Reflection among competitors as a fundamental factor affecting Internet prices

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Origin of the problem

E-commerce has all the characteristics associated with *perfect competition*.

Consumers can compare many firms's prices with a click of mouse, there are low barriers to entry, and firms can change prices at low cost (Bailey 1998; Brynjolfsson and Smith 1999).

Hypotheses:

1. the law of one price prevails;
2. firms' price rankings vary over time;
3. a tradeoff between price and services or fees exists.

There are evidence and papers *contradicting all these hypotheses*.

Price dispersion: measure and evidence

Two standard "metrics" of dispersion:

1. coefficient of variation,
2. price range relative to the average (minimum*) price

Review of Pan, Ratchford and Shankar (2004)

PERIOD OF DATA	(2)	(1)	CATEGORY	# OF SEL
Nov 1999 - May 2001	57*	12.6	Electronics (36)	$\approx$ 20
example	107*	22.4	flat panel monitor	
Aug 2000 - Mar 2001	40*	10	Electronics (1000)	2-40
Nov 2001	22.12	8.22	Electronics (94)	$\approx$ 12
Feb 2003	30.99	10.83	Electronics (110)	$\approx$ 9

Why does online price dispersion exist?

There is not a "one-size-fits-all" model of equilibrium price dispersion (Baye, Mortan and Scholten 2006).

Three approaches:

- "search-theoretic" models
- "information clearinghouse" (Internet price comparison site):
  the fees charged by the information gatekeeper
  the cost of subscription for consumer (information asymmetry)
  influence of consumer loyalty
- bounded rationality of firms (Nash assumption is relaxed)

Even in the *Lab experiments* (homogeneous Bertrand competition, Baye et al., 2004) price dispersion occurs.
Some fundamental reason excluding consumers' factor must exist.
Bounded rationality approach looks the most promising.

Our contribution

Our data

Market.Yandex, July 3rd till October 20th, 2015. Moscow region. 30 models supplied by 276 e-shops by top five models in six subcategories of household appliance (fridges, cooker hoods, warm ovens, cooktops, dishwashers, washing-machines). 4 observation per day.

Theoretical model (one-day cut)

Price competition with differentiated product (for each item at each period). The reason for differentiation – e-shop brand awareness.

Equilibrium concept (in pure strategies, multiple)

Nash-2 equilibrium approach: attempts to predict reaction of some sample of competitors ("direct" competitors, consolidated in the notion of "reflection network"). Cautious behavior in view of such possible reaction. Generates high prices and *high dispersion of prices*.

Algorithm of our work

- Data description
- Model of price competition with differentiated product
  - preliminaries
  - representative consumer (weak link in our current model)
  - firm's problem
- Nash-2 equilibrium theoretical solution for any reflection network
- Detecting reflection network: pairwise Granger causalities between price series of each pair of e-shops for certain good during all period of observation (use dynamic data)
- Estimation of parameters of the theoretical model (use static data): check if there exist such parameters that all prices in every period satisfy equilibrium conditions:

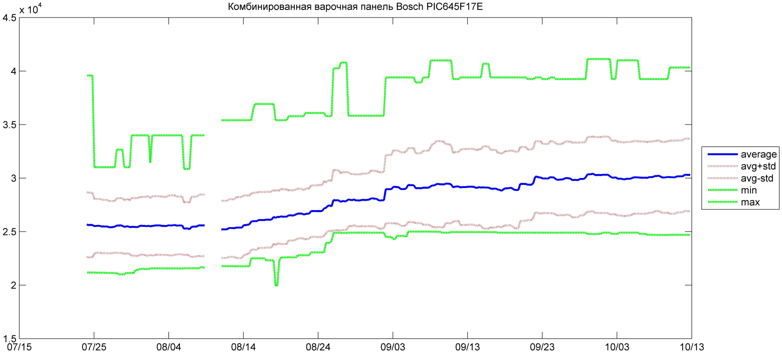
  YES! (for checked model and date)

Testing the rest data – in progress.

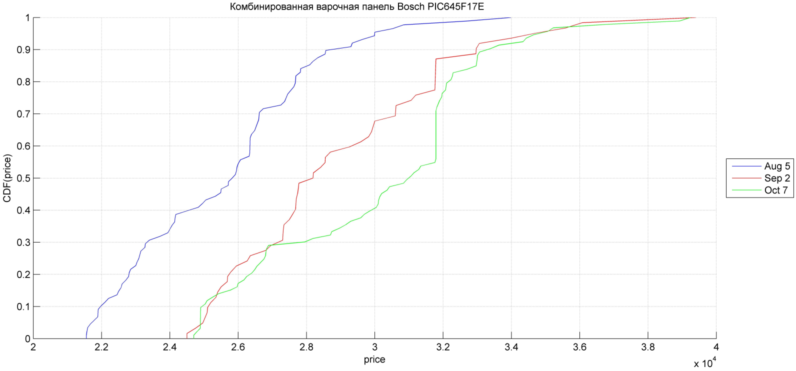
List of models

Product	Avr price RUB	Var %	Min price RUB	Range %	# Sel
Bosch PIC645F17E	27968	12.9	23686	86.9	88
Cata Ceres 600 Negra	19389	23.1	12430	192.2	40
LG F-1096SD3	21759	7.4	19605	58.9	72
Bosch KGS 39XW20 R	34535	11.9	30170	116.4	47
Gorenje BO 73 CLI	27128	14.0	22946	89.4	51
BOSCH AW SPV40E10RU	24386	11.5	21671	90.9	62
HANSA BHI68300	16356	13.2	14035	70.6	63
Ariston LSTB 4B00 RU	17166	9.9	15710	155.1	42
Hansa ZIM 436 EH	20156	12.6	17541	74.6	19
liebherr SBSesf 7212	123527	5.0	111186	119.3	38
Gorenje gw 65 cl i	17209	15.8	14835	98.9	48

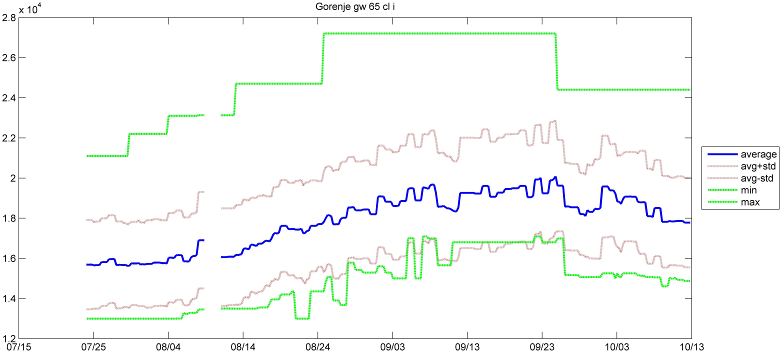
Combined cooktop Bosch PIC645F17E



Combined cooktop Bosch PIC645F17E



Gas cooktop Gorenje gw 65 cli



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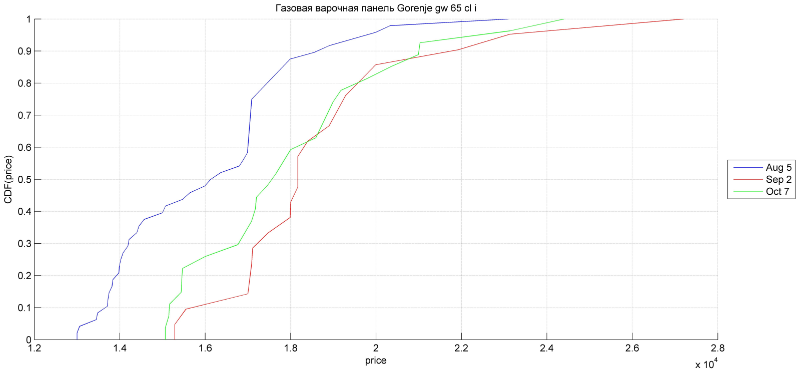


Preliminaries

InSales Survey on E-commerce in Russia 2014

- at least 60% consumers indicate *cheapness* as a major factor of choosing the shop:
  - low cost
  - simpler to find a shop with low price
  - easy to compare prices
- in home appliance about 30% of sales are made in internet
- most consumers use delivery; region-segmentation: Moscow is the largest region
- Yandex is the leader of Russian e-shop-comparison sites (3 times more users than at all other shopbots in sum)

Loyalty: about 13% of users choose the e-shop where they have already made a successful purchase

Representative consumer

Assume there is a continuum of consumers of the same type. Utility function of representative consumer is given by

$$U(\mathbf{p},\mathbf{q}) = \sum_{i=1}^{n} \alpha_i q_i - \frac{1}{2}\left(\sum_{i=1}^{n} q_i^2 + \sum_{i=1}^{n}\sum_{j=1, j\neq i}^{n} \gamma_{ij} q_i q_j\right) - \sum_{i=1}^{n} p_i q_i, \qquad (1)$$

where α_i is a consumer valuation of "product" i, coefficients of substitutions are $0 < \gamma_{ij} < 1$.

Product, or good, means here **a service of selling the same model of good by a specific e-shop**.

Optimal consumption of product i in the form of inverse demand function:

$$p_i = \alpha_i - q_i - \sum_{j=1, j\neq i}^{n} \gamma_{ij} q_j. \qquad (2)$$

Inverse it.

Firm's problem

$\alpha = (\alpha_1, \ldots, \alpha_n)$, B is $n \times n$ matrix with $B_{ii} = 1$, $B_{ij} = \gamma_{ij}$. Introduce the following notation:

$$a_i = \sum_{j=1}^{n} (B^{-1})_{ij} \alpha_j, \quad b_i = (B^{-1})_{ii} > 0, \quad c_{ij} = -(B^{-1})_{ij} > 0. \tag{3}$$

Then, the demand and markup of ith firm is

$$D_i = q_i = a_i - b_i p_i + \sum_{j=1, j \neq i}^{n} c_{ij} p_j. \tag{4}$$

$$M_i = p_i - mc. \tag{5}$$

The utility function of ith firm is given by:

$$u_i(\mathbf{p}) = M_i D_i. \to \max \tag{6}$$

Nash assumption is relaxed

One-shot game:

Nash players: maximize under expectations that other players' strategies are fixed and can't change after their move. They play *best response* to a situation (and all agents do).
Nash-2 players (Sandomirskaia 2016): recognize that after their own improvement some other agents will also try to improve. After some of such counter-moves initial player can loose in comparison with the initial state. So players cautiously avoid such risky improvements.

Cognitive limitations: they are not able to predict all reactions of all competitors. So, they determine for themselves the subset of agents whose reaction they take into account (direct competitors) and reflect about them, while do not worry about all others.

Reflection network

Let us define the reflection network g by the following rule:

- nodes are players i in I;
- links $g_{ij} = 1$ from player i to j exists iff player i "takes into account" possible profitable deviations of player j;
- $g_{ij} = 0$ otherwise.

Note that the reflection network is a *directed* graph.

If a player has no out-neighbors (fully myopic) then she deviates always if this is profitable.
The more out-neighbors a player has, the more cautious her behavior is and the more stable outcomes exist.

Topology of reflection network affects equilibrium set and may support very "asymmetric" equilibria.

Conditions for Nash-2 equilibrium in our model with arbitrary reflection network g

Conditions (7)-(9) for any firm i:

$$M_i \geq 0, \quad D_i \geq 0, \quad p_i \geq BR_i. \qquad (7)-(9)$$

Further conditions for NE-2 differ from the out-degree of firm in the reflection network g. Denote by $N_i(g)$ the set of out-neighbors of node i in the network g.

- Myopic firm. Assume that $N_i(g) = \emptyset$, then

$$p_i = BR_i. \qquad (10)$$

Conditions for Nash-2 equilibrium in our model with arbitrary reflection network g

- Farsighted firm.

  Assume now that $N_i(g) \neq \emptyset$ and the firm i follows f other firms (f – farsighted). Guaranteed demand is

$$D_{iN_i} := D_i + 2 \sum_{k \in N_i(g)} c_{ik}(BR_k - p_k). \tag{11}$$

If $C(N_i(g)) := 1 - \sum_{k \in N_i(g)} \frac{c_{ik}^2}{b_k} > 0$, then NE-2 condition is

$$(M_i C(N_i(g)) - D_{iN_i})(M_i C(N_i(g)) + 3D_{iN_i}) \leq 4M_i C(N_i(g)) D_i. \tag{12}$$

If $C(N_i(g)) < 0$, then this profile is a NE-2.

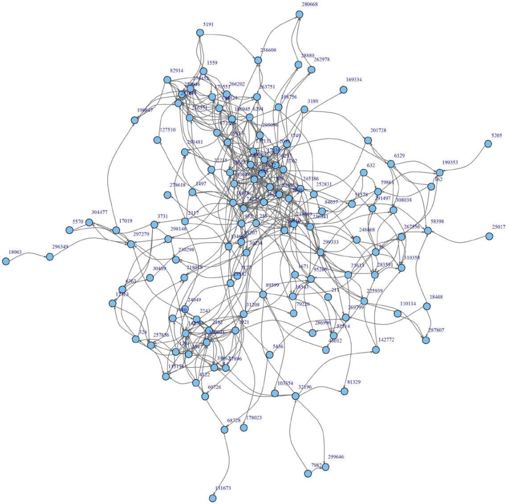
1. How we build the reflection network?

We assume that the relation "firm A reflects about firm B" means that the price series of firm B is useful to forecast the price series of firm A (Granger causality).

1. Fix the specific good from our sample
2. For each pair of e-shops we calculate Granger causality between price series X and Y (standard procedure, OLS regressions including Wald and F-tests on lagged values of X, that those X values provide statistically significant information about future values of Y).

Features: lag is 1 day; missing values are filled with zero prices; sometimes this method demonstrates false links.

Reflection network for Washing Machine LG F-1096SD3



2. Estimation of parameters for a given day

Aug 5, Sept 2, Oct 7

	# sel	non-myopic	# edges	min price	max price	mean price
Aug 5	72	49	170	18227	24140	20385
Sept 2	65	45	153	20100	28690	22156
Oct 7	77	55	209	20370	25640	22497

We apply the method of interior point to find values of parameters satisfying *all* constraints:

	Aug 5			Sept 2			Oct 7		
mc	9121			10050			10208		
	min	max	mean	min	max	mean	min	max	mean
a_i	180.1	180.5	180.3	198.9	199.5	199.0	201.4	201.7	201.5
b_i	3.52	6.47	4.5	4.15	5.44	4.96	2.83	8.53	4.44
c_{ij}	0	0.48	0.06	0	0.29	0.078	0	1.18	0.059

Conclusion

We obtain some evidence supporting main hypothesis:
selective farsightedness among competitors may generate high online price dispersion in equilibrium.

To be done (in progress):

- finalize the check of all days and models
- check the robustness of reflection network
- find the intervals for feasible parameters

Further research:

- improve the model (try discrete choice models for consumers' behavior)
- check some alternative to Granger causality techniques

Thank you for your attention!