	2002	Consumer Electronics (France)	3.0% - 15.3%	Coefficient of Variation
		Consumer Electronics (Italy)	4.3% - 14.2%	Coefficient of Variation
		Consumer Electronics (Netherlands)	5.6% - 20.4%	Coefficient of Variation
		Consumer Electronics (Spain)	2.2% - 13.3%	Coefficient of Variation
		Consumer Electronics (Sweden)	6.6% - 14.0%	Coefficient of Variation
		Consumer Electronics (UK)	3.5% - 16.2%	Coefficient of Variation
		Consumer Electronics (Denmark)	6.3% - 20.2%	Coefficient of Variation
		Consumer Electronics (France)	7.8% - 47.4%	Range
		Consumer Electronics (Italy)	9.3% - 27.8%	Range
		Consumer Electronics (Netherlands)	8.9% - 54.8%	Range
		Consumer Electronics (Spain)	3.8% - 32.4%	Range
		Consumer Electronics (Sweden)	16.4% - 50.4%	Range

Empirical literature on price dispersion(3/3)



		Consumer Electronics (UK)	7.0% - 54.9%	Range
		Consumer Electronics (Denmark)	12.8% - 42.0%	Range
		Consumer Electronics (France)	1.6% - 16.1%	Gap
		Consumer Electronics (Italy)	3.6% - 13.7%	Gap
		Consumer Electronics (Netherlands)	8.9% - 34.8%	Gap
		Consumer Electronics (Spain)	3.7% - 18.0%	Gap
		Consumer Electronics (Sweden)	5.9% - 15.6%	Gap
		Consumer Electronics (UK)	2.5% - 14.5%	Gap
		Consumer Electronics (Denmark)	3.6% - 31.8%	Gap
Hong and Shum (Forthcoming)	2002	Books	\$8.19 - 27.05	Range
		Books	6.2% - 8.5%	Coefficient of Variation
Janssen, Moraga-Gonzalez and Wildenbeest (2005)	2004	Market for Keyboards	\$6.50 - \$91.67	Range
		Market for Keyboards	8.0% - 52.0%	Coefficient of Variation
Pan, Ratchford and Shankar (2002)	2000	Books	15.0%	Coefficient of Variation
		Compact Discs	15.4%	Coefficient of Variation
		DVDs	12.7%	Coefficient of Variation
		PDAs	11.8%	Coefficient of Variation
		Software	11.7%	Coefficient of Variation
		Consumer Electronics	9.6%	Coefficient of Variation
Pan, Shankar and Ratchford (2003)	2000 - 2003	Consumer Electronics and Books	9.8% - 11.7%	Coefficient of Variation
		Books	33.3% - 48.9%	Range
		Compact Discs	22.2% - 51.0%	Range
		DVDs	30.7% - 43.7%	Range
		Computers	15.0% - 34.4%	Range
		Software	19.0% - 35.6%	Range
		Consumer Electronics	22.1% - 45.7%	Range
Smith and Brynjolfsson (2001)	1999	Books	28.0% - 33.0%	Value of Information
		Books	\$6.29 - \$10.51	Standard Deviation

Morgan & alii (2006): experimental evidence

Search externalities

In the WSV model:

- ⑥ as uninformed customers become informed
- ⑥ lower expected prices for all

Received conclusion

- ⑥ there is a positive externality
- ⑥ more search increase consumers' welfare
- ⑥ the promotion of internet access increases social welfare

Our point:

- ⑥ the externality may be negative if we include *partially informed* buyers

The digital divide

Rosenthal (1980) on the WSV model:

- ⑥ more firms \Rightarrow increase of expected charges
- ⑥ more competition is bad

Morgan & alii (2006) (Digital divide):

- ⑥ more firms \Rightarrow decrease expected price for informed buyers
- ⑥ competition is bad for uninformed but good for informed

Our point:

- ⑥ it is not competition *per se* that creates digital divide
- ⑥ if the sampling set of already partially informed buyers increase it is bad for low-informed buyers, good for high-informed ones

The model: a one-shot game

- ⑥ one good, n homogeneous firms, constant marginal cost ($c = 0$)
- ⑥ mass 1 of buyers, one unit of good per capita
 - △ q_1 of them see a single price at random
 - △ q_2 of them sample two prices, ...
 - △ q_n are totally informed
 - △ $\sum_{i=1}^n q_i = 1$, \vec{q} is the *search distribution*
- ⑥ consumers buy at lowest price, if not above r
- ⑥ firms compete on prices
 - △ they know only distribution \vec{q} (marketing surveys)
 - △ any $p \geq 0$ is in the strategy profile

A network interpretation

An alternative interpretation of the model:

- ⑥ buyers and sellers are on a fixed exogenous bipartite network
- ⑥ sellers know only the degree distribution
 - △ Bayesian Nash equilibrium as in Galeotti & alii (2007)
- ⑥ Kranton & Minehart (2001), Corominas–Bosch (2004) and Blume et al. (2008):
 - △ bargaining with full information
 - △ soon very complex

Bertrand competition and monopoly

Lemma 1 (Bertrand competition)

If $q_1 = 0$, each firm will set $p = 0$. ■

Idea of the proof

- ⑥ to charge alone maximal price \bar{p} gives null profit
- ⑥ at least two charge the same price p
- ⑥ suppose $p > 0 \Rightarrow p - \epsilon$ is better

Lemma 2 (Monopoly) If $q_1 = 1$, each firm will set $p = r$. ■

The interesting case is $0 < q_i < 1$

Price distribution

Proposition 3 Take \vec{q} with $q_1 \in (0, 1)$:

- ⑥ no equilibrium in pure strategies
- ⑥ unique symmetric equilibrium in mixed strategies
 - △ price distribution function $f_{\vec{q}}(p)$
 - △ cumulative distribution $F_{\vec{q}}(p) = \int f_{\vec{q}}(p) dp$
 - △ support on $[p_{min}, r]$

$$p_{min} = \frac{q_1 r}{\sum_{j=1}^n j q_j}$$

$$F_{\vec{q}}(p) = 1 - \Phi_{\vec{q}}^{-1} \left(\frac{q_1 r}{p} \right), \quad \text{with} \quad \Phi_{\vec{q}}(x) \equiv \sum_{i=1}^n i q_i x^{i-1}. \quad \blacksquare$$

Idea of the proof

⑥ no equilibrium in pure strategies

- △ any point of mass in the distribution is dominated by a small shift above or below

⑥ there exist an equilibrium in mixed strategies

- △ check that the proposed one works
- △ same expected profit as r for any price in the support

$$p \sum_{j=1}^n j q_j [1 - F(p)]^{j-1} = q_1 r$$

- △ that is $\Phi_{\vec{q}}(1 - F(p)) = \frac{q_1 r}{p}$

- △ $\Phi_{\vec{q}}$ monotonically increasing: $F_{\vec{q}}(p) = 1 - \Phi_{\vec{q}}^{-1}\left(\frac{q_1 r}{p}\right)$

Expected payments

Lemma 4 The expected price paid by a buyer sampling i sellers is (i.i.d. distributions)

$$p_i = i \int_{p_{min}}^r p (1 - F(p))^{i-1} dF(p) = q_1 r \int_0^1 \frac{ix^{i-1}}{\Phi_{\vec{q}}(x)} dx \quad \blacksquare$$

It is clear from the definition that $p_1 > p_2 > \dots > p_n$.

Average expected payments equal expected profits

$$\sum_{i=1}^n q_i p_i = q_1 r \int_0^1 \sum_{i=1}^n q_i \frac{ix^{i-1}}{\Phi_{\vec{q}}(x)} dx = q_1 r \int_0^1 \frac{\Phi_{\vec{q}}(x)}{\Phi_{\vec{q}}(x)} dx = q_1 r$$

Search distribution \vec{q} determines expected payments, but only q_1 influences the average.

Global welfare is trivial

- ⑥ the goods sold in equilibrium are constant (one for each consumer, normalized to 1)

A tractable example

- ⑥ Logarithmic search distribution: $q_i \propto \frac{\alpha^i}{i}$
- ⑥ setting $n \rightarrow \infty$ and normalizing:

$$q_i = \frac{\alpha^i}{-i \log(1 - \alpha)}$$

$$F(p) = \frac{p}{\alpha r} - \frac{1 - \alpha}{\alpha}$$

- ⑥ uniform distribution for $p \in [(1 - \alpha)r, r]$:

$$p_i = r \left(1 - \frac{i}{i + 1} \alpha \right)$$

- ⑥ the effect of a change in α is clear

Comparative statics (1/2)

Proposition 5

- ⌚ take a search distribution \vec{q}
- ⌚ consider \vec{q}' where $q'_1 = q_1 - \Delta$ and $q'_m = q_m + \Delta$
- ⌚ then $f_{\vec{q}}(p)$ FOSD $f_{\vec{q}'}(p)$ and $p'_i < p_i$ for any i . ■

Idea of the proof $F_{q'}(p) > F_q(p)$ for $p \in (p'_{min}, r]$ because

- ⌚ $p'_{min} < p_{min} = \frac{q_1 r}{\sum j q_j} \Rightarrow$ OK for $p \in (p'_{min}, p_{min}]$
- ⌚ for $p > p_{min}$ we have

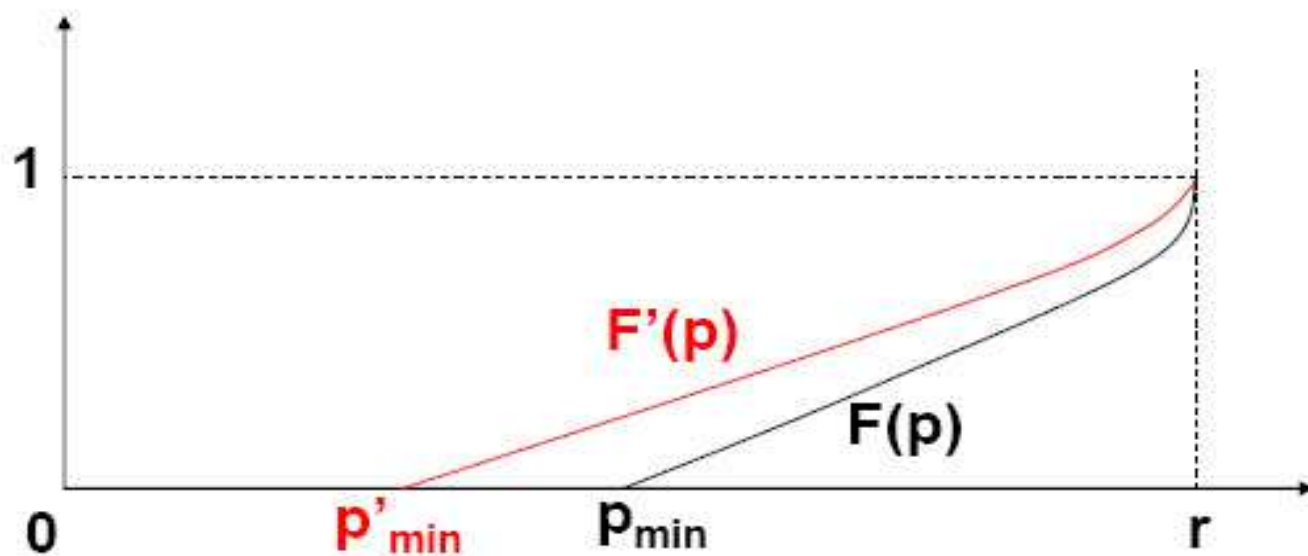
$$\sum_{j=2}^n j q_j [1 - F(p)]^{j-1} = q_1 \left(\frac{r}{p} - 1 \right)$$

- ⌚ moving Δ from q_1 to $q_m \Rightarrow$ LHS \uparrow and RHS \downarrow
- ⌚ \Rightarrow OK also for $p \in (p_{min}, r]$

Positive search externality

Prop. 5: if we let some uninformed buyers search more

- more search is beneficial for all other buyers
- more competition \rightarrow smaller expected prices
- expected profit of firms decreases ($\frac{q'_1 r}{n} < \frac{q_1 r}{n}$)



Example: The WSV model

The case of either uninformed or fully informed buyers is

- ⑥ $q_1 + q_n = 1$, so that

$$p_1 = q_1 r \int_0^1 \frac{1}{q_1 + nq_n x^{n-1}} dx, \quad p_n = q_1 r \int_0^1 \frac{nx^{n-1}}{q_1 + nq_n x^{n-1}} dx$$

- ⑥ By Prop.5 a shift from q_1 to q_n lowers both p_1 and p_n
- ⑥ Morgan & alii (2006):
increasing firms leads to $p'_{n+1} < p_n$ but $p'_1 > p_1$
- ⑥ the aggregate expected profit of firms does not change

$$q_1 r = q_1 p_1 + q_n p_n = q_1 p'_1 + q'_{n+1} p'_{n+1}$$

Comparative statics (2/2)

Proposition 6

- ⑥ take a search distribution \vec{q}
- ⑥ consider \vec{q}' where $q'_m = q_m - \Delta$ and $q'_{m+1} = q_{m+1} + \Delta$ ($m \geq 2$)
- ⑥ there is a $i^* \geq 2$ such that $p'_i > p_i$ for $i < i^*$, and $p'_i \leq p_i$ for $i \geq i^*$. ■

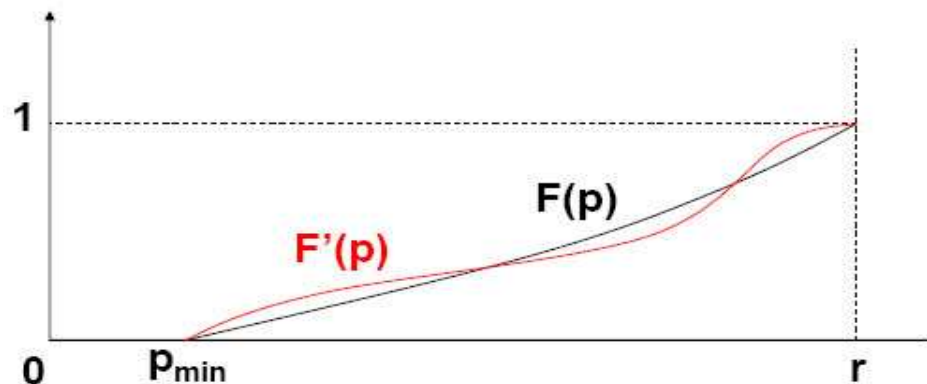
Idea of the proof there is no stochastic dominance

- ⑥ we apply Riemann definition of integrals
- ⑥ $p'_1 > p_1$, $p'_i - p_i$ decreases in i and $\lim_{i \rightarrow \infty} p'_i - p_i$ is negative

The digital divide

From Prop. 6, if we let some already informed buyers search more

- ⑥ firms will simultaneously move probability weight on extrema
 - △ monopoly price $p = r$ and competitive price $p = p_{min}$
- ⑥ even if the average of charged prices increase, more sampling is beneficial from a certain point on
- ⑥ the externality of more search is bad for low-informed and good for highly-informed
- ⑥ the aggregate expected profits of firms will not change



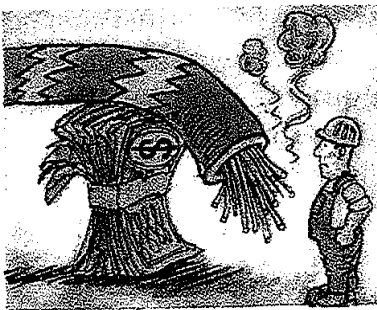
The digital divide

'The Economist', January 31st 2009

Broadband stimulus

Not so fast

There is much talk about subsidies for high-speed broadband, but other causes are more deserving



IN HIS first radio address as president, Barack Obama spoke of “expanding broadband to millions of Americans”. Britain’s prime minister, Gordon Brown, has likened his government’s efforts to extend the country’s digital infrastructure to “the roads and the bridges and the railways that were built in previous times” to stimulate the economy. Investing in broadband access sounds like a good way for governments to boost flagging economies. Digging up roads and laying all that optical fibre will create jobs; equipment-makers will have to crank out lots of new gear; and people for whom online commerce or remote working are today out of reach will be brought into the digital fold. One study suggests that increasing broadband infrastructure in a typical American state by a

band access”. Grand words have given way to puny deeds.

Campaigners and industry lobbies are livid. But the case for large-scale government investment in broadband is not as strong as its proponents claim. When it comes to promoting economic activity, it is easy to see why having broadband is better than not having it, but most benefits are likely to come from wiring people up in the first place rather than making existing connections hum faster. In Japan and South Korea over 40% of households have fibre links capable of blazing speeds, but that does not seem to have resulted in more rapid economic growth, or the emergence of new applications unavailable to consumers with ordinary broadband. So focusing on the extension of access into new areas is the right approach. Alas, that will not involve laboriously digging up lots of roads. Investing in, for instance, retrofitting buildings to make them more energy-efficient would create far more jobs.

Negative externalities to all

It is possible that $i^* > n$

⑥ Simpson paradox:

- △ it can be that $p'_i > p_i$ for all i such that $q_i > 0$
- △ even if $\sum_{i=1}^n q_i p_i = \sum_{i=1}^n q'_i p'_i$
- △ because \vec{q}' has shifted weight on smaller prices

Example $q_1 + q_2 + q_3 = 1$ and $r = 1$

⑥ $\vec{q} = \left(\frac{1}{4}, \frac{1}{4}, \frac{1}{2}\right)$: $p_1 \simeq 0.3761$, $p_2 \simeq 0.2408$ and $p_3 \simeq 0.1915$

⑥ $\vec{q}' = \left(\frac{1}{4}, \frac{1}{5}, \frac{11}{20}\right)$:
 $p'_1 \simeq 0.3832 > p_1$, $p'_2 \simeq 0.2434 > p_2$ and $p'_3 \simeq 0.1919 > p_3$

⑥ $p'_4 < p_4$ but $q_4 = 0$

Increasing search may not be enough



Example $n \geq 4$ and $r = 1$:

- ⑥ $\vec{q} = \left(\frac{1}{20}, \frac{9}{10}, \frac{1}{20}\right)$:
 $p_1 \simeq 0.0895$, $p_2 \simeq 0.0470$ and $p_3 \simeq 0.0376$
- ⑥ suppose that all the non-uninformed agents start sampling 4 firms
- ⑥ $\vec{q}' = \left(\frac{1}{20}, 0, 0, \frac{19}{20}\right)$: $p'_1 \simeq 0.2789$ and $p'_4 \simeq 0.0380 > p_3$
- ⑥ the negative externality from $q_2 \rightarrow q_4$ affects heavily q_1 but also $q_3 \rightarrow q_4$

Open questions

- ⑥ Can we endogenize non-trivially buyers' types?
- ⑥ Buyers sample a fixed number of random firms
 - △ what if they were sampling always the same firms?
 - △ what would happen if firms could somehow learn buyers' type?
 - △ we would need a network environment
- ⑥ In the model the demand function is constant:
 - △ would it be tractable otherwise?
 - △ could we consider welfare issues?